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THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

THE NewSpace Frontier

IEEE-Eta Kappa Nu

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IEEE-Eta Kappa Nu (IEEE-HKN) was founded by Maurice L. Carr at the University of Illinois at Urbana- Champaign on 28 October 1904, to encourage excellence in education for the benefit of the public. IEEE-HKN fosters excellence by recognizing those students and professionals who have conferred honor upon engineering education through distinguished scholarship, activities, leadership, and exemplary character as students in electrical or computer engineering or by their professional attainments. *THE BRIDGE* is the official publication of IEEE-HKN. The ideas and opinions expressed in *THE BRIDGE* are those of the individuals and do not necessarily represent the views of IEEE-HKN, the Board of Governors, or the magazine staff.

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Dr. Jason K. Hui

Epsilon Delta Chapter

"It is truly an exciting time to be in if you're a space enthusiast."

THE BRIDGE, February 2024

Letter from the Editor-in-Chief

Dear IEEE-HKN Members and Friends,

Happy New Year, and welcome to the first issue of 2024! *THE BRIDGE* Editorial Board has been busy planning this year's issues, and we hope that you'll find our selected themes on NewSpace, Fusion, and the CHIPS Act to be interesting, informative, and thought-provoking.

The term NewSpace, also known as Space 2.0, refers to approaches to spaceflight development from an emerging private industry as opposed to a government agency such as NASA or the European Space Agency. You may have heard of SpaceX, Blue Origin, and Virgin Galactic, but there are many more companies now contributing to the future of space exploration and commercialization. It is truly an exciting time to be in if you're a space enthusiast. We express our appreciation to Editorial Board Member, Burton Dicht, for serving as guest editor and the authors of the feature articles.

This issue also looks back at 2023 with the IEEE-HKN Annual Report, highlighting the year in review on awards, inductions, activities, community service hours, and Chapters. We recap last November's highly successful Student Leadership Conference held at the University of Houston, the largest ever in IEEE-HKN history.

In addition, we have the pleasure of featuring six new members of the IEEE-HKN Board of Governors and hearing from the IEEE-HKN President, Dr. Ryan Bales, on his goals and priorities for the year. The professional profile is on our HKN colleague, IEEE President and Chief Executive Officer, Dr. Tom Coughlin.

IEEE-HKN strives for effective communication through its various channels, including our website, YouTube, Facebook, LinkedIn, and this magazine. You can reach the Editorial Board by email at info@hkn.org, and they welcome your content and ideas. And as always, *THE BRIDGE* is available on the IEEE App (older archival issues can be found in the Engineering and Technology History Wiki).

About the Cover

A now common-place occurrence, the side boosters from SpaceX's Falcon Heavy demo flight performed a synchronized landing at the company's landing zone at the Cape Canaveral Air Force Station (now Cape Canaveral Space Force Station) in Florida on February 6, 2018. *Photo credit: SpaceX*

Burton Dicht

Eta Chapter

"As the space industry expands, students and early-career engineers will find themselves at the forefront of innovation, poised to contribute to the next wave of technological advancements that will shape our future on and beyond Earth."

THE BRIDGE, February 2024

Intro from the Guest Editor

As a member of the Apollo Generation who has closely followed the journey of space exploration, both as an enthusiast and a professional, several historic events have left an enduring impact on me. Notable among these are the Apollo 11 moon landing, the inaugural flight of the Space Shuttle, and the awe-inspiring images captured by space telescopes and robotic explorers. These experiences have shaped my connection with the evolving nature of space exploration. But nothing illuminates this evolution more than witnessing the Falcon Heavy side boosters execute a synchronized landing (cover photo).

No matter how many times I see it, the precision and choreography in their simultaneous descent send a wave of excitement through me and highlight the incredible technological capabilities of our new space age. Today's space landscape is vastly different from the one I experienced during Apollo, where the main players were the United States and the Soviet Union. Today, there are space agencies in more than 70 countries, and in addition to government spending, private investment has increased and a large number of new businesses run by entrepreneurs in the space industry have emerged.

This new era has been broadly labeled "NewSpace," and it refers to the new generation of companies making private investments and bringing fresh ideas that have altered the space industry paradigm. I am honored to serve as the guest editor for this issue as we introduce the concept of NewSpace to you and provide a guide to current professionals and an inspiration to the next generation of engineers.

You will explore NewSpace through three fascinating articles, each offering a distinct perspective from one of our accomplished authors. In an overview piece, Rod Pyle, Editor-in-Chief of the National Space Society's ad Astra magazine and a renowned space author, delves into the historical roots of NewSpace and what is also known as Space 2.0, providing insightful commentary on current programs, companies, and future trajectories. The second article explores a consequential aspect of NewSpace: the reduction in launch costs and its profound impact on harnessing a key space resource: solar power from the Sun.

The concept of space solar power (SSP) has existed for decades and envisions a constellation of solar power satellites harvesting the Sun's limitless energy and transmitting this clean power to Earth with zero carbon emissions. There are no significant technological barriers impeding SSP, and dramatically lower launch costs make the concept more feasible. John Mankins, a distinguished NASA veteran with 25 years of experience and recognized expertise in SSP technology, provides a comprehensive guide in his article. This inclusive guide covers the background, core concepts, key technologies, and, most importantly, the potential for SSP to address the world's growing energy needs.

The concluding piece offers a perspective from Grace Robertson, an early-career engineer in the field of NewSpace. As an astronaut scholar and flight controller candidate at Sierra Space, Grace shares her transformative journey from STEM student to NewSpace engineer. She details the catalysts that sparked her interest in a STEM career, recognizes the influential figures who inspired her and reflects on the pivotal choices that led to her current position.

While these articles can be informative and inspiring to engineers of any age, I especially hope they will give insights to students considering NewSpace careers. As the space industry expands, students and early-career engineers will find themselves at the forefront of innovation, poised to contribute to the next wave of technological advancements that will shape our future on and beyond Earth.

Ryan Bales

2024 President,
IEEE-Eta Kappa Nu

Gamma Theta Chapter

Dear HKN Members,

I'm writing this letter just as the IEEE-HKN Board of Governors has concluded its annual retreat to envision and plan 2024. Words cannot adequately convey our board members' excitement for the coming year. Our retreat was held in conjunction with the IEEE Rising Stars Conference, where our board members met with many outstanding students between sessions. It was an inspiring way to kick off the year, and it was incredibly energizing to have so many board members together to focus on HKN for two days. Many thanks to Mike Andrews, founder of Rising Stars, and the 2024 organizing team for your hospitality and for inviting us to join an amazing event!

Our strength and energy going into 2024 are thanks to the hard work and dedication of our predecessors. Thank you to 2023 President Sampathkumar Veeraraghavan for his boundless energy and leadership, and to the Board, Committee Chairs, and volunteers for their commitment to advancing HKN for all of our members. As an organization, we reached some noteworthy milestones in 2023. We chartered five new Chapters, including our first Hungarian and Ecuadorian Chapters. We also inducted 100 professional members into the Eta chapter from around the world—a testament to the impact of HKN and the appeal it holds for service-minded engineers to engage with students and participate in our society (Remember that all Chapters can induct professional members—this is a great way to recognize the contributions of local experienced engineers). We saw a 40% increase in inter-chapter activities. It is wonderful to see Chapters reach out to each other to build a stronger community and take on more ambitious service and social projects.

In 2024, we aim to continue delivering quality programming and resources for our Chapters and developing new opportunities for interactions among students, alumni, and professional members. Whether through mentoring, speaking engagements, chapter coaching, or networking, there are exciting and rewarding ways for alumni and students to work together and for our members to engage with HKN throughout their careers.

The focus of the Board of Governors has been—and continues to be—on the student experience and on supporting our Chapters in serving their universities and communities. However, HKN is far from a student-only organization. Membership in HKN is a lifetime designation. After graduation, HKN alumni go on to make technical contributions, provide leadership in engineering and other disciplines, and serve their communities and the profession. You have the opportunity throughout your career to strive toward the ideals of scholarship, attitude, and character and to lead by example. Your continued dedication to these ideals as a professional reflects well on HKN and maintains the standard of the society for the members who follow you.

I greatly look forward to the activities, service, and camaraderie that 2024 will bring. Thank you to all of our volunteers, chapter leaders, advisors, members, staff, and supporters for all that you do on behalf of IEEE-HKN.

Best regards and warm wishes,

Ryan Bales

You can choose to directly support IEEE-HKN via the IEEE Foundation to one of the IEEE-HKN Funds: Chapter Support Initiative, including Chapter Support Grants and the "Passing the Gavel" officer training, and Student Leadership Conference. Invest in the next generation of HKN leaders!

Embracing the Coming Change

Doug Tougaw, 2023-24 President of ASEE

It's been said that the only true constant in life is change, but many in higher education see change only as a threat to the well-oiled academic machine that they have spent their careers building. The recently published book by Brian Rosenberg, "Whatever It Is, I'm Against It," illustrates the challenges facing academic leaders who want to bring any kind of innovation to their campuses. However, societal, technological, and financial pressures are beginning to overcome this resistance on most of our campuses. We should see this transformation not as a threat but as an opportunity to design our institutions to be stronger, more financially sustainable, and more student-focused than they have ever previously been.

One key change that we have little control over is the preparation of our students when they arrive on campus. The challenges created by the pandemic have disrupted our students' pre-college education, causing them to be less well prepared for the rigors of an engineering education. This makes it more important than ever to help our students fill in the gaps in their preparation before those gaps force them to give up on their dream of becoming engineers. The American Society for Engineering Education (ASEE) is leading this effort through their "Weaving In, Not Weeding Out" program, which is being led by past president Jenna Carpenter in collaboration with the National Academy of Engineering (NAE) and funded by the National Science Foundation (NSF). ASEE, NAE, and NSF are working together to identify and share best practices that are known to support student success and to replace outdated approaches that see students as products in a pipeline, some of whom are destined to be rejected during the inspection process. Rather, we must see our students as what they truly are - humans with strengths, weaknesses, and the ability to grow and build on both.

Just as it is essential to focus on the humanity of our students, we must do the same for our faculty and staff. As anyone who has participated in a faculty search recently can attest, it's a seller's market when it comes to engineering expertise. We must strive to create an environment in which faculty are valued and supported to the greatest extent possible throughout their careers. One way to show this support is by providing opportunities for lifelong professional development. ASEE is also very active in this area through the offerings of ASEE Learning, most notably the DELTA Institutes for future faculty, junior faculty, new department leaders, and aspiring deans.

We are also facing technological changes that will transform the way we teach our courses. Rapid improvements in artificial intelligence (AI) have introduced new challenges to the way we teach our courses and write and grade our assignments. For our colleagues in the liberal arts, the existential threat is AI-written essays, but those same AI tools also make it possible to automatically generate the solution to nearly any closed-ended textbook problem engineering faculty can write. Of course, our predecessors probably felt similarly overwhelmed by the changes that came about as a result of the calculator, the personal computer, and the Internet. In each of those cases, new technologies gave students the ability to quickly overcome problems that had been challenging for the previous generation of students. And in each case, faculty adjusted their problems to make them richer, more contextual, and more representative of real-world engineering. We can do so again by eliminating all but the necessary closed-ended problems and replacing them with more rewarding project-based learning that will more fully engage and excite our students. The universities that develop a reputation for doing so will have no problem filling their classes with exceptionally bright and dedicated students who are seeking the opportunity to help change the world for the better.

The next several years will be very interesting in our field. It's the faculty and universities that accelerate into the inevitable change and see it as an opportunity for growth who will thrive the most. I believe that members of Eta Kappa Nu, especially current and future faculty, are extraordinarily well positioned to help lead those change efforts on their own campuses.

Doug Tougaw is the Dean of Engineering at Valparaiso University, where he has served since 1996, beginning as an Assistant Professor of Electrical and Computer Engineering. He is the 2023-24 President of the American Society for Engineering Education, having previously served in a variety of leadership roles in the Illinois/Indiana Section, the Ethics Division, and the Entrepreneurship and Engineering Innovation Division. He previously served on the ASEE Board of Directors as Zone II Chair and as the Vice President of Finance. He was inducted into the Epsilon Eta chapter of Eta Kappa Nu at Rose-Hulman Institute of Technology in 1990, and he was the founding advisor of the Mu Rho chapter at Valparaiso University in 2018.

IEEE-HKN Welcomes New Members to its Board of Governors

IEEE-Eta Kappa Nu (IEEE-HKN) Board of Governors welcomed six new members at its 9 November 2023 meeting. The governors took office on 1 January 2024.

Dr. Ryan Bales, Gamma Theta Chapter, will lead the honor society in 2024 as president. He served as IEEE-HKN Governor At-Large from 2020 to 2022. Dr. M. Ryan Bales is a principal research engineer in the Sensors and Electromagnetic Applications Lab (SEAL) at the Georgia Tech Research Institute (GTRI). He serves as chief scientist of the Sensor Systems Engineering Division and specializes in FPGA and embedded system design for electronic warfare applications. His work has been the subject of 19 scholarly refereed publications, and he is an IEEE Senior Member and a professional engineer licensed in the state of Georgia. He received the 2019 GTRI Award for Outstanding Performance in Research and Development. He mentors junior engineers in the areas of embedded system design and signal processing and encourages service as part of their professional growth.

Dr. Sean Bentley, Gamma Theta Chapter, was elected to serve as the 2024 president-elect. Dr. Bentley is currently an associate professor of physics at Adelphi University. He has previously served IEEE-HKN as a Regions 1-2 Governor in 2018-2019 and the HKN Faculty Advisor Committee from 2018-2020. He is currently a member of *THE BRIDGE* magazine's editorial board. The American Association of Physics Teachers, which presented him with the David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching in 2022, as well as Adelphi University, which presented him with the Tenured Teaching Excellence Award in 2013, have both recognized his outstanding contributions to teaching.

Sampathkumar Veeraraghavan, Epsilon Delta Chapter, led the society as president in 2023 and will serve as its 2024 past president. As president, Veeraraghavan made significant progress in developing global partnerships for HKN. He is best known for his technological innovations in addressing global humanitarian and sustainable development challenges. He has successfully delivered cutting-edge technologies in areas of conversational artificial intelligence (AI), natural language understanding, cloud computing, enterprise systems, infrastructure technologies, and assistive and sustainable technologies.

Dr. Colleen Bailey, Lambda Zeta Chapter, will serve as the Region 5-6 Governor for a three-year term. She is an assistant professor in the electrical engineering department at the University of North Texas and the principal investigator of the Optimization, Signal Processing, and Control Algorithm Research Laboratory. In addition to serving as the advisor for the Lambda Zeta Chapter, Dr. Bailey is the IEEE Fort Worth Section Chair and IEEE Fort Worth Computational Intelligence Society Chair. She is the recipient of the UNT College of Engineering Faculty Teaching Award in 2023 and the UNT Advisor of the Year Eagle Award in 2022.

John D. McDonald, P.E., Beta Chapter, was elected to serve a three-year term as a Governor At-Large. He is Smart Grid Business Development Leader for GE Vernova's Grid Solutions business. John has 49 years of experience in the electric utility industry. As an IEEE Life Fellow, McDonald has a long history of service to IEEE, including being the IEEE Power & Energy Society Past President 2006-2007, IEEE Board of Directors, and Division VII Director 2008-2009, among other positions. More recently, he has been the director of the IEEE Foundation 2021-2023. He was awarded the IEEE Millennium Medal in 2000, the IEEE PES Meritorious Service Award in 2015, and the Purdue University Distinguished Engineering Alumni Award in 2023. His generosity made the IEEE-HKN Chapter Grants Initiative possible, and he serves as a mentor to many HKN students.

James Jefferies, Beta Psi Chapter, will be serving a three-year term as the MGA Governor At-Large. He is a retired AT&T and Lucent Technologies executive who, in 33 years, rose from a manufacturing engineer to vice president. He was the 2015 President

of IEEE-USA, supporting the globalization of its policy initiatives, and in 2018, he served as the IEEE President and CEO. He also played pivotal roles in the following IEEE activities: IEEE Board of Directors 2012-13, 2015, and 2017-19; IEEE-USA Entrepreneurship and Innovation Policy Committee 2008-16; IEEE Employee Benefits and Compensation Committee 2015-16; Region 5 Director 2012-13; IEEE Audit Committee 2012-13; IEEE-USA Board of Directors 2009-16; IEEE-USA Vice President – Professional Activities 2009; IEEE-USA Vice President – Government Relations 2010-11; IEEE-USA Government Activities Committee 2006-11; IEEE-USA R&D Policy Committee 2005-08; IEEE Member Services Committee 2011.

Obafemi Jinadu, Epsilon Delta Chapter, was elected to a one-year term as Student Governor. He is a Ph.D. student at Tufts University, conducting research in the fields of artificial intelligence and computer vision. He earned his undergraduate degree in 2019 at the Obafemi Awolowo University in Nigeria, where he was awarded the Chevron/Nigerian National Petroleum Corporation (NNPC) Joint Venture National University Scholarship Award and the Petroleum Technology Development Fund (PTDF) Local Scholarship Scheme Undergraduate Award. As a member of the National Society of Black Engineers (NSBE) and Black in AI (BAI) communities, he is committed to promoting diversity and inclusion within and beyond the field of engineering.

Trinh Huynh, Mu Mu Chapter, was elected to a one-year term as Student Governor. She is pursuing a master's degree in robotics at the University of Michigan. She served as the president of the Mu Mu Chapter in 2022-2023 where she was instrumental in revitalizing her chapter, including facilitating tutoring sessions, organizing fundraising activities, and sponsoring seminars and workshops for the benefit of her fellow students. In 2021, she was selected as one of the inaugural cohorts for the Women Leadership Initiative, where she underwent specialized training in leadership skills. Additionally, her commitment to academic excellence and being a first-generation college student was acknowledged through her induction into the Tri-Alpha Honor Society.

This iconic picture shows Earth peeking out from beyond the lunar surface as Apollo 8, the first crewed spacecraft to leave Earth orbit, orbited the Moon in December 1968 Photo Credit: NASA

Welcome to Space 2.0: It's a Bold, New Space Age

Rod Pyle, Editor-in-Chief, Ad Astra magazine

Back in 2019, I had the good fortune to give the keynote address at the IEEE Metrocon conference in Dallas. The theme of my talk was the relationship between the Space Race and the new Space Age, often referred to as NewSpace or Space 2.0. Afterwards, several younger volunteers asked to discuss some of the concepts I had raised in more detail. I was happy to do so.

Some of the questions from the engineering students focused on my experience growing up during the Space Race. So many emotions and memories sprang to mind, and I became increasingly passionate as I described watching the Apollo program evolve and grow, highlighting seminal moments—the daring voyage of Apollo 8, the triumph of Apollo 11, and perhaps most remarkably, the fact that the United States was, for some time, sending incredible missions of science and exploration to the Moon every few weeks.

Mid-sentence, I overheard someone sniffling and looked over to see one of the students receiving comfort from a classmate. I was confused—tears were a first for me in this setting—so I stopped and asked her if there was something wrong. Between sniffles, she said, "You have no idea how lucky you are to have lived at a time when you could experience that!" I was stunned and realized she was right—I was incredibly lucky to have grown up in the 1960s and 1970s. I witnessed every Apollo mission firsthand, and it was like living a dream of the future.

We all have our memories and tales of great deeds, but my point is that the first Space Age—arguably spanning from the launch of Sputnik in 1957 through Skylab, America's first space station in 1973—was indeed an amazing time to be alive. This is not a knock on the Space Shuttle, which served the nation from 1981 through its final mission in 2011. It not only advanced partially reusable technology but also facilitated the assembly of the International Space Station (ISS), showcasing remarkable feats of aerospace engineering that are a testament to human ingenuity. This era, often referred to as "the golden age of NASA," was amazing to witness. We are, however, squarely in the middle of another "golden era," a new space age, today.

A New Way of Doing Business

Not since the 1960s have we seen this level of activity in space, and this time for far less money and with less wasteful urgency. At the height of the Apollo program, the U.S. was spending nearly five percent of the federal budget on the space program. Without adjusting for inflation, federal spending on NASA was approximately nine-fold higher at the peak of the Apollo program (1965) than it is today. Today, NASA's annual budget is about one-half of one percent[1]. That is a stunning contrast.

Other comparisons are more challenging. While the U.S. is launching far more rockets than in the 1960s, most are uncrewed, and most are built and flown by Elon Musk's SpaceX, which delivers an array of private cargo to low-Earth orbit. These range from his own Starlink satellites to commercial satellites and military payloads. SpaceX also launches the few crewed flights that take off from American spaceports, which primarily transport crews to and from the ISS. Although NASA and the U.S. government fund many of those missions, SpaceX is undoubtedly a private company.

[1] https://www.planetary.org/space-policy/nasa-budget

Falcon 9 rocket launch from Cape Canaveral Space Force Station carrying 40 satellites for OneWeb on March 9, 2023; Photo Credit: Burton Dicht

Other commercial launch providers, principally United Launch Alliance (ULA) and a handful of smaller companies, are striving to maintain competitiveness. After a series of delays, Boeing is slowly finalizing its Starliner space capsule to augment SpaceX's crew deliveries. Other companies are ramping up efforts to fly orbital hardware of various types as well. At the heart of this renaissance is the strategy that underlies the new space age: private-public partnerships.

By 2008, it was clear that the shuttle program would wind down by 2011. That deadline prodded NASA to issue its first fixed-price commercial agreements with private industry—one contract to SpaceX and another to Orbital Sciences (now part of Northrop Grumman). This was, at the time, a stunning move for industry watchers accustomed to business conducted on a cost-plus basis, which passes ever-escalating final costs to the government. To be fair, aerospace companies were incentivized to bid at unrealistically low rates to secure the contracts, and both sides knew that costs were likely to escalate. It was how business was done for decades.

But with President Obama having just taken office and new NASA staff—notable among them NASA Deputy Administrator Lori Garver—change was in the air. The shuttle had suffered two fatal flight accidents, and the fleet was aging. It was also expensive to operate. While there had been proposals for shuttle replacements, the paradigm shift to fixed-price contracting and purchasing services from commercial operators was an enormous leap of faith.

Lori Garver; Photo Credit: NASA

Not surprisingly, Garver suffered substantial pushback for her efforts—"old space" didn't favor this new arrangement. But as these privately operated flights commenced in 2012, with SpaceX beginning cargo runs to the ISS, it quickly became evident that this new style of public-private partnership was operationally sound and unprecedentedly efficient. By some estimates—including those performed by the U.S. government itself—SpaceX's contracts have proved extremely cost-effective, with some programs saving 50 to 90 percent of the cost of traditional practices. It just makes good business sense.

ULA, under pressure from competitors such as SpaceX, strived to cut costs on their workhorse launcher, the Atlas V, and prepare a more cost-effective replacement, the Vulcan, which made its inaugural flight in January. Additionally, a number of fresh, smaller launch service providers have emerged, including Firefly, Astra, Rocket Lab, and Relativity Space. Even former Amazon CEO Jeff Bezos has joined the fray, starting his own rocket company, Blue Origin, in 2000 (two years before SpaceX was founded). Blue Origin is slowly preparing for the maiden launch of their heavy-lift New Glenn rocket. Some of these companies will be more successful than others, and not all will cross the finish line. But it's a promising trend, since many of these entrepreneurial "NewSpace" operators are delivering access to orbit at a fraction of the price we saw just a decade earlier.

New Glenn's second stage tank at Space Launch Complex 36 at Cape Canaveral Space Force Station; Photo Credit: Blue Origin

Towering over this revolution is SpaceX's own Starship launcher. Having perfected near complete reusability with the Falcon 9 and larger Falcon Heavy–the first stages and nose fairings are recovered and reused–the company is flight testing the Starship/Super Heavy system, a Saturn V-class fully reusable rocket. But that is where the comparisons stop. The cost of delivering equipment and supplies to Earth orbit and beyond will decrease by an order of magnitude if Starship/Super Heavy is even half as effective as Musk claims. A lot is riding on Musk's colossal Starship rocket— the new Space Age hinges upon operational cost, reliability, and rapid flight cadence.

Growing Smartly

These are the broad strokes of Space 2.0, but the devil is in the details. Indeed, there are thousands of details that must be identified and mastered. Yet, we have already seen huge changes. Besides cost savings, the U.S. now leads the world in launches, primarily due to SpaceX's Falcon family of vehicles. Of the 183 successful launches in 2023 (as of October), 87 were by SpaceX, a handful by other U.S. operators and Europe, and most of the remainder were by China. Were it not for U.S. private operators and their services, China would long ago have surpassed the U.S. total. More on this international footrace later.

This success has allowed for rapid growth in multiple areas. Primary among them are private and government satellites,

The SpaceX Starship/ Super Heavy lifting off on its second test flight from Boca Chica, TX on Nov 18, 2023; Photo Credit: John Kraus

with over 4,500 U.S.-owned operational units now orbiting overhead (there were just 1,200 less than 10 years ago). Trailing far behind are China with about 586 and Russia with about 177[2]. Most of the U.S. total consists of SpaceX's Starlink broadband satellites, but missions of all kinds that would have been unaffordable just a decade ago are now underway. These include government weather satellites and various private orbiters that deliver mountains of data on everything from weather prediction to resource utilization to navigation and communications. Almost every facet of modern life and our technological civilization, has some relationship to orbital assets today, including oceanic navigation, cargo tracking, agriculture, military operations, and even banking. Just imagine your daily routine without GPS or ATMs. All these conveniences are benefits of the new space age.

Science has also reaped enormous dividends. NASA's myriad robotic missions have realized meaningful cost savings thanks to cheaper access from U.S. launch providers, and the returns are striking. Small CubeSat-class satellites can now be built at universities and by small companies and flown at a previously unthinkable price. The agency's planetary probes, which often require heavy lift capability, are catching rides on the Falcon 9, and NASA's flagship mission to Jupiter's moon Europa will launch on a Falcon Heavy in 2024. More will follow suit.

The success of SpaceX's Starship/Super Heavy vehicle will mark an enormous boost in capability, as will the entrance of the dark horse in this race–Blue Origin's New Glenn rocket. Besides the New Glenn, Blue Origin is building rocket engines for ULA's Vulcan at a price competitive with their former Russian suppliers. Blue Origin is running late in the game. The company began operations two years before SpaceX, but it promises to be flying its large cargo carriers in 2024. Their emergence as a launch provider will provide solid competition for SpaceX, likely resulting in further cost reductions.

White Elephant or Prized Possession?

There is much to be optimistic about, but there is an elephant in the room, and a huge one. NASA's single-use heavy lift rocket, the Space Launch System, or SLS, has been in the works for over a decade. It has launched just once, lofting an uncrewed Orion capsule around the Moon in late 2022. Built by Boeing on a traditional cost-plus contract, NASA's "mega Moon rocket" is pricey and may represent

NASA's Space Launch System rocket carrying the Orion spacecraft launches on the Artemis I flight test, Wednesday, Nov. 16, 2022; Photo Credit: Bill Ingalls

the last gasp of old-school contracting for the space agency.

As of today, the SLS is the world's most powerful operational rocket and is slated to carry crews to the Moon within a few years, but at over $4 billion per launch, it's a budget-buster and will only fly every year or two—a far cry from Apollo's pace. It will be used to lift NASA's Artemis program to land astronauts on the Moon—an effort now joined by dozens of nations—but when this will occur is debatable. Most observers do not expect a crewed landing before 2026 or 2027. Notably, the watchdog Government Accountability Office (GAO) recently suggested at least a two-year delay beyond NASA's long-held projected date to place boots on lunar soil in 2025.

To further complicate matters, NASA has contracted both SpaceX and Blue Origin to supply the needed lunar landing services to the program to deliver those crews via fixed-price agreements; however, the build-and-test schedules are already slipping. There's little doubt that they will eventually succeed—the two companies are owned by the richest business tycoons on Earth with substantial skin in the game—but this is new territory for everyone.

There is also rising competition. Years ago, China announced its intent to land its own astronauts (called "taikonauts") on the Moon and has been diligently working on its ambitious lunar program for about a decade. Beijing's space efforts are far less transparent than those of the West, and the Asian giant touts its successes rather than reporting intentions or incremental progress. But China has clearly stated its lunar ambitions. It is a well-funded effort that avoids the yearly budget reviews or political shifts at the executive level that NASA routinely suffers. In broad terms, once the commitment is made and funding is allocated, China inexorably plows ahead until it achieves its goal. Barring any huge internal economic woes, expect to see a Chinese crew on the lunar surface by 2030, if not before (2029 is the 80th anniversary of the People's Republic of China and a possible target date).

The effect of Chinese competition has been to escalate the new space age into a new space race. Like the Space Race of the 1960s, when the U.S. committed itself to landing Americans on the Moon before the Soviet Union,

[2] It is important to note the issue of orbital congestion, particularly in low-Earth orbit. There are currently 26,700 satellites in orbit as of 2023 [https://www.statista.com/statistics/1422809/number-of-satellites-cataloged-decayed-orbit/], and tens of thousands more are planned by 2030. Most of these will be deployed to low-Earth orbit, the most cluttered region. Adding to this is enormous mass to other orbital debris—spent rocket stages (whole and debris of exploded ones), chunks of ice from vented propellants, and ice and rock from the early solar system. This has generated concern from both the governments who track these debris (chief among them the United States). Orbital debris presents a threat to rocket launches, transiting spacecraft, orbital facilities like the International Space Station, and other active satellites. Astronomers have also expressed deep concern about the light pollution caused by brightly lit satellites. Various efforts at satellite-camouflage are underway, as well as debris remediation projects, but progress is slow.

America is now pressured to repeat a more sustainable version of the Apollo program—at a far lower cost—before Chinese taikonauts leave footprints on the lunar surface. This may not be a bad thing. For better or worse, the U.S. has always innovated and performed best when under external pressure. U.S. private operators are, for the most part, ahead of their Asian competitors, but the U.S. government feels the geopolitical pressure acutely. Geopolitics was the driving force behind the first Space Race—the West was competing with the Soviet Union for influence with non-aligned nations across the globe, and the race to the Moon was driven more by national prestige and the quest for geopolitical influence than something as mundane as science.

"What's In It for Me?"

What does all this mean for the average U.S. citizen? Does the person on the street really care about "winning" a competition to land astronauts on the Moon before China? For decades, polling has yielded mixed messages. Today, as in the 1960s, the public appears largely indifferent to a lunar landing program. People like the NASA "brand" and the general concept of leadership in space but are far less enthusiastic about spending significant sums to send people back to the Moon. A recent poll placed support for the lunar goal at about 12 percent of those surveyed.[3] Reaching the Moon with astronauts, it seems, is optional for the average American but imperative for the U.S. government. That said, when American astronauts return to the lunar surface, expect an outpouring of pride and enthusiasm, just as we saw in the 1960s.

Other countries are also concerned about progress in space. Russia struggles to maintain a robust space program on diminished budgets, and China and India are prominent among emerging space powers, with both countries recognizing the benefits of an active space program, including human spaceflight. It is noteworthy that the citizens of these nations generally poll higher with regard to attitudes about spaceflight—there is a significant sense of national pride for spaceflight achievements and the technological prowess they represent.[4]

In general terms, it is worth remembering the benefits of investing in space. For each dollar spent on the Apollo program, between $16 and $24 was returned to the U.S. economy. In addition, U.S. STEM education and technical expertise have flourished during surges in space spending. While Tang was not invented for spaceflight—that's a popular myth—kidney dialysis, digital computers, and even iPhones all trace their source technologies to the Space Race. Countries like China and India also recognize—perhaps more keenly than the average American—that national spaceflight programs stimulate technological proficiency and the development of STEM-savvy workers.

Moonstruck

The Artemis lunar program is a long-term project. Success will be measured in decades, but that success is intimately tied to the advances of NewSpace. Recall that both SpaceX and Blue Origin are providing lunar landing services to Artemis. This multi-billion-dollar investment by NASA has boosted and accelerated both companies' technological expertise. The same is true for smaller firms that have similar arrangements with NASA. This first big step by humans into cislunar space will pave the way for tourism, semi-permanent lunar habitats, and perhaps most importantly, orbital and cislunar infrastructure. And that will kick off a NewSpace gold rush through the innovative use of private-public partnerships in spaceflight.

Orbital Reef concept showing station modules and visiting spacecraft
Photo Credit: Blue Origin

If properly coordinated, the combined efforts of private companies and government partnerships will create something new: space infrastructure. Orbiting fuel depots and space stations will be the first private, publicly orbital and cislunar infrastructure. There is urgency to both since NASA will begin deorbiting parts of the ISS after 2030, after more than 30 years of continuous operation. Prior to this, the space agency plans for smaller commercial space stations to operate in tandem with the ISS and has devoted substantial funds to supporting this effort. A company called Axiom Space is building a private station segment to dock with the ISS, which can later detach and become a free-flying facility. Blue Origin is working on a larger station called Orbital Reef, describing it as a "mixed-use business park."

Another proposed station called Starlab is underway with NewSpace companies Nanoracks, Voyager Space Holdings (owned by billionaire Dylan Taylor), and traditional aerospace contractor Lockheed Martin. All these companies have been primed with NASA funding and are well positioned to succeed. Other firms are also eyeing the potential of independent orbiting space stations, and additional research platforms and orbital hotels should follow. The same is true for fuel depots in space. All current U.S. plans for astronauts on the Moon—and the semi-permanent habitats there—will require multiple refuelings in orbit, and NASA will look to private companies to fulfill this need.

[3] https://www.pewresearch.org/science/2023/07/20/americans-views-of-space-u-s-role-nasa-priorities-and-impact-of-private-companies/

[4] While surveys differ regarding questions asked and how they are expressed, the results (especially in the U.S., which has been polling public attitudes about spaceflight since the 1960s) are remarkably consistent. Polling on this topic in China and especially India is a more recent development, and both nations (especially China) have notably different media environments, with China's being largely state controlled. Nevertheless, polling provides useful metrics, with a recent poll of Chinese citizens revealing about 78 percent of those surveyed supportive of their national spaceflight efforts [https://www.sciencedirect.com/science/article/abs/pii/S0265964621000527], as opposed to 65-70 percent of U.S. citizens [https://www.pewresearch.org/science/2023/07/20/americans-views-of-space-u-s-role-nasa-priorities-and-impact-of-private-companies/]. More revealing is the question of sending their citizens to the Moon, with Chinese and Indian citizens appearing to be broadly supportive of crewed lunar

A Red Moon?

NASA and the West are not alone in their lunar ambitions. China and Russia have preliminary plans to build their own International Lunar Research Station (ILRS) in the same lunar south polar regions as the U.S. and have invited other international partners. China has, in the past decade, successfully flown an increasingly ambitious series of lunar orbiters and landers, and Russia has announced plans for near-term robotic landers as well. China also has crews orbiting Earth in their own permanent space station. Their overarching goal is to build a joint Sino-Russian ILRS facility near the south lunar pole in the early 2030s, supplied and crewed by multiple countries.

The Chandrayaan-3 lunar lander, developed by the Indian Space Research Organization, was launched on a LVM3- M4 rocket on July 14, 2023; Photo Credit: ISRO

The space arena continues to evolve with the rise of new players. India has already flown multiple robotic probes into lunar and Martian orbits and is set to launch a crewed spacecraft into Earth orbit within a few years. These efforts by both India and China deserve close attention. With far lower labor costs, technologically capable workforces, and substantial government support, both nations will increase their space activities in the next five years.

Regardless of specific achievements, however, there is growing concern that the first party to establish a semi-permanent presence on the lunar surface–particularly near the coveted water ice deposits in the south polar region—will set the rules for ongoing access. Water ice located in permanently shadowed craters can be converted to fuel, air, and potable water. The West wants an open playing field and a rules-based system for accessing such lunar resources. What China and Russia desire regarding these resources is less clear.

NewSpace Writ Large

What's the big picture for NewSpace? Writ large, it is an expansion of human society into space. While we are merely taking the first tentative steps, these activities are the leading edge of an overall societal movement off-Earth by multiple nations. As a species, we are returning to the Moon and increasing our presence in Earth orbit. Traffic for both people and goods to and from the Moon will increase dramatically in the coming decade. That is a profound development.

Just as commercial spaceflight infrastructure is replacing government monopolies on Earth, similar infrastructure—initially government-supported but increasingly commercialized—will be built in cislunar space. As launch costs continue to fall and human spaceflight becomes routine and easier, more people will be needed to support this growing marketplace beyond Earth. Perhaps by the late 2030s, Mars will be within reach. Earth orbit, the Moon, Mars, and some regions of open space will play host to thousands or tens of thousands of humans pursuing rewarding careers and lifestyles. A peaceful collaboration between international partners and private players will ideally be able to accomplish this.

Toward that goal, numerous private companies are entering the NewSpace arena as first-movers in this new enterprise. Most are based in the U.S., but Europe and China are also incentivizing private enterprise. These endeavors are fueled by a combination of government and private investment—about $274 billion in private funds have been invested in NewSpace since 2013, mostly in the U.S. Some of these companies will succeed. Many will fold their tents before building a single piece of hardware. Risk and reward are how it works—and has always worked—when opening new frontiers. Where one company fails, two will replace them. There will be ebbs and flows, false starts, and money gambled and lost. But without question, we are entering a bold new era of space exploration, development, and utilization, with benefits for all, both in space and on our home planet, with the bonus of building a trillion-dollar space economy by 2040, according to some projections.

Astronauts on the Moon; Photo Credit: Shutterstock

That young engineering student was correct—I was indeed fortunate to experience the first Space Age. But I would also like to point out how fortunate we both are to be living in this new, sustainable space age. Four years later, that young lady may be ensconced in an aerospace job, creating her own place in NewSpace. However, no more dashing breathlessly to the goalposts; no need for a budget-busting wartime footing. This time, we are going because we want to, because we have new and evolved technologies, because a handful of wealthy industrialists are leading the charge, and because substantial amounts of private capital are being invested. And also, for the first time, because it makes business sense. This time, we're going there to stay and prosper.

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Unveiling the Potential: A Comprehensive Guide to Space Solar Power

John C. Mankins

Abstract

Space Solar Power (SSP) is the concept of harvesting sunlight in space and delivering it 24/7 to markets on Earth. During the past decade, advances have occurred that increase the likelihood that SSP will be realized – and soon. First, prospects for dramatically lower launch costs have become more realistic. Second, a wide range of novel technologies have progressed that hold promise for making cost-effective manufacturing and deployment of exceptionally large space structures, such as SPS (solar power satellites), feasible in the near term. Third, new market opportunities have emerged – particularly the need for sustainable and global carbon-zero energy sources – that improve the economic context for SSP. Finally, novel highly modular systems concepts have been defined, such as the 2012 SPS-ALPHA (SPS by means of Arbitrarily Large Phased Array) that promise a clear, affordable path to deploying this new energy option.

Keywords: SPS, SSP, Solar Power Satellite, Space Solar Power, SPS-ALPHA

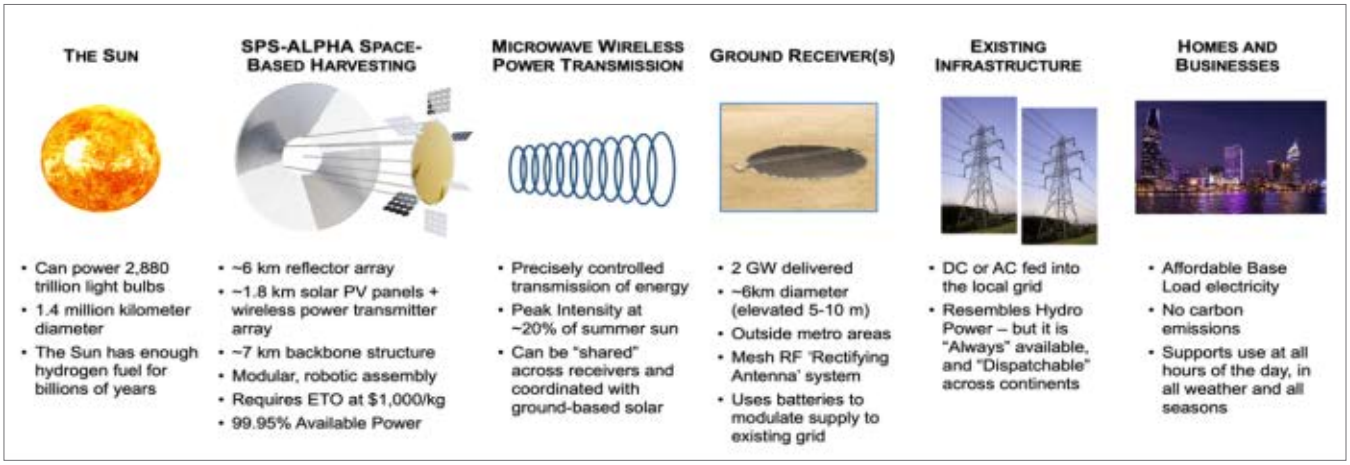

Figure 1 The Concept of Space Solar Power

1. Introduction

Significant new energy sources are required to meet the still-growing demand for electrical power globally, due not only to increasing efforts to transition from the use of fossil fuels but also to the continuing growth in populations and economic activities globally. As is now well recognized, there are limits to the use of traditional sustainable energy (e.g., wind, solar, and hydropower) because of its intermittent nature – the wind does not always blow, the sun does not always shine, and reservoirs are not always full. Innovative technologies are needed to meet carbon net-zero policy goals. One option is space solar power, the concept of harvesting solar energy in space and delivering it safely and affordably to markets on Earth.

Figure 1 illustrates the primary functions of an SSP system. Those functions include: (1) solar energy is intercepted in space by a large "solar power satellite" and converted into electricity; (2) the SPS in turn converts the electricity into an electromagnetic (EM) wireless power transmission (WPT), typically in the microwave region of the EM spectrum; (3) the SPS transmits that energy to receivers on Earth; and (4) converting that WPT back into electricity and distributing it into the local power grid for use as needed. The receiver typically includes additional functions, such as sending a pilot signal to the SPS to guide the WPT; providing local energy storage at modest scale to assure power is available even if the WPT is interrupted for any reason; and ensuring safety during operations.

Several new capabilities, changing market opportunities, and novel concepts have emerged during 2021-2023 that improve prospects for economically feasible SSP systems. These include: (1) low-cost launch; (2) hyper-modular systems concepts that enable low-cost manufacturing of SPS hardware; (3) carbon net-zero policy-driven pricing; and (4) more sustainable Concepts of Operations (CONOPS) for both the space and ground segments. Although there are concerns about orbital debris and operational difficulties, SSP proponents are addressing these.

An innovative idea for SPS systems that came up in 2012 is SPS-ALPHA, which stands for "SPS by means of arbitrarily large-phased array." It is very modular and scalable, and it's a great way to do SSP quickly and cheaply. 'Hyper-modular'

SPS-ALPHA platforms in geosynchronous orbit (GSO) or geostationary orbit (GEO) are particularly attractive due to scalability and broad market access.

2. Background

The idea of delivering solar energy from space to earth was first mentioned in a 1940s short story entitled "Reason," written by Isaac Asimov.[1] The key technologies required for SSP emerged as a result of the pressures of World War II and later competition among the major players in the Cold War. The space age's technological advancements and William Brown's work at the Raytheon Corporation in the area of wireless power transmission (WPT) served as inspiration for Dr. Peter Glaser of the Arthur D. Little Corporation to develop the first practical SPS in the late 1960s.[2, 3]

Although the newly formed U.S. Department of Energy with NASA studied space solar power extensively in the 1970s, all U.S. work stopped circa 1980 because of the extremely high estimated costs of using the technologies of the mid-1970s. However, there was an increase in activity both domestically and internationally, and NASA revisited SSP in the late 1990s. Although cost estimates for new SPS concepts using innovative technologies were much lower, interest by NASA and other space agencies remained minimal, and U.S. work stopped again in the early 2000s. Then, by the first years of the 21st century, a new driver for SSP and other novel carbon-net zero energy sources emerged: the risk of carbon dioxide-driven climate change.[4]

In 2018, there were only a handful of ongoing efforts in the field of SSP: in Japan (focusing on high-payoff research and development), in the U.S. (within the U.S. Air Force for Department of Defense (DoD) applications and at Caltech with private funding), and in China (at multiple universities and with support from the Chinese Academy of Space Technology (CAST)). Changing market opportunities and novel concepts have emerged during 2021-2023 that will impact prospects for economically feasible, hyper-modular SSP systems.

The lower costs of SpaceX's Falcon 9 reusable booster have completely transformed the global launch market. SpaceX's planned Starship and heavy booster, a reusable two-stage-to-orbit launch vehicle, is also expected to lower costs. And a number of other countries and companies have all announced plans to develop their own reusable launchers.

In addition, numerous nations have recently announced ambitious carbon net-zero goals. As of 2023, it appears that carbon policy-driven pricing on low-emission technologies, such as SSP, will increase their attractiveness soon, making it more likely that risks associated with such technologies can be overcome.

Finally, there have been significant advances in the CONOPS being defined for future SSP. Most important has been the transition in planning since the 1970s studies away from the baseline of human astronaut construction and maintenance of SPS and toward robotic assembly, maintenance, and servicing. Based on ongoing advances for a wide variety of terrestrial and in-space applications, this has dramatically reduced the projected costs of future SPS systems.

3. Approaches to Realizing Space Solar Power

The other major development has been the emergence of a variety of different approaches to the challenge of SSP. The section that follows provides a summary of some of the approaches to SSP, including the background and history of SSP and several of the key technologies required to deliver baseload energy from space to Earth.

As is true for many large infrastructure projects, there are multiple ways in which one might implement SSP. In the 1970s, the technologies available for SSP were severely limited. As a result, the cost to develop and deploy the first SPS and deliver the first kilowatt-hour was estimated at around $1T (2023 USD). However, since then, numerous advances have transformed the prospects for the viability of SSP; many of these involve the system approaches to the SPS platform and the coupled question of the ground receiver.

At a high level, some of the key design choices include the approaches to: (1) wireless power transmission; (2) SPS location (e.g., GEO); (3) power management and distribution (PMAD) architecture; (4) energy conversion approach (including solar, electrical, and thermal); (5) platform architecture (i.e., degree of modularity); and (6) markets served. Other design options include transportation; deployment, assembly, and maintenance; and various critical technologies (such as power generation, materials, structural dynamics, attitude control, and others). Organizing this plethora of information is critical to understanding the options and how they compare.

3.1 A Space Solar Power Taxonomy

The International Academy of Astronautics (IAA) has drafted an SSP taxonomy. Figure 2 presents this integrated high-level taxonomy for space solar power, updated for 2023 by the recently formed IAA Permanent Committee on SSP, including updates to the space segment and the terrestrial receiver. (There are multiple other required systems and supporting infrastructures, such as mission control, transportation, and others; these are not delineated in the taxonomy.) The following paragraphs sketch different SSP concepts, either well-known or currently under study.

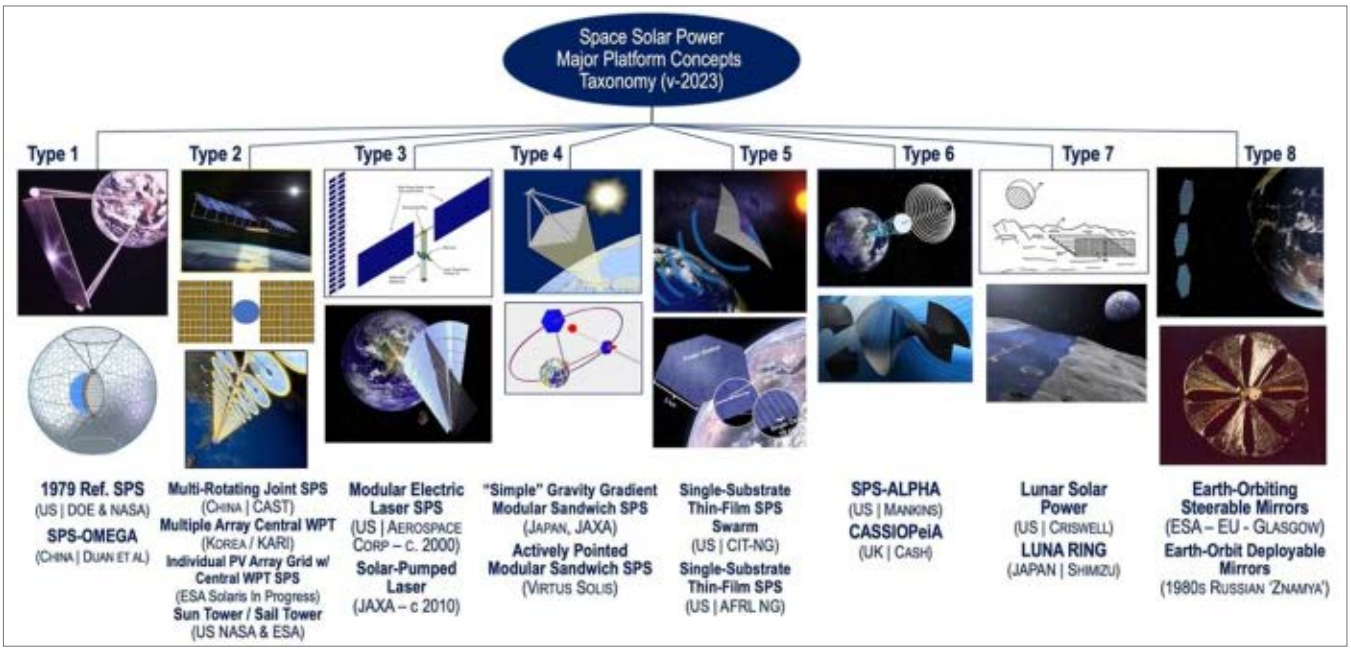

Figure 2 2023 Taxonomy for SSP (International Academy of Astronautics)

3.1.1 Single Integrated PMAD System: 1979 SPS Reference System and Related (Type 1)

The key design feature of Type 1 SPS is its reliance on a single, integrated (and extremely high-voltage) PMAD system. This SPS type also involves the use of microwave WPT on Earth. For example, the 1979 SPS Reference System (Type 1-1) involves a single platform to deliver on the order of 5 GW of electricity to a single receiver on Earth. This concept required a huge waveguide structure, fed by 'electron tube' DC-to-RF power converters such as gyrotron or magnetron tubes. The waveguide structure was presumed to be flat with less than a centimeter of deviation across 1,000 meters of diameter. The CONOPS involved extensive use of exceptionally large, astronaut-intensive space infrastructures.

Another variety of integrated PMAD SSP uses a large reflector system (Types 1-2): "SPS-OMEGA" (Space Solar Power Station via Orb-shape Membrane Energy Gathering Array), invented c. 2015 by researchers in China.[10] In this concept, sunlight is reflected by an array of reflectors on a spherically shaped structural system. This is a phased array microwave WPT concept, but it involves a number of interesting features. For example, the SPS-OMEGA's heliostats direct sunlight toward a compact solar array, from which generated electricity is transmitted through high-voltage PMAD across not two large rotating couplers, to reach two points on either edge of the km-class microwave transmitter, from which the power must be distributed to points across the back of the transmitter.

3.1.2 SPS with a Primary Power Backbone and Distinct Photovoltaic Arrays (Type 2)

There are a number of approaches to SSP related to Type 1, but which are more modular, easier to manufacture, capable of being assembled with robotics, and hence lower in cost to deploy. Type 2 SPS concepts involve microwave WPT, distinct and individually-pointed solar arrays, and varying degrees of modularity, with some elements of the SPS platform being highly modular but others involving largely integrated systems. The Multi-Rotary Joints SPS is an illustration of this SPS, Type 2-1, that the CAST has presented. It involves multiple rotary photovoltaic (PV) arrays feeding through a central PMAD backbone into a centralized microwave WPT array. The Korean Aerospace Research Institute has also looked into this approach.

Quite recently, a related concept, Type 2-2, has been under preliminary study by ESA's SOLARIS program. Here, the individually pointing solar arrays are configured in a single large, fixed matrix to eliminate the need for the PMAD to operate across rotating joints.[7] Information concerning the details of this concept is limited. However, the main design goal is the modularity of the solar arrays and their associated pointing systems, allowing a simpler fixed high-voltage PMAD connecting without rotating joints the 'PV wings' and the WPT transmitter.

All Type 2 cases use phase array microwave WPT. However, only Type 2-1 is 24-7. The ESA concept entails power output drops twice per orbit when the individually pointed

but structurally fixed PV arrays self-shadow one another (e.g., at dawn and dusk). Sun Tower and Sail Tower suffer power drops at local noon when the PV arrays may self-shadow.

3.1.3 Laser SPS (Type 3)

Another fundamental characteristic defining an SSP system is the WPT approach. Although most SPS architectures presume 'lower' frequencies in the microwave portion of the EM spectrum, there are two basic SSP varieties involving high-frequency, typically laser WPT with precision optical beam expanders to direct the energy toward Earth. The concepts listed under 'Type 3' use lasers for power transmission and large precisely pointed optical systems to send that power to a particular PV array receiver on Earth.

Type 3.1.3 involves electrically powered lasers. NASA and the Aerospace Corporation looked at a modular electric laser SPS as an example of this strategy in the late 1990s. This system was conceived to operate in a swarm constellation so that multiple platforms, each delivering less than 10 MW, would operate in conjunction to deliver large-scale power to a receiver on Earth. The Japan Space Exploration Agency (JAXA) studied an alternative laser concept, Type 3.2, involving an integrated solar-pumped laser SPS with very large precision optics for intercepting and delivering concentrated solar energy to a large fiber laser to be 'pumped.' A precisely pointed optical beam expander was also required. However, to date, research has consistently shown solar-pumped laser conversion efficiency to be drastically lower than any other WPT approach.

From a market perspective, the significant shortcoming of laser-based SSP of either variety is their inability to deliver power to a receiver through haze, overcast, or precipitation. Also, laser WPT is significantly lower in energy conversion efficiency in transmission and at the receiver, resulting in a higher cost per power delivered, even without weather attenuation. Another market issue for Type 3 SSP concepts is that they often involve high-power density and potential weaponization, creating a barrier to market acceptance.

3.1.4 "Simple" Sandwich SPS (Type 4)

A key design goal for SSP is to avoid very high-voltage, very large-scale PMAD systems. The so-called 'sandwich' approach accomplishes this by locally integrating the Energy Conversion Array (ECA) with PV and WPT in close proximity to one another. There are two basic SSP approaches that involve a 'simple' sandwich panel SPS. The first of these, Type 4.1,is from JAXA's Institute of Space and Aeronautical Studies, which has developed a simple SPS concept involving a highly modular integrated sandwich panel platform that would incorporate an ECA with PV cells on one side and RF transmitters on the other. An advanced technology option for this SPS concept would involve having PV arrays on both sides of the sandwich panel to increase the time during which power could be delivered. This concept would be based in a GEO orbit and use gravity gradient stabilization, with the RF WPT array surface facing toward Earth at a constant angle.

A start-up company (Virtus Solis) developed SSP Type 4.2, the second sandwich panel SPS, which uses multiple SPS to serve fewer ground receivers (e.g., three SPS and two ground sites), with the sandwich SPS in a highly elliptical orbit (e.g., a Molniya orbit). This concept incorporates as its baseline PV arrays on both sides of the sandwich panel modules comprising the SPS, with microwave WPT on a single side. This concept incorporates as its baseline PV arrays on both sides of the sandwich panel modules comprising the SPS, with microwave WPT on a single side. The platforms must be actively pointed throughout each orbit, balancing capturing sunlight and WPT to Earth.

3.1.5 Single-Substrate Thin-Film "Swarm" (Type 5)

Another version of the sandwich SPS, Type 5, was devised by Caltech and Northrop Grumman Space Technology (NGST) as a single-substrate, thin-film SPS module. Such modules are conceived to operate in a close formation swarm to allow larger apertures and higher power to be delivered. There have been two significant development projects, one of which NGST supported[11] through a donation to Caltech. The other was supported by a U.S. DoD appropriation managed by the U.S. Air Force Research Laboratory with sole-source funding to NGST. Both addressed the same systems concept, although the focus of the Caltech effort over roughly 6-7 years was on technology research, although it resulted in a LEO (Low Earth Orbit) experiment in Winter 2023, and the focus of the NGST effort over 4-5 years appears to be on preparing for a technology flight demonstration.

The primary design driver for this concept was to achieve the lowest possible mass per unit area (kg per m2). Hence, the concept requires fabricating all active electronics on a single thin-film substrate, with PV on one side, RF antennas on the other side, and electronics also printed on the film. In one version, the basic module is a kinematically-deployed 'sail-type' system 60 m by 60 m square (3,600 m2 area) that would generate power, transmit microwave WPT to a receiver on the ground, and fly in very close proximity in a 'swarm' with other such units to make up an overall SPS system. The primary technological challenges are evident: improved efficiency, thin-film PV, high-efficiency microwave electronics, low-mass, and high-reliability structural systems. For a typical set of key performance parameters (KPPs), a single 3,600 m2 module of several tons of mass might generate 400-1,000 kW of RF power, requiring thousands of modules to deliver power to a terrestrial market.

This concept has a number of outstanding challenges that have not yet been well defined. For example, beam-steering will be accomplished by active laser metrology of the surface of the total array of some thousands of modules at a scale of centimeters or less (Retro-directive phase control is not employed here). The details of the attitude control and propulsion systems are yet to be refined, although they are critical to the concept.

The market challenges for Type 5 SSP are similar to those of Type 4, simple (discrete component) SPS: WPT must face Earth, but during the course of an orbit, the PV array will point fully at the Sun only at 'local noon'; during the remainder of the orbit, it will operate either at lesser power levels or at 'zero power' during the time around 'local midnight', Added to the market challenges associated with the simple sandwich SPS, however, there is also the problem that this SSP type must fly—and maneuver – in a very close (1 cm class) formation with thousands of neighboring arrays. A final challenge for the CONOPS for this variety of SSP system is that no provision for repair and maintenance has been defined. When an SPS swarm fails, assumed to be at around 15 years, it is to be taken out of service. Unfortunately, no conceptual approach for removing the thousands of modules in the swarm has been identified yet. This places an added financial risk on the concept.

3.1.6 Hyper-Modular Solar Reflector SPS (Type 6)

An essential problem for 'sandwich' type SPS, i.e., where the PV and WPT are close to one another, is pointing the WPT toward Earth while intercepting sunlight arriving from changing directions as the platform orbits. Type 4 and Type 5, discussed above, do not attempt to continuously intercept sunlight but rather live with the periodic loss of power. Type 6 SPS use reflectors to intercept sunlight continuously, redirecting that insolation to SPG that are locally connected to the modular microwave WPT array facing Earth.

Type 6-1 is SPS-ALPHA (solar power satellite, by means of arbitrarily large-phased array), which was conceived of by the author as the first practical hyper-modular SPS concept studied in 2011 with sponsorship from NASA's Innovative Advanced Concepts (NIAC) program.[5, 7] SPS-ALPHA comprises extremely modular, massively redundant elements that are designed for robotic assembly. A defining characteristic is the use of adaptive optics – pointing heliostats – to deliver sunlight to the PV, which continuously compensates for any variations in the large structural system.

SSP Type 6-2 is another variety of reflector SSP system known as "CASSIOPeiA" (Constant Aperture Solid-State Integrated Orbital Phased Array) SPS, invented c. 2015 by Ian Cash of the UK.[9] The design vision for the CASSIOPeiA as originally conceived was very elegant: an entirely solid-state SPS, with no moving parts. However, the platform (as illustrated in Figure 2) would still entail large thin-film mirrors roughly 1-3 km in diameter (depending on the power output of the platform) that point constantly at the Sun, reflecting solar energy toward a helically-shaped structure on which PV cells and RF transmitters are alternatively located, with the PC facing either up or down toward one of the reflectors and the RF 'facing' toward the side for power transmission out through the 'louvers' of the energy conversion array. Assembly is presumed to be robotic, although details of the structural system are still being defined.

3.1.7 Lunar Solar Power (LSP; Type 7)

A different approach to space solar power (also invented in the early 1980s or late 1970s) was that of lunar solar power (LSP), created by Dr. David Criswell. In Criswell's original LSP concept, Type 7-1, the operational elements of the SSP system would be fabricated and deployed on the lunar surface, transmitting microwave WPT from there to Earth. This system would also involve reflectors in Earth orbit (e.g., GEO) to redirect the transmitted RF energy to markets on the side of the Earth facing away from the Moon at any given time. However, because Earth's distance from the Moon is very roughly 10-times greater than from GEO, the diameter of a lunar transmitter must be 10-times greater in diameter and involve 100-times more active phased array elements and a similarly larger PV array. The need for exceptionally large-scale utilization of lunar materials (mining, extraction, manufacturing, etc.) to produce the hundreds of thousands of metric tons of hardware required for a single LSP system dominates the technological challenges for LSP.

3.1.8 Reflecting Mirrors SSP (Type 8).

Finally, Type 8 involves a radically different 'WPT' approach: delivering solar energy from space to Earth via exceptionally large, low-mass mirrors in orbit, where they reflect sunlight down. There are two basic markets. The first, Type 8-2, examined in the 1980s, used a large reflector to illuminate a far northern latitude city – not generating power but off-setting the need for street lights, etc. The second, Type 8-2, uses a network of enormous, flawlessly flat reflectors (1,000 meters in diameter) in a sun-synchronous orbit (SSO) to deliver sunlight to terrestrial PV arrays. The Arthur D. Little Company is currently examining this technology with ESA sponsorship.

The difficulty of this approach lies in the physics. Due to the geometry of the Sun (an object about 1,400,000 km in diameter) and the distance of Earth from the Sun (about 150,000,000 km on average), the reflected image of the Sun on the surface of the Earth from space will be enormous, and the intensity of the reflected sunlight will be proportionately low. For a low SSO, the received sunlight

on Earth from a reflector of 1,000 m in diameter will be 6 watts/m2. This number is the best case given that fog, clouds, or precipitation will completely stop power delivery and an SSO-based satellite only passes over a target around dawn or dusk, delivering no power at night.

Key technology requirements and challenges for Type 8-1 and Type 8-2 SSP concepts involve the use of reflected sunlight as the 'power transmission' approach. However, these systems must also be very low mass, resulting in the need to use thin-film reflecting materials that are typically presumed to be deployed. The constellation of very large mirrors would also require precision real-time pointing to track an 'in-view' ground-based PV array and deliver power to it.

4. Findings and Conclusions

This paper has reviewed the remarkable advances of the past several years for the concept of the SPS. It has given us a picture of how changes in technology have affected the technical and economic viability of many SPS platform and ground receiver ideas that are being studied, each with its own technology problems and unique features in terms of the markets it could serve.

The following findings stand out: (1) SPS concepts with local and low-voltage PMAD appear more promising than those involving large-scale, high-voltage PMAD; (2) concepts that can operate in any weather are more promising than those that require clear skies; and (3) modular systems that allow mass production of lower-cost hardware are more promising than integrated, more traditional, and much more expensive space systems.

Diverse international activities are now underway with many countries, commercial firms, and others. In addition, the IAA has created a permanent committee on the topic of space solar power; during the coming several years, this committee will be examining key topics such as spectrum management and international cooperation important to the eventual realization of carbon net-zero SSP globally.

John C. Mankins is an IEEE member, an entrepreneur, and internationally recognized leader in technology, systems innovation, and management. He is the founder and president of Mankins Space Technology, Inc. and Artemis Innovation Management Solutions LLC.

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Dream Chaser prior to shipment in the Sierra Space manufacturing facility in Louisville, CO; Photo Credit: Dustin Koehler/Sierra Space

From LEGO® Bricks to the Dream Chaser: An Early Career Engineer's NewSpace Journey

Grace Robertson, ECLS Flight Control, Sierra Space

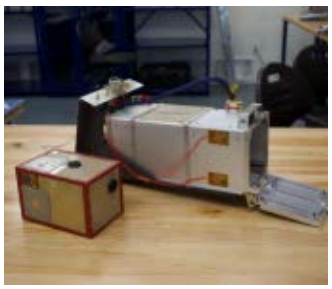
The first research paper I ever wrote was on the solar system in the fifth grade. We were given free rein to choose whatever topic we were pleased to write about, and my curiosities led me to our planetary system. This example of my ten-year-old self is one of the earliest I can think of that specifically highlights my interest in space, though my scientific curiosities were prevalent long before then. For as long as I can remember, I loved tinkering with LEGO® bricks more than any other toy, indicating a strong engineering aptitude from a young age. Ironically enough, I have a collection of space-themed LEGO® models on my desk even today.

These curiosities and aptitudes would not have manifested into much if it were not for key people in my life who molded my interests into passions and later skills. From the second grade on, I was pulled into advanced science and math courses, which challenged me enough to keep me intrigued and always asking more questions. Outside of school, my father took the brunt of those curiosity-based questions as I constantly asked, "How does that work?" about nearly everything around us. Once I got to high school, my tenth-grade chemistry teacher assigned our class a one-page report on a university that offered a degree program potentially leading to a career of interest to me. I have that teacher, Mr. Holmes, to thank for setting me up for one of the most important decisions of my life. It was due to that one-page assignment that I found my undergraduate program at Embry-Riddle Aeronautical University (ERAU) in Daytona Beach, Florida. From that point on, I knew that my future lay within ERAU, and I was set on doing anything in my power to make sure I ended up there.

For the rest of high school, I spent every day working to make sure I would go to Embry-Riddle, and working even harder to earn the academic scholarship I knew I needed to be able to attend. Most days I found myself falling asleep on textbooks in the late hours of the night, even after sports practices and music rehearsals. A visit to the ERAU campus my junior year further solidified that I had found not only my academic future at Embry-Riddle, but also my home. I was the first in my family to go away to college, and I knew I was taking a leap of faith in doing so. This is a key point in which trusting my gut instinct led me deeply in the right direction.

That leap of faith led me to the best, and toughest, four years in academia that I could have ever imagined. It took me a while to recalibrate my compass to know where I was headed next. As a freshman, I started investigating solutions to remove microplastic from beach sand. Living at the beach at the time and still having that scientific

curiosity I had since childhood, I saw a problem very close to home and naturally wanted to do something to solve it. We worked on that project through the end of its prototype phase, at which time I pivoted to work in the Space Technologies Laboratory with Dr. Troy Henderson. For two years, and more hours and sleepless nights than I can count, I worked with my team on the development, assembly, and test of the EagleCam CubeSat that will be flying on Intuitive Machine's first lunar lander mission, IM-1.




EagleCam complete in the Space Technologies Laboratory prior to mission integration with Intuitive Machines; Photo Credit: Daniel Posada/ERAU, right photo - EagleCam electrodynamic dust shield camera integration; Photo Credit: Daniel Posada/ERAU

Working on EagleCam was one of the first opportunities I had to really hone my engineering skills with spaceflight hardware. What you learn in a classroom is valuable as a foundation, but no beautiful architecture is ever complete just at the foundation. Working on EagleCam as a test engineer and interning on aircraft flight test programs provided me with the deep hands-on experience I needed to not only keep that childhood curiosity alive but also drive me to the next steps in my career. Climbing those next steps came through both engineering experience and philanthropic efforts.

My main volunteer effort grew out of the pandemic era, when I knew I wanted to do something that had a direct impact on the community around me. Together with Dr. Geoffrey Kain, I formed a relationship between ERAU and a local community center, Derbyshire Place. It was at this community center that we spent hundreds of hours volunteering with a group of ERAU Honors Program students to grow and distribute food to the local community. This community was in dire need, living in mostly subsidized housing and lacking affordable fresh food. The Derbyshire Place Community Garden has become an oasis in the desert, distributing thousands of pounds of food since the volunteer partnership was formed. Leading this effort as the volunteer director taught me not only the true value of community but sparked my graduate thesis idea and my wonder for what plants could provide for us as part of a spacecraft life support system.

The combined output of my work on EagleCam, internships in flight test engineering, and volunteer work at Derbyshire allowed me to earn the Astronaut Scholarship. I had no idea how much my life would change as a result of that one-page paper in my sophomore year of high school and a scholarship from the Astronaut Scholarship Foundation (ASF). When I was awarded the 2021 ASF scholarship, it was the first time any ERAU student had received the award. The selection process is rigorous and dives into who a student is holistically, especially with their community contributions. Becoming an Astronaut Scholar opened a world of opportunities for me that I didn't even know existed.

In my award year, I was handed my certificate by former NASA astronaut Curt Brown while surrounded by some of the greatest names in spaceflight history. The award was presented in front of my university community months later, and I shared the three things I wish I knew most going into my undergraduate program: learn fast, love hard, and laugh often. Learning fast is key to picking up the concepts you need to succeed and superimposing them to develop unique solutions. Many folks say you need to love what you do because if you aren't happy doing it, then you won't be able to do your best. Laughing often keeps your perspective in check. We're all just doing our best with what we're given, and sometimes a real laugh is all you need to reset at a hard time. At the end of it all, the hard thing you're going through right now only seems hard because it's new, until you reach the next hardest thing.

Chasing hard problems seems to be the way of the engineer, especially in the space industry. Chasing that next hard problem can sometimes be the problem itself, because deciding the next steps in your path means embracing uncertainty. This can seem so counterintuitive, yet it is vital for making goal-oriented moves. Finishing my undergraduate program and wrapping up work on EagleCam presented me with another array of opportunities. My dream had long been to become a flight controller, to be in mission control as a spacecraft operator. I was further nudged towards this field by the ASF community, which included many historic greats from NASA Mission Control. I had the opportunity to go through NASA flight controller training directly after my undergraduate program. This was something I had never expected to be within reach at a young age, yet a gut feeling told me it was not the right time to pursue controller certification. At the time, I had a few job opportunities on my plate to juggle. Weighing the importance of those in light of my values, passions, and future dreams was the most difficult part.

In another moment of trusting my gut, I walked away from the NASA flight controller opportunity, knowing there was something else out there for me that would still lead to that dream. I took a job with Sierra Space as an instrumentation systems engineer, working primarily on the assembly, integration, and testing of the first Dream Chaser flight vehicle, named "Tenacity." Sierra Space is the entity responsible for the world's only commercial spaceplane, Dream Chaser, capable of orbital cargo transit.

This vehicle will fly a minimum of six cargo missions to the International Space Station and is the planned transportation to Sierra Space's future commercial space station, Orbital Reef. I had thought working on EagleCam was a lot of long days, but it pales in comparison to my role on Dream Chaser. Working on the development of the first flight vehicle has come with its own intricate difficulties, each novel in its own way. My first two years at Sierra Space have been dominated by mastering those intricacies and interlacing them with each vehicle subsystem to ensure maximum expected functionality.

The Dream Chaser program has allowed me to step up as a leader far sooner than I expected in my professional career. My peers have taught me invaluable lessons in having hard conversations, both technical and in leadership strategies. Leadership happens at all levels, in all decisions, and certainly in every presentation you make to a large group. The instrumentation technical knowledge I gained while working in this role now supports not only my current flight controller training but also my graduate thesis work at the University of Colorado, Boulder.

Placing lens covers on the video cameras on the Shooting Star Cargo Module Photo Credit: Dustin Koehler/Sierra Space

The calculated risk I took walking away from the NASA flight controller job offer was well worth the reward, as I have now fully transitioned within Sierra Space to train as a spacecraft subsystems controller. In a roundabout yet still more efficient way, I have ended up in mission control having collected skills along my journey to help me become an effective controller. My console is the Environmental Control, Life Support, and Thermal Control systems under the call sign ECLS. This is the dream. This is the job that I have always wanted, and I always wondered if I would have one day. I have been training in mission simulations for over a year now, and every time I step into the control room, the chills never go away. I truly never thought I would achieve this dream so early in my career, yet I will always remain grateful for the chance to wake up every day and do it all over again. I will be supporting Dream Chaser's first mission from inside the control room and celebrating all the little wins along the journey of the mission.

Finding those little bits of joy and those little wins is what keeps me going in my professional, academic, and athletic ventures. Keeping up with my pursuits outside of work keeps me well-rounded, focused, and, most importantly, happy. Later in my career, I plan to re-enter the academic sphere to become a professor. So many teachers and professors have changed my life for the better, and I can only hope to have that same positive influence on young students. With the aspiration to become a professor, I will continue my academic pursuits toward a Ph.D. in bioastronautics while supporting flight control operations at Sierra Space. The juxtaposition of these two unique experiences creates the perfect middle-ground for me to instruct at the collegiate level in the future and pay it forward as so many have done before me.

At some point outside of all of this, I feel it is incredibly important to be more than just your career. Life is deeper than solving engineering problems or getting to your next technical accomplishment. Training for Spartan races and making small improvements to my race performance take up the majority of my time outside of work. Most importantly, training and racing are fun and remind me to get outside and get moving. In my peak race season, I'm training twice a day, anywhere from 8-10 times a week. This is my chance to quiet my mind and experience the world around me in incredible ways. None of this would be possible without my coaches or loved ones who constantly stand in my corner through it all.

I have discussed several key people that have made lasting impressions in my life, and to them I will never be more grateful. Sometimes the impact of someone's influence may not sink in for years to come. My mother, from the time I was probably an infant, always told me to go to college. I just don't think she expected me to move a thousand miles away at the age of 18 to do so, or that I would keep going to pursue a Ph.D. I trusted my gut instinct that something better for me was out there in the world, starting at Embry-Riddle, and there is likely so much more yet to come.

My father, an engineer himself, helped to mold my curiosities and was always patient when I would barrage him with questions about how the mechanisms of the world worked. My college roommate and I strategically took all our classes together so we could collaborate while studying. The keys to the doors of the engineering realm come through collaboration, even if that's first learned in all-day homework sessions in a college apartment. Some of the brute force problem-solving methods we developed while using our windows as a whiteboard still hold for how I solve problems at work today. Solving those problems can get mundane when they stack up, so it is important to remind myself how remarkable it is to be living my childhood dream while fostering the next one.

Dreams are a funny thing when you achieve them. You've worked so hard to get there, so what now? Enjoy it, figure out what worked to get there, and figure out where


Model of the Nova-C lunar lander; Photo Credit: ERAU

you're going next. After I started my undergraduate program, I needed to recalibrate. I'm sure I will have to do that for the rest of my career in the space industry. I have already adjusted my goals to include earning my Ph.D., contributing to industry using my dissertation work, supporting Dream Chaser flights from mission control, and eventually sharing that wealth of knowledge with university students in the future. I know that my future decisions will not always be driven by knowing every single factor going into them.

Trusting my decisions, calling a friend across the country, and having loved ones believe in you when you forget to do it yourself – this is how I've made it in my marathon-length journey. By sharing my story, maybe someone else will have the courage to trust their instincts about the next big decision or to move across the country unsure of what's to come next. No path is linear. None of the information is ever apparent at the start, but it all works as a compilation of hard decisions, little moments of joy, and a vision for the future.

Grace Robertson is a dedicated graduate student in the bioastronautics department at the University of Colorado, channeling her passion for aerospace into her work in flight operations at Sierra Space. Beyond her professional pursuits, Grace is committed to making a positive impact by actively engaging in volunteering, public speaking, and mentorship circles to pay the good forward in the world.

Guest Editor's Note: The EagleCam, carried aboard the Nova-C lunar lander was successfully launched on a SpaceX Falcon 9 rocket February 15, 2024 at 1:05 am EST. It is targeted to land on the Moon on February 22.

For more information:

Astronaut Scholarship Foundation

Sierra Space

Intuitive Machines

EagleCam

Interested in learning more about NewSpace efforts?

Check out these stories in IEEE Spectrum

How Small Satellites Are Providing Low-Cost Access to Space

Five Companies That Cater to Space Tourists

Relativity Space: 3D Printed Rockets Compete with SpaceX

The LEO Satellite Industry Needs More Engineers

Civilian Satellites Descend Into Very Low Earth Orbit

Over 300 IEEE-HKN Students Convene at the University of Houston for its 2023 Student Leadership Conference

What happens when you bring together hundreds of bright, eager future engineers from around the world with industry, IEEE Societies, and academic leaders for three days? Collaboration, idea exchanges, mentorship, career and technical skill development, friendships, and much, much more! On 3-5 November 2023, 300+ attendees representing 55 Chapters gathered at the University of Houston for the IEEE-HKN Student Leadership Conference (SLC), representing a 25% increase in registrations over 2022. The SLC is HKN's largest annual gathering that takes place in the fall, offering a unique opportunity for its students to learn from practitioners that influence and inspire their career trajectories, build their professional networks, and strengthen their leadership skills. Seven graduate schools, 12 IEEE Technical Societies, and 20 businesses sponsored the conference. Generous funding from the Samueli Foundation provided each Chapter attending with a hotel room for students and their chapter advisors.

This year's conference was graciously hosted by Dr. Badri Roysam, Chair of the Department of Electrical and Computer Engineering at the University of Houston's Cullen College of Engineering, and featured 20 impactful sessions and engaging discussions, four workshops, four region meetings, and a robust recruitment fair featuring 35 companies, IEEE Societies, and graduate schools. Popular session topics included, "What they don't teach you in school," "Planning a Career Path for Jobs That Don't Exist—Yet," and "The Roadmap of 6G," which gave students insights on how to connect their academic journeys to their future career paths. A session track was also devoted to sharing best practices and ideas on how students can strengthen their Chapters' performance.

On Saturday night of the conference, an awards banquet was held, which included recognizing two Eminent Members–Frank Chang and Ming Hsieh. Dr. Karen Panetta, Dean of Graduate Education for Tufts University's School of Engineering, received the Sperry Award on behalf of Dr. Asad Madni. The evening also featured the announcement of Key Chapter recognition for 55 Chapters which showed that they implemented best practices over the course of the 2022-2023 academic year.

According to Cade Wilburn, a senior studying electrical engineering at the University of Kansas, Gamma Iota Chapter, who attended the conference, "I thought it was extremely well organized, and I got a lot out of the workshops I attended (CHIPS Act, Leading a Volunteer Organization, Career Takeaways, Networking for Introverts). This was the first conference I have been to in college, and it definitely set the bar high. I was also glad to have met with other Chapters within our region to gain insight about how to increase our presence on campus. I would highly recommend this conference to every HKN member. It was very clear to me from the beginning that a lot of time and effort was put into planning this conference, and you can tell that the top priority was to pack as much value into the weekend as possible."

The energy and inspiration gained from the conference will be felt for a long time to come. Please check out the video and photos from the conference. We are already looking forward to 2024!

2023 Year in Review

	2022	2023 | % Increase YOY ⬆
Number of **ACTIVITIES**	1,694	9% ⬆ 1,843
Service, Education, Outreach **HOURS**	39,113	18% ⬆ 46,259
Total Hours of **STEM OUTREACH EVENTS**	7,163	46% ⬆ 10,489

2,000 Total Inductions

1,000 Conference Attendees

44 Conference Sponsors

55 Key Chapter Recognitions

16 Reactivated Chapters

5 New Chapters

2023, A Year of Unprecedented Growth and Opportunity

From double-digit increases in conference attendance to a strengthened graduate student/alumni mentoring program and an exponential surge in inducted professional members, the year 2023 will be remembered as one where we truly began to operationalize what it means to be HKN for life. New partnerships with IEEE societies and industry provided our students with glimpses into the real- world applications of the latest technologies, pointing them to new career possibilities. Generous giving from our donors made it possible to lower any barriers to taking advantage of these opportunities for our students. We invite you to read about just some of our 2023 successes made possible by the contributions of our dedicated volunteers and the visionary leadership of our Board of Governors.

Region 9 newly-inducted HKN members and ceremony attendees

2023 saw a *record number of new professional members inducted* into the Eta Chapter of the Board of Governors!

With six in-person ceremonies held around the world and three virtual ceremonies, HKN welcomed 92 new professional members into the Eta Chapter, an increase of 240% over the number of people inducted last year. These professionals were nominated for induction by HKN members because they embody the core values of Eta Kappa Nu, namely outstanding scholarship, impeccable character, and a dedication to lifelong learning and service. They have demonstrated significant leadership and service during their careers and will contribute their dedication and personal integrity by sharing their professional skills and personal time. According to the chair of the Professional and Graduate Members Committee, Bala Prasanna, "Looking into the pool of abundant IEEE-inspired connections and the strategic recruitment process that seeks to identify nominees excelling in scholastic, character, and attitude abilities, I feel we have assembled a community of exceptional professionals for our HKN honor society that celebrates and acknowledges the outstanding achievements of students, fostering a culture of excellence and inspiration."

Many of the newly inducted members are dedicating their considerable talents to HKN by jumping right into service. For example, new Eta member Jennifer Franco, who will be serving as the 2024 board secretary, stated, "Personally, I have always wanted to do something in my life where I can give back to others, even if all I can offer is my time. Being inducted lets me know that I am achieving part of that goal and will continue to motivate me to do more."

In-person induction ceremonies were held throughout the year and throughout the world at:

- Region 9 Meeting, Panama City, Panama
- SoutheastCon, Orlando, FL
- Regions 1 & 2 Meeting, Valley Forge, PA
- IEEE June Meeting Series, Chicago, IL
- IEEE Sections Congress, Ottawa, Canada
- IEEE November Meeting Series, Washington, DC

In addition, three virtual induction ceremonies were held to accommodate those members who were unable to attend an in-person one. According to Franco, "The ceremony was really great; all the members and inductees have such great energy, and it's contagious."

Induction ceremonies are being planned throughout 2024. If you know a professional who embodies the attributes of HKN (scholarship, character, and attitude), you can nominate him or her for the Eta Chapter here. With your help, 2024 will be another successful year for the Eta Chapter of HKN!

Outstanding HKN Engineers Elevated to Eminent Members

Announced in August 2023, three outstanding HKN members, Frank Chang, Ming Hsieh, and Sandra Magnus, were elevated to Eminent Members, HKN's highest honor, in recognition for their contributions to the advancement of technology in service to humanity. Frank Chang received this honor for being responsible for many breakthroughs in cellular phone technology, including the high linearity and efficiency of GaAs heterojunction bipolar transistors

(HBT) and BiFET power amplifiers (PAs), which have been the most prevalent IC technology to dominate worldwide cell phone transmitters over the past three decades. Ming Hsieh was nominated for his major technical contributions to biometrics and genetic testing solutions. Dr. Sandra H. Magnus, an HKN professional member of Gamma Theta since 2011, was recognized for her contributions as the deputy director for engineering within the Office of the Under Secretary of Defense for Research and Engineering.

Frank Chang and Ming Hsieh elected to receive this honor at the awards and recognition ceremony at this year's Student Leadership Conference. Dr. Chang took the opportunity to inspire students by relating how he and his team developed the technology currently used in cell phones around the world. Dr. Magnus was bestowed Eminent Member status at the IEEE November Meeting Series as part of the Educational Activities Awards Ceremony.

2023 Eminent Member Ming Hsieh addressing students at the Student Leadership Conference.

Second Round of Graduate/Alumni Mentoring builds on last year's success

With the goal of giving graduate students critical career, professional, and personal advice to augment their degree, HKN's first professional-to-student mentoring program sustained its momentum this year with 7 mentors and 13 mentees across four continents (North America, Europe, Asia, and Africa). Seeing the value of the program as filling a critical need, we were fortunate to have three returning mentors: Ryan Bales, John McDonald, and Jenny Marley. Joseph Greene, the chair of the Graduate Student Subcommittee, has been leading the initiative on the program.

Feedback on the program from last year shows not only impact and growth on the part of mentees but also on the mentors. According to one mentor, "As a mentor, I have greatly enjoyed the time I've spent with my mentees. Our conversations have given me new perspectives on some of my own experiences and have made me more appreciative of my own career trajectory. I have also gained insight into some common concerns and interests of recent hires at my own company. Articulating my thoughts in response to some of my mentees' questions has made me more cognizant of my positions on related issues in the workplace." For mentees, being able to meet with someone who understands the challenges of graduate school on a regular basis is invaluable. One mentee put it this way, "Having someone who has been through the Ph.D. process to talk to helps calm my anxiety about my own Ph.D. program. [My mentor] is also helping me be a better leader by getting in the right mind frame."

Mentors and Mentees meeting up at the 2023 Student Leadership Conference

Generally, mentees and mentors agree upon a meeting schedule and sign a mentoring agreement that outlines the logistics and expectations of the mentoring relationship. Most mentees and mentors meet every other week for an hour. If you would like to make an impact in a graduate student's life, are also open to learning about their perspectives, and are willing to devote 2-4 hours per month of your time, please reach out to us to see if there is still space for the next round of mentoring or for future ones.

Alumni Reconnect from Coast-to-Coast

HKN Alumni Receptions offer a chance for HKN alumni to share memories, meet with current students, and network with each other. Such gatherings have been growing in popularity and frequency as our alumni ranks swell to over 40,000. As an honor society that is over 120 years old, the receptions also offer a way for alumni to learn about HKN's current offerings and opportunities to be a part of its work.

Last year, HKN held three receptions:

- 14 April 2023 at SouthEastCon, Orlando, FL
- 2 October 2023 at Qualcomm, San Diego, CA
- 18 October 2023 at Frontiers In Education Conference, College Station, TX

Over 80 alums attended one of the three ceremonies, and we look forward to hosting even more in the coming year. We were very fortunate to have HKN Eminent Members Marty Cooper (a father of the cell phone) and Patrick

Group photo from the October 2, 2023 Alumni Reception at QualComm

Nunally (the father of the arbitron rating system) with us to cut the cake in San Diego!

If you are interested in hosting or attending an upcoming HKN Alumni Reception, contact Nancy Ostin at n.ostin@ieee.org or complete the Alumni Reconnect Form to be kept abreast of alumni news and events.

Funding for our alumni receptions was provided by a generous donation from Dr. and Mrs. Richard Gowen.

IEEE-HKN Website and *THE BRIDGE* Magazine Win APEX Awards

The newly designed website on the WordPress platform went from its launch in 2022 to becoming an APEX Award winner in 2023. The website (hkn.org) allows staff and volunteers to quickly update content to keep all HKN's varied audiences abreast of the latest news and resources. The functionality of the website makes it possible to manage all aspects of HKN, including ordering from its online store, reconnecting with alumni, and chapter management, resulting in the website being the hub of HKN's activities around the world, creating community, and contributing to its unique identity. Kudos to Katie Brinker, Chair of the Public Relations and Communication Committee, and Jason Hui, Chair of the Website Subcommittee, who led the efforts of the redesign and implementation!

THE BRIDGE magazine wins an APEX Grand Award for Publication Excellence in 2023. The October 2022 issue of *THE BRIDGE* was recognized for its special issue on engineering space exploration. Congratulations to the issue guest editor, Sean Bentley, and the 2022 Co-Editors-in-Chief, Sahra Sedigh Sarvestani and Steve E. Watkins. Less than ten percent of the over 1100 entries were recognized with Grand Award status. It is the 10th year that *THE BRIDGE* and IEEE-HKN have been recognized.

HKN Installs Two New Chapters

Nu Theta Installation Ceremony

IEEE-Eta Kappa Nu has expanded its global reach by installing two new Chapters this fall: Nu Eta at the Sri Sairam Engineering College, Chennai, India, and Nu Theta Chapter at Purdue University Northwest. 2023 IEEE-HKN President, Sampathkumar Veeraraghavan, presided over the Nu Eta Chapter installation on 29 September 2023, where 11 students and two professional members took the oath to uphold HKN's tenets of scholarship, character, and attitude. Over 1,000 people attended the ceremony, which was a part of the National Conclave. The Nu Theta Chapter is the first one in the state of Tamil Nadu.

2023 IEEE-HKN President-elect, Ryan Bales, conducted the installation ceremony for the Nu Theta Chapter at Purdue University Northwest on 19 October 2023, in Hammond, Indiana, where 13 students were inducted into the 119-year-old honor society. The new Chapter jumped right into the HKN family, sending a delegation of seven to the recent HKN Student Leadership Conference in Houston, Texas.

Three more new Chapters have been approved by the HKN Board of Governors and will be installed in 2024.

Growing HKN Social Media Presence Provides Platforms to Broaden Reach!

Social media is an important means of connecting and growing our network and amplifying the great work of HKN. Due to the extraordinary efforts of Katie Brinker, chair of the Public Relations and Communications Committee, our social media followers grew across our platforms by double digits, with LinkedIn increasing by 41% (2511), Instagram increasing by 27% (862), and YouTube by 23% (408). Everyone can help in these efforts in 2024 by liking and sharing content. Our social media supports all HKN initiatives—awards, conferences, chapter news, alumni, etc. – and tells stories of our impact in communities around the world.

Part of the success of our social media is the creation of relevant and interesting content through the production of podcast episodes and the posting of sessions from our virtual conferences, Pathways to Industry and TechX. The Young Alumni Committee led by HKN Board Member, Amy Jones, produced a timely and well-received Career Conversations episode on the importance of mental health with Haley DeGreve, founder of the mental health awareness and suicide prevention non-profit, The Gray Matters Collective, about mental health in our personal lives and in the workplace. In addition, the committee also produced a podcast featuring Ryan Bales, 2024 IEEE-HKN President.

Joe Greene, Chair of the Graduate Student Subcommittee, produced several episodes of the popular GradLab podcast that featured Dr. Hulya Kirkici, Chair of the University of South Alabama ECE department and HKN Board Member, who spoke about tackling common fears and anxieties about conducting research as a graduate student called, "What's the Big Picture

in Graduate Research." Dr. Kirkici returned for a second webinar entitled, "Demystifying Academia" that featured key lessons and perspectives that help students recognize their accomplishments and contextualize their contributions as they transition into industry or continue in academia.

2023 HKN Awardees at the IEEE November Meeting Series

The IEEE-HKN Awards were presented on Friday, 17 November 2023, in Washington, DC, as part of the IEEE Educational Activities Awards Banquet, presided over by Rabab Ward, Vice President of IEEE Educational Activities. The following honorees received plaques and much-deserved gratitude for their inspiring contributions:

IEEE-HKN Asad M. Madni Outstanding Technical Achievement and Excellence Award: *Dr. Karen Ann Panetta*, 2019 IEEE-HKN President and Dean for Graduate Education, Tufts School of Engineering. She received this honor for her development of high-impact computer vision and simulation algorithms and for leadership in programs advancing female participation in STEM.

IEEE-HKN Distinguished Service Award: *John DeGraw*, 2018-2020 HKN Board of Governors Member, in recognition of his over 4 decades of service to Eta Kappa Nu in support of alumni and student award activities.

C. Holmes MacDonald Outstanding Teaching Award: *Dr. Colleen Bailey*, Assistant Professor of Electrical Engineering, College of Engineering, University of North Texas. Bailey was honored for her impact on electrical engineering undergraduate education and STEM outreach.

Outstanding Young Professional Award: *Dr. DongHyun (Bill) Kim*, Assistant Professor of Electrical and Computer Engineering, Missouri University of Science and Technology, in recognition of his outstanding contributions toward the characterization and modeling of dielectric materials and via structures to ensure signal integrity and reduce crosstalk levels in high-speed digital channels.

Dr. Sandra Magnus also received her elevation to Eminent Member status at the event. Additional photos of the ceremony can be found here. The 2024 IEEE-HKN Awards cycle is now underway. If you know of a colleague who is making outstanding contributions and should be considered for one of the above awards, please learn more and submit a nomination here before 6 May 2024.

HKN Conferences Attract Over 1,000 Participants

HKN hosted three conferences in 2023: Pathways to Industry, TechX, and the HKN Student Leadership Conference, which drew a record number of participants. Each conference had a different focus, with Pathways to Industry, held in February 2023, being devoted to helping students and young professionals have the professional

Screenshot from Patrick Nunally's keynote address at the virtual Pathways to Industry Conference

skills they need to secure internships and full-time jobs. With engaging sessions such as "How to Maximize Your LinkedIn Profile" and keynotes by luminary HKN engineers, Patrick Nunally and Tom Coughlin, the virtual conference was jam-packed with practical information as well as inspiring messages. HKN TechX followed in April, with a focus on sharpening technical skills needed for the future. HKN conferences offer great opportunities to bring together academic leaders, industry professionals, and IEEE Society partners to share with students and young professionals advice and opportunities to help them succeed. Read about this year's SLC on page 25.

New Asad, Gowhartaj, and Jamal Madni Family Scholarship Announced

Thanks to the generosity of the Madni Family, a new scholarship was established that will support three qualified undergraduate student recipients and up to two qualified graduate student recipients pursuing a degree in the fields represented by IEEE-HKN and who are members of an active IEEE-HKN Chapter. The scholarship is another manifestation of the Madni family's commitment to education, having already established a scholarship at UCLA. Asad Madni is an Eminent Member of HKN and winner of the Vladimir Karapetoff Outstanding Technical Achievement Award in recognition of his illustrious career as the president of BEI Technologies, where he led the development and commercialization of intelligent sensors, systems, and instrumentation, including the control system for the Hubble Space Telescope's Star Selector. To qualify for the Madni Scholarship, a student must be a U.S. citizen enrolled as a full-time student in electrical engineering or related fields at an accredited U.S. university or college. Further qualifications include being an inducted member of IEEE-HKN, and having completed his or her third year in an IEEE-HKN field of interest. The award will be $1,000 per student to cover school expenses such as tuition, books, and fees. The scholarship was launched at the HKN Student Leadership Conference in November. Applications will be accepted until 1 April 2024, and can be submitted here.

IEEE-HKN Chapter Support Initiative Builds on Success in 2023!

Started in 2022 with a generous donation from John McDonald, Beta Chapter, and his wife, Jo-Ann, the IEEE-HKN Chapter Support Initiative was designed to create and enhance the resources, training, and programs every chapter needs to reach their full potential. Through the initiative, Chapters may apply for small grants to support community service, academic, or Chapter-building activities as well as receive coaching from HKN volunteers and staff. In the initial year of the program, eight grants were awarded, and 20 Chapters initiated formal coaching relationships. 2023 saw an increase in the number of grant recipients, the continuation of the coaching relationships, as well as the number of Chapters who started new coaching relationships – 22 grants were awarded and 21 Chapters entered coaching.

The results of these efforts have been impressive:

- Chapters coached in 2022 reported a combined total of over 2,600 hours of activity during the 2022-2023 reporting year. This is a 240% increase over their 2021-2022 reporting year numbers
- The number of coached Chapters reporting activities doubled year-over-year
- A "Passing the Gavel" Ceremony was piloted for the 2024 official launch to support successful officer transitions

Another outcome of the program has been its impact on inductions:

- 19 Chapters held one or more induction ceremony post-coaching meetings
- 326 new members (students and professionals) were inducted into Chapters involved in 2022 and 2023 coaching
- 2023 saw a 155% increase in the number of inductees for Chapters coached in 2022

While the numbers from this program show its impact, the success of this program is best articulated by those students who have benefited from it, as seen in this video.

If you are interested in volunteering to support Chapters at all levels, your help is needed to:

- review inquiries from universities wanting to start new chapters
- join coaching meetings
- help with post-meeting follow-up and MORE

Contributions to the Chapter Support Fund make all this important work possible, and we are greatly appreciative of any donation so that we can keep the momentum going in 2024!

If you would like to support HKN efforts like these, please consider giving to our Chapter Support Fund.
See the Chapter Support Initiative in action, here.

Two HKN Chapter Presidents Play Prominent Roles at their Commencement Ceremonies

As a testament to the leadership and scholarship shown by HKN students, two students, Christian Winingar, President of the Gamma Theta Chapter at Missouri University of Science and Technology, and Lauren Myrna-Renee Silva, Chapter Officer of the Zeta Beta Chapter at Texas A & M University – Kingsville, were chosen by their respective universities to represent their fellow students at their recent commencement ceremonies.

Winingar Dec 2023 Mace Bearer

Christian Winingar, an electrical engineering senior, was one of two students to represent the College of Engineering and Computing as Mace Bearer at the December Commencement of the Missouri University of Science and Technology. Christian was selected due to his campus involvement, including his service as president of the Gamma Theta Chapter of IEEE-Eta Kappa Nu and as past commander of the campus Sigma Nu Fraternity. He received the chapter's Excellence in Leadership Award. He has accepted full-time employment at Burns & McDonnell.

Lauren Silva giving commencement speech

After an arduous selection process, Lauren Myrna-Renee Silva was chosen to be the fall 2023 commencement speaker at a ceremony held in the Steinke Physical Education Center at Texas A&M University - Kingsville last fall. Nominated to speak by the Dean of the College of Engineering, Silva had to compete against many other students by submitting her biography and speech. According to Silva, "It was an honor to be able to deliver the commencement speech to my family, friends, and university community. I was able to gain some public speaking and writing skills from this opportunity, as it took hours of preparation to be 100% ready for the day of graduation."

Her future plans include pursuing her master's in business administration at Texas A&M University - Kingsville and studying to take the FE exam later this year. Upon completing her MBA, she hopes to accept a position at American Electric Power (AEP) as an electrical engineer.

IEEE-Eta Kappa Nu (IEEE-HKN) Announces Key Chapter Recipients for 2022-2023

University Chapters of the IEEE Honor Society Celebrated for Engagement and Community Involvement

IEEE Eta Kappa Nu (IEEE-HKN) is excited to announce that 55 Chapters have achieved Key Chapter status for the 2022-2023 academic year.

University of North Texas

The Key Chapter recognition celebrates Chapters that participate in activities identified as the best practices of successful Chapters. Every Chapter has the potential to earn the Key Chapter recognition.

Key Chapter banners were presented on 4 November 2023, during the Awards and Recognition Banquet at the Student Leadership Conference.

Congratulations to the members, officers, advisors and department heads of the following Chapters:

Alpha	University of Illinois, Urbana-Champaign
Beta	Purdue University
Beta Alpha	Drexel University
Beta Delta	University of Pittsburgh
Beta Epsilon	University of Michigan
Beta Eta	North Carolina State University
Beta Gamma	Michigan Technological University
Beta Mu	Georgia Institute of Technology
Delta Omega	University of Hawaii, Manoa
Delta Xi	Air Force Institute of Technology
Epsilon	Pennsylvania State University
Epsilon Alpha	Cleveland State University
Epsilon Beta	Arizona State University
Epsilon Eta	Rose-Hulman Institute of Technology
Epsilon Mu	University of Texas at Arlington
Epsilon Sigma	University of Florida
Gamma Alpha	Manhattan College
Gamma Bet	Northeastern University
Gamma Gamma	Clarkson University
Gamma Iota	University of Kansas
Gamma Kappa	New Jersey Institute of Technology
Gamma Mu	Texas A&M University, College Station
Gamma Omega	Mississippi State University
Gamma Theta	Missouri University of Science and Technology
Iota Gamma	University of California, Los Angeles
Iota Zeta	California State University, Chico
Kappa Lambda	University of Memphis
Kappa Omicron	State University of New York, New Paltz
Kappa Phi	University of North Carolina Charlotte
Kappa Ps	University of California, San Diego
Kappa Upsilon	University of Texas, San Antonio
Kappa Xi	University of South Florida
Lambda	University of Pennsylvania
Lambda Beta	California State University, Northridge
Lambda Lambda	American University-Sharjah
Lambda Omega	National University of Singapore
Lambda Omicron	Miami University
Lambda Tau	University of Puerto Rico, Mayaguez
Lambda Xi	Hofstra University
Lambda Zeta	University of North Texas
Mu	University of California, Berkeley
Mu Alpha	UCSI University – Kuala Lumpur
Mu Beta	Arab Academy For Science & Tech – Alexandria
Mu Mu	Wentworth Institute of Technology
Mu Nu	Politecnico Di Torino
Mu Xi	Indian Institute of Science – Bangalore
Nu Alpha	Univ Nacional De Educacion A Distancia
Nu Epsilon	Kennesaw State University
Nu Gamma	The College of New Jersey
Psi	University of Texas, Austin
Theta	University of Wisconsin, Madison
Theta Lambda	University of South Alabama
Zeta Iota	Clemson University
Zeta Lambda	Prairie View A & M University

Celebrating the Research Contributions of Our Graduate Student Members

Graduate students, an important and growing part of the IEEE-HKN global community, are performing groundbreaking research. We have developed this award-winning section in *THE BRIDGE* to celebrate and elevate their research contributions. The HKN Graduate Student Research Spotlight is a standing feature in *THE BRIDGE*. The profiles of the students and their work will also be shared on our social media networks.

Each profile will showcase the intellectual merit and broader impact of HKN graduate student members' research and provide information about the students' backgrounds and where people can learn more about them and their work.

We will spotlight these achievements while also showing potential graduate students what is possible!

Would you like to be featured?

Fill out our submission form. Submissions will be reviewed, assembled into a profile template, and posted on HKN's social media pages. A select number of profiles will also be featured in *THE BRIDGE*.

Advertising Opportunity

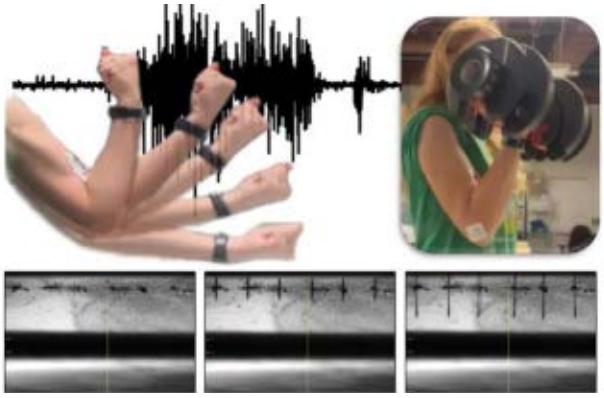
IEEE-HKN is the professional home to the world's top graduate students in electrical and computer engineering, computer science, and allied fields of interest. Get your company or university in front of these students and HKN's undergraduate students who are considering their next steps by advertising in a special section of *THE BRIDGE*. Click here for more information and rates.

Allyson Tesky

Lambda Zeta Chapter
University of North Texas, M.S. student in biomedical engineering

RESEARCH TOPIC
Solution Processed Graphene for Wearable Technology

With home healthcare becoming more prevalent, reusable dry electrodes provide a promising alternative to the downsides of the 3-D wet disposable electrodes that currently dominate the market but require extensive preparation and can cause irritation. Graphene's high conductivity and low dimensionality make it a perfect candidate for 2-D electrodes and other biosensing devices. However, most solution-processed graphene uses toxic solvents or is only used with certain techniques, like screen-printing. Allyson's research focuses on making renewable and biocompatible graphene inks for the versatile technique of inkjet printing. This inkjet-printed graphene can be used in biosensors, from the simple respiration monitor to the potential dry electrode.



Electromyography provides the basis for research into inkjet-printed renewable inks.

LEARN MORE
https://kaulgroup.engineering.unt.edu/

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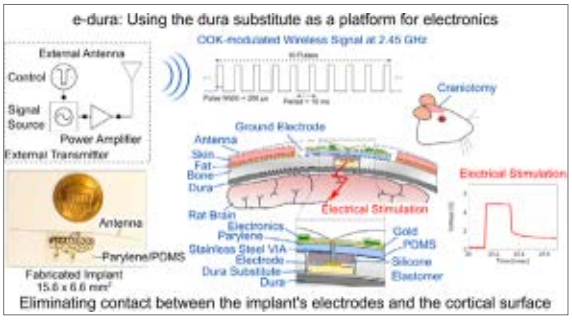
Abed Benbuk

Epsilon Beta
Arizona State University, Ph.D. candidate in electrical engineering

RESEARCH TOPIC
Wireless Stimulation of Motor Cortex Through a Collagen Dura Substitute Using an Ultra-Thin Implant Fabricated on Parylene/PDMS

This research is within biomedical circuits and systems, and with a focus on the design of wireless, battery-free implants for brain stimulation. Electrical stimulation has several therapeutic applications, such as recovering from trauma, treating movement disorders, or even combatting addiction. Wire movement, wire failure, and battery replacement are the three main sources of complications for patients with biomedical implants. The research presented here shows the idea of e-dura, which is an ultra-thin, wireless, and battery-free implant that is put on top of an FDA-approved collagen dura substitute. This is used to seal a craniotomy site after brain surgery to replace dura that has been damaged or lost. The wireless implant augments the function of the dura substitute by supplying electrical stimulation. The implant can deliver wireless stimulation through the dura substitute without making any contact with the brain surface. Therefore, this work allows surgeons to utilize a multi-functional dura substitute that combines the therapeutic properties of the dura substitute with electrical stimulation for enhanced recovery. The main advantages of this approach are the enhanced safety profile due to eliminating contact between the electrode and the brain surface and the ability to deliver the implant as part of a pre-planned surgery.



The e-dura concept and in vivo test setup are used in this study. The implant is positioned in a rat-sized craniotomy to deliver electrical stimulation through the FDA-dura substitute.

LEARN MORE
https://scholar.google.com/citations?user=4Dh-2moAAAAJ&hl=en

PUBLISHED JOURNAL ARTICLE IEEE TBIOCAS
https://doi.org/10.1109/TBCAS.2023.3329447

Prabhu Vellaisamy

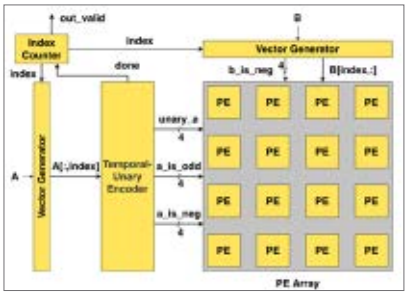
Sigma
Carnegie Mellon University, Ph.D. student in electrical & computer engineering

RESEARCH TOPIC
Leveraging Neuromorphic Principles for Efficient Implementation of AI Accelerators

The rapid advancement of deep learning (DL) has solidified its position as an indispensable tool for solving complex real-world problems. However, the computational demands associated with DNNs have grown exponentially. Therefore, deploying such complex AI models at the edge presents additional hurdles due to the resource limitations of edge devices.

Prabhu's research is centered around harnessing key neuromorphic principles to develop novel hardware solutions for DL. The inspiration for this research comes from neuromorphic computing, a field that seeks to emulate the efficiency and processing of the human brain. The key principles guiding this research are (i) temporal-unary computation, (ii) low-precision computation, and (iii) sparse computation.

Prabhu's prior publications demonstrate the efficacy of applying these principles to develop novel matrix multiplication units. His contributions include the development of TuGEMM (ISCAS'23), a fully temporal matrix multiplication unit adept at exploiting data sparsity in DNN models and demonstrating state-of-the-art hardware metrics, outperforming other unary-based works. Subsequently, in collaboration with MediaTek USA Inc., Prabhu designed TubGEMM (ISVLSI'23), a temporal-binary hybrid matrix multiplication unit that exhibits an exponential reduction in compute latency when compared to TuGEMM, significantly boosting its energy efficiency. Rigorous evaluations were performed by running MobileNetv2 and ResNet-50 benchmarks.



For tugemm.png - TuGEMM (ISCAS'23)
For tubgemm.png - TubGEMM (ISVLSI'23)

LEARN MORE
https://scholar.google.com/citations?user=ePfYSNsAAAAJ&hl=en

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Sascha Kirch

Nu Alpha
UNED - National University of Distance Education, Madrid, Spain, Ph.D. student multi-modal generative deep learning

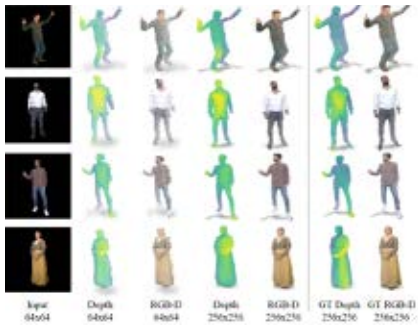
RESEARCH TOPIC
Single-View 3D Reconstruction of Humanoid Subjects

From immersive communications, games, and virtual production to virtual try-ons and virtual fitting rooms, having an accurate 3D representation of the body of a person is fundamental.

One would typically need to use a professional 3D capture stage with many cameras pointing at the person and then put all the videos together using 3D reconstruction algorithms. These setups are complex and expensive. To overcome these challenges, modern deep learning techniques aim to simplify the capture process by replacing the multi-camera setup with a single camera, from a single viewpoint.

Some approaches include depth information, which typically comes from a consumer-level depth sensor. Although new generation consumer-level depth sensors have significantly improved, they still present high levels of noise and sometimes fail to capture details when the subjects are at a distance where their bodies can be fully captured. They are sensitive to sunlight, dark materials, and non-Lambertian surfaces.

Sascha's work focuses on supporting single-view 3D reconstruction with generative deep learning techniques. His recent work, "RGB-D-Fusion: Image-Conditioned Depth Diffusion of Humanoid Subjects," suggests a diffusion model to generate high-resolution depth maps from a single image to remove the need for depth sensors while increasing the quality of the reconstructed 3D model.



RGB-D-Fusion framework. This diffusion model-based framework takes an RGB image as input and outputs an RGB-D image. First, we predict the perspective depth map of a down-sampled RGB image using a conditional denoising diffusion probabilistic model. We then combine the predicted depth map with the input RGB into a low-resolution RGB-D image. We further apply a super-resolution model conditioned on the low-resolution RGB-D to obtain a high-resolution depth map. The predicted high-resolution depth map is combined with the input RGB to construct the final output: a high-resolution RGB-D image.

LEARN MORE
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Journey to the Stars: Women Shaping the Future of Space Exploration

Burton Dicht, Eta Chapter

When Wally Funk's mother was 17 years old, she yearned for a barnstorming ride, but her father (Funk's grandfather) vetoed the idea, asserting, "Ladies do not fly".[1] This sentiment would persist for much of Funk's life as she pursued a career in aviation. Funk attributes her passion for flight and the support for her aviation career to her mother. She embarked on her aviation journey at the age of 9, securing her pilot's license at 17. Over her lifetime, Funk amassed more than 19,000 flight hours, equivalent to more than 792 days in the air. However, her lifelong dream of venturing into space remained elusive for an extended period of time.

Wally Funk with a T-33 at Fort Sill (1960); Photo Credit: Wally Funk

Her initial venture into the space program involved participating in medical and psychological tests conducted by William Randolph Lovelace to assess women for spaceflight in 1960-61. Funk was part of the "Mercury 13," a group of 13 female aviators who completed tests identical to those performed on the original Mercury 7 astronauts. In many cases, they outperformed their male counterparts. NASA halted this initiative as Lovelace's program lacked agency approval, stifling the dreams of Funk and the other female aviators. Interest in the Mercury 13 resurfaced when Soviet cosmonaut Valentina Tereshkova became the first woman to fly in space on June 16, 1963. However, NASA did not select its first female astronauts until the first space shuttle class in 1978, naming six.

Funk clung to her dream and, finally, soared into space on a Blue Origin New Shepard suborbital flight. On July 20, 2021, at the age of 82, Funk became the oldest woman to experience space. Reflecting on her legacy, Funk remarked, "I've had a wonderful career in aviation. I even broke a couple of glass ceilings for women along the way".[2] Female astronauts who followed paid homage to Funk and the Mercury 13. Colonel Eileen Collins (U.S. Air Force retired), the first female Space Shuttle commander, wrote, "In 1990, I was selected as the first woman to train as a pilot astronaut in the space shuttle program. It took many years for NASA to get to that point, but I believe the Mercury 13 helped make it happen".[3] Collins honored Funk and other Mercury 13 members by inviting them to her STS-63 launch on February 3, 1995, when she became the first woman to pilot the Space Shuttle.

The Mercury 13 legacy continues today as women all over the world are contributing to the advancement of space science and exploration. Since the beginning of the space age, women have played key roles as scientists, engineers, mission controllers, and astronauts. Unfortunately, the role of women in space has often been overlooked. The movie (and book) Hidden Figures, from 2016, shared the untold story of African American female mathematicians, or "computers" as they were called, who made critical contributions in the early days of the space race. But there are many other untold stories. With Women's History Month in March just around the corner, this is the perfect opportunity to share the space accomplishments of several remarkable women who are not household names.

Dr. Margaret Burbridge and the B2FH Paper

Margaret Burbidge; Photo Credit: American Institute of Physics

Margaret Burbidge was one of the foremost astronomers in the world and served as a trailblazer for women in the field. She was a native of England but worked largely in the U.S. Despite facing obstacles, such as being rejected from a Mount Wilson Observatory fellowship due to gender restrictions on telescope use, she persisted. One of her notable achievements was co-authoring the influential 1957 paper "Synthesis of the Elements in Stars," widely recognized as a groundbreaking contribution to astrophysics. This paper, also known as the B2FH paper, proposed the theory of stellar nucleosynthesis, where all heavy elements in the universe were created within stars via nuclear fusion.[4]

This theory challenged the prevailing belief that all elements originated from the Big Bang. B2FH is now widely accepted. Burbidge's pioneering work alongside her

husband, Geoffrey Burbidge, physicist William Fowler, and astronomer Fred Hoyle revolutionized the understanding of modern nuclear astrophysics. Neil deGrasse Tyson hailed the B2FH paper as "the greatest gift of astrophysics to civilization in the 20th century.[5]

JoAnn Morgan – From the Firing Room to Breaking Glass Ceilings

The photo showed her seated in the middle of a crowded room with men in white shirts and dark ties. All of them had their eyes affixed to the windows as they watched the huge Saturn V rocket thunder its way to orbit, carrying the crew of Apollo 11 on their historic first moon landing. JoAnn Morgan was an instrumentation controller for Apollo 11, the only woman working inside the firing room of the Launch Control Center. She is well known for that unique moment captured in time, but her contributions to NASA and the space program spanned more than 45 years.

Morgan in the Firing Room; Photo Credit: NASA

Morgan began work during the summers as a University of Florida trainee for the U.S. Army at Cape Canaveral Air Force Station at age 17, and her college course work in data systems and computers led her to become a data systems engineer at the Kennedy Space Center (KSC). Like other women working in a male-dominated profession, she faced many obstacles during her career, but she broke many glass ceilings for herself and others that followed. She was the first woman at NASA to win a Sloan Fellowship, the first female engineer at KSC, the first woman division chief, the first woman senior executive at KSC, the first woman associate director, and the first woman director of Safety and Mission Assurance. She retired in 2003 as director of external relations and business development, leaving a decorated legacy at NASA.[6]

JoAnn Morgan, at right, speaking to Charlie Blackwell-Thompson, the first female launch director; Photo Credit: NASA

Dr. Nancy Grace Roman – The Mother of the Hubble

Enthralled by the night sky at a young age, Nancy Grace Roman started an astronomy club with her friends, which was the beginning of a career dedicated to exploring the cosmos. She joined NASA one year after it was founded and became the first chief of astronomy. She was also the first woman in a NASA leadership position. Roman was instrumental in advancing space-based astronomy, and she is recognized as the "Mother of Hubble." Roman oversaw the early planning for the Hubble Space Telescope, which has contributed much to our understanding of the universe.

Nancy Grace Roman, standing in front of a 1/6-scale model of the Hubble Space Telescope; Photo Credit: NASA GS

The idea for a space-based telescope had been around since the 1940s, but the technological feasibility and the cost dissuaded many from pursuing it further. As technology and cost converged, Roman made it happen. "It was Nancy in the old days before the internet and before Google and email and all that stuff who really helped to sell the Hubble Space Telescope, organize the astronomers, and eventually convinced Congress to fund it," commented Edward Weiler, Roman's successor as Hubble chief scientist. Roman retired from NASA in 1979, before the Hubble was launched in 1990, with her place in history established.[7] Like Burbidge, Roman was a trailblazer for women in science, and she sought to inspire girls to pursue careers in science. In her honor, NASA has named its next space-based telescope the Nancy Grace Roman Space Telescope, which is scheduled to launch by May 2027.

Dr. Helen Sharman – The First British Citizen in Space

Following Tereshkova's flight, a 19-year gap ensued before the next woman ventured into space. Svetlana Savitskaya, hailing from the Soviet Union, achieved her first space flight on August 19, 1982. Astronaut Dr. Sally Ride, on June 18, 1983, made history as the first American woman in space. It would be another eight years before the first non-Soviet, Russian, or American woman launched into space when, on May 18, 1991, Helen Sharman, the first British citizen in space, launched aboard a Soyuz rocket, making her the second woman to fly to a space station, the Soviet Mir.

What sets Sharman's spaceflight apart is its unique funding through Project Juno, a private company-sponsored

Sharman in 1991; Photo Credit: Helen Sharman

initiative. Selected from more than 13,000 applicants, Sharman, a 27-year-old research scientist with a Ph.D. in chemistry, underwent rigorous psychological, medical, and technical assessments. Following her selection, she completed an 18-month training period at Star City in the Soviet Union. Her eight-day mission included experiments in medicine, agriculture, and chemistry. Although Sharman never returned to space, she utilizes her spaceflight experience to promote scientific awareness, inspiring the next generation through speaking engagements and public science events.[8]

In this issue, the focus on NewSpace highlights the dynamic space ecosystem offering opportunities for the next generation of engineers and technology professionals. As we look to the future, it is crucial to explore our past, recognizing and understanding women's contributions to astronomy and space exploration. This Women's History Month, let's celebrate the significant impact these women had and acknowledge the untold stories that propelled us into space.

Burton Dicht, a member of IEEE-HKN's *THE BRIDGE* Editorial Board, previously served as the Director of Student and Academic Education Programs within the IEEE's Educational Activities Department. With a background as a lead engineer in the aerospace industry, Burton brings extensive expertise to the field and is a sought-after guest speaker on space history and technology. Additionally, Burton is a member of HKN's Eta Chapter and the Managing Director of Membership for the National Space Society.

Recommended Reading List

A History of Women in Astronomy and Space Exploration: Exploring the Trailblazers of STEM by Dale Debakcsy

Rise of the Rocket Girls: The Women Who Propelled Us From Missiles to the Moon to Mars by Nathalia Holt

Almost Heaven: The Story of Women in Space by Bettyann Holtzmann Kevles

A Passion for Space: Adventures of a Pioneering Female Flight Controller by Marianne Dyson

Rocket Girl: The Story of Mary Sherman Morgan, America's First Female Rocket Scientist by George Morgan

Women in Space: 23 Stories of First Flights, Scientific Missions, and Gravity-Breaking Adventures by Karen Bush Gibson

Making Space for Women: Stories from Trailblazing Women of NASA's Johnson Space Center edited by Jennifer M. Ross-Nazzal

Through the Glass Ceiling to the Stars: The Story of the First American Woman to Command a Space Shuttle Mission by Col Eileen Collins with Jonathan Ward

Diary of an Apprentice Astronaut by Samantha Cristoforetti

The Mercury 13: The Untold Story of Thirteen American Women and the Dream of Space Flight by Martha Ackmann

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[1] M. Weitekamp (2021, July 16), "Never Say Never: Wally Funk's Space Flight Dream Comes True," https://airandspace.si.edu/stories/editorial/never-say-never-wally-funks-space-flight-dream-comes-true

[2] W. Funk (2020), *Higher Faster Longer: My Life in Aviation and my Quest for Spaceflight,* p. vii, Traitmarker Books

[3] W. Funk (2020), *Higher Faster Longer: My Life in Aviation and my Quest for Spaceflight,* p. iii, Traitmarker Books

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"The field of engineering is very dynamic and full of constant innovation, requiring professionals to keep up with daily advances."

Edoardo Colella

Politecnico di Torino, MSc in Computer Engineering, focus on Software Engineering, Mu Nu Chapter

Edoardo began his journey with HKN in 2021, when he joined the Mu Nu Chapter. Within a year, he assumed the role of president, a position that has allowed him to actively contribute to this dynamic community. He is fueled by a commitment to continuous improvement in both academia and personal development, and he chose to study engineering because of his passion for math and logic. According to Edoardo, "At the age of 11-12, during middle school, I discovered a Python 2.7 tutorial on YouTube. The moment I got into programming, I knew it was the path for me." He added that he loves engineering because "engineering embodies the powerful fusion of creativity and precision."

However, he finds that in the field of engineering, constant pressure and competitiveness can be discouraging, stating that "the field is very dynamic and full of constant innovation, requiring professionals to keep up with daily advances." He takes inspiration from other HKN members whom he sees striving for personal growth and positive impact. Colleta's dream job is to be a software architect, with his passion lying in designing and defining the architecture of complex computer systems that are not only functional but also scalable, secure, and efficient. He states, "Being a software architect would allow me to combine my technical skills with a strategic mindset, contributing to the development of cutting-edge technologies and leaving a lasting impact on the software landscape."

Speaking about his own academic journey, he advises other students to "treasure the multitude of learning experiences and collaborative projects because they contribute significantly to the development of knowledge and skills" and attributes his school experience to providing a solid foundation for his personal and professional growth.

Always looking to challenge himself to expand his knowledge, he states, "If I had more time, I would like to explore new destinations, satisfying my desire to travel. And I have at least 20 books that I still can't find time to read!"

John Deere Appreciates HKN Intern Talent

John Deere looks to HKN conferences and career fairs to recruit top talent. For 2023, these interns worked on a variety of innovative projects spanning the construction division, from hardware design to software testing to systems engineering. This includes battery-electric vehicle design, the introduction of sensing components, and display verification.

According to Amelia Smith, Manager Engineering Services at John Deere, "As a technology company on the cutting edge of agriculture and construction, **we have been very impressed by the technical skills and leadership qualities of the students that have joined our company through IEEE-HKN.** Without fail, these students display strong character and an eagerness to learn. These are skillsets we seek out for emerging talent coming to John Deere."

Back row: Matthew Thienel, Jared Reiss-Lavoie, Michael Drobot, Trent Fleege (Engineering Supervisor) Front row: Amy Jones (Displays Delivery Manager), Alex Reynaga, Yazan Alshabani, William Browning

Tom Coughlin, President, Coughlin Associates, is a digital storage analyst and business and technology consultant. He has over 40 years of experience in the data storage industry, having held engineering and senior management positions. Coughlin Associates consults, publishes books and market and technology reports, and puts on digital storage and memory-oriented events. He is a regular contributor to Forbes.com and M&E organization websites. He is an IEEE Fellow, 2024 IEEE President, Past-President IEEE-USA, Past Director IEEE Region 6, and Past Chair Santa Clara Valley IEEE Section. He is also active with SNIA and SMPTE. He is a recipient of the 2020 MGA Leadership Award, a SCV Section Leadership Award, and a volunteer award from CTSoc. He has a B.S. in physics and an M.S. in electrical engineering from the University of Minnesota, and a Ph.D. in electrical engineering from Shinshu University in Nagano, Japan. For more information on Tom Coughlin go to www.tomcoughlin.com.

Thomas Coughlin

President, Coughlin Associates, Inc.
2024 IEEE President & CEO
Chapter of Induction: Eta Chapter

Tom Coughlin was inducted into the Eta Chapter in 2010 and has been a frequent contributor to Eta Kappa Nu's events and educational offerings, most recently as the keynote speaker for the 2022 Pathways to Industry conference. Inspired by scientists Albert Einstein and Thomas Edison as well as philosophers Mahatma Gandhi and Henry David Thoreau, Coughlin knew that he wanted to be a scientist and involved in technology since he was a child, stating, "I read biographies of famous scientists and inventors and science fiction, and I was inspired to try and make the things that I read about real." This desire led to an illustrious career that spans over 40 years, spurred on by his love of learning and desire to "figure out how things work and make new and useful things." He has seen many changes in the field of engineering, including personal computers, the Internet, open-source software, SoCs, smaller and smaller microelectronics, putting fantastic space telescopes into operation, people returning to space, drones, smartphones, ubiquitous cell phones, new developments in AI, and electronics and software infusion.

> "...be a member and a volunteer with a technical organization, such as IEEE...this will help you stay up to date with the latest developments in your field and related fields and to make a network of people who can help you with your career."

He predicts that over the next 10 years, engineering in IEEE fields of interest will bring "more AI applied to more applications and modeling, augmented and virtual reality used for design, testing, and training, telepresence getting good enough to reduce some travel, and more automation and robotics combined with AI as engineering assistants." In addition, Coughlin sees engineering in space emerging as people move to use extraterrestrial resources. Despite the technological advances envisioned by Coughlin, he emphasizes that "people do engineering, and people make decisions on what to do with technology. It is important for technologists to understand how to work with people to get things done."

To help prepare for these future advances, he advises recent graduates entering the field to "be a member and a volunteer with a technical organization, such as the IEEE," further stating that "this will help you stay up to date with the latest developments in your field and related fields and to make a network of people who can help you with your career." He specifically supports IEEE-HKN because of its important role as a technical professional association that nurtures smart people who can make the world a better place. Apropos of this *THE BRIDGE* issue devoted to NewSpace, Coughlin stated, "I look forward to the first HKN chapter off the Earth. Will we have non-human HKN members?" Closer to earth, he challenges us to think about how to develop training and career opportunities in underdeveloped countries so that people from local cultures can apply technology to make their lives and the world better.

A final, fun fact about IEEE's 2024 President is that he is a rock collector, and as a child, he would try to find fossils in the pre-Cambrian rocks in South Dakota, where he grew up.

Free Offerings from IEEE-USA for IEEE Members

Georgia C. Stelluto

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In the third IEEE-USA digital e-comic in the e-book robot series, *Rover Boy and Samson Team Up*, author Harry T. Roman pairs up Rover Boy (a robot) with Samson (also a robot), under the supervision of Jen (a human), to conquer an environmental hazard.

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IEEE-USA's November Free, New Audiobook Touta Speakers Bureaus for Developing Career, Life Skills

Harry T. Roman first joined a speakers bureau more than 50 years ago. In his new IEEE-USA audiobook, *The Value of a Speaker's Bureau,* he draws on his years of experience talking to civic groups, schools and senior clubs on such topics as the value of nuclear energy, alternative

energy options, and energy and the environment. Roman not only outlines the advantages of speaker bureaus for companies, but he also stresses the value to participants—employees who step up and venture into the community to educate people about their companies or to garner support for an important company initiative.

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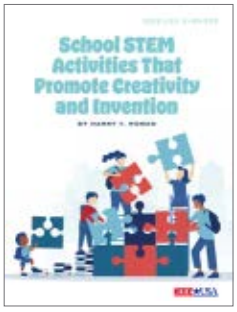

IEEE-USA's New, Free January E-Book: *School STEM Activities that Promote Creativity and Invention*

Free New January E-Book for Members Infuses STEM Activities into the Classroom

Harry T. Roman has written several books for teachers laying out creative ways to engage and stimulate students about STEM. In his new IEEE-USA e-book, *School STEM Activities that Promote Creativity and Invention*, Roman laser focuses the activities on the environments students know best -- mainly their school, but also the communities where they live. He believes focusing on the school can "stimulate students' creativity." Roman also believes this approach can broaden students' and teachers' views on STEM, demonstrating how "the STEM philosophy of problem-solving can reach far across technology and non-technology subject matters."

The book is divided into four sections (Creativity and New Insights, Solar and Alternative Energy, Writing Activities, and Design Challenges), with each section packed full of classroom activities and exercises that stretch a student's thinking-- giving them insights into the engineering process. Roman offers a broad array of activities teachers and students can apply to many school settings, and that appeal to students with diverse interests.

IEEE Members: Download your free e-book, by going to: https://ieeeusa.org/product/school-stem-activities-that-promote-creativity-and-invention/

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