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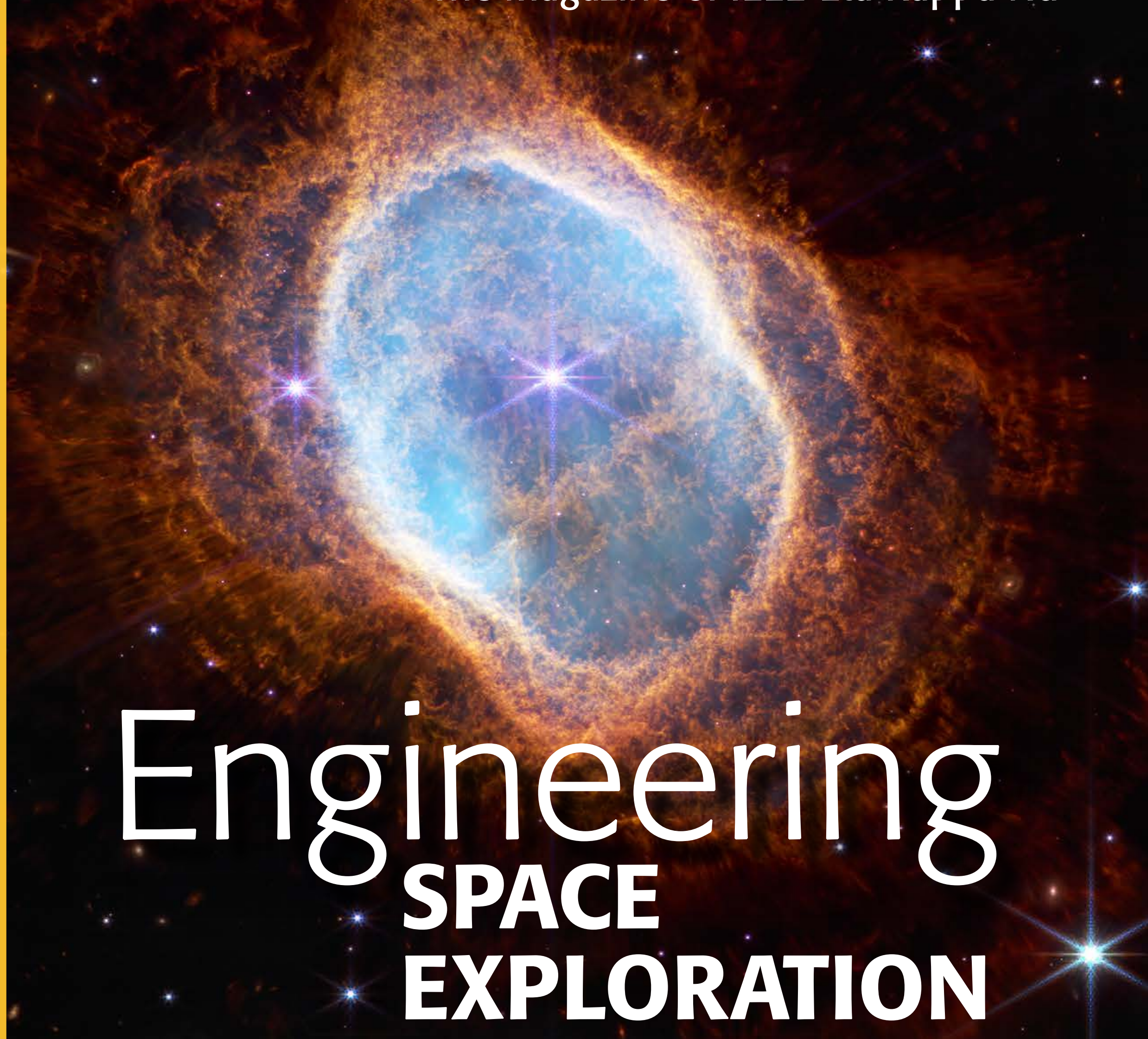
THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu



Engineering SPACE EXPLORATION

IEEE-Eta Kappa Nu

IEEE

IEEE-HKN AWARDS PROGRAM

As the Honor Society of IEEE, IEEE-Eta Kappa Nu provides opportunities to promote and encourage outstanding students, educators, and members.

Visit our new website to view the awards programs, awards committees, list of past winners, nomination criteria, and deadlines.

ALTON B. ZERBY AND CARL T. KOERNER OUTSTANDING STUDENT AWARD (OSA)

Presented annually to a senior who has proven outstanding scholastic excellence and high moral character, and has demonstrated exemplary service to classmates, university, community, and country.
(Deadline: 30 June)

C. HOLMES MACDONALD OUTSTANDING TEACHING AWARD (OTA)

Presented annually to electrical engineering professors who have demonstrated, early in their careers, special dedication and creativity in their teaching, as well as a balance between pressure for research and publications.
(Deadline: Monday after 30 April)

DISTINGUISHED SERVICE AWARD (DSA)

Recognizes members who have devoted years of service and lifetime contributions to Eta Kappa Nu (or IEEE-HKN), resulting in significant benefits to all of the Society's members.
(Deadline: Monday after 30 April)

OUTSTANDING CHAPTER AWARD (OCA)

Recognizes chapters for excellence in activities and service at the department, university, and community levels. The award is based on the content contained in their Annual Chapter Report for the preceding academic year.
(Deadline: 31 July)

OUTSTANDING YOUNG PROFESSIONAL AWARD (OYP)

Presented annually to an exceptional young engineer who has demonstrated significant contributions early in his or her professional career.
(Deadline: Monday after 30 April)

IEEE-HKN ASAD M. MADNI OUTSTANDING TECHNICAL ACHIEVEMENT AND EXCELLENCE AWARD

Presented annually to a practitioner in the IEEE technical fields of interest who has distinguished himself or herself through an invention, development, or innovation that has had worldwide impact.
(Deadline: Monday after 30 April)

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. 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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Features

Departments

IEEE-HKN INTERNATIONAL HEADQUARTERS

Editorial inquiries: IEEE-Eta Kappa Nu, 445 Hoes Lane, Piscataway, NJ 08854, USA
US Toll Free: +1 800 406 2590
Outside US: +1 732 465 5846
Email: info@hkn.org | www.hkn.ieee.org

Subscription address and email changes: IEEE Contact Center
US Toll Free: +1 800 678 4333 | Outside US: +1 732 981 0060 | Fax: +1 732 562 6380 | Email: contactcenter@ieee.org

Dr. Sahra Sedigh Sarvestani

Beta Chapter

Dr. Steve E. Watkins

Gamma Theta Chapter

THE BRIDGE, October 2022 Letter from the Editors-in-Chief

This issue of *THE BRIDGE* magazine highlights engineering advancements for space-based technology, to coincide with and celebrate the release of images from the James Webb Space Telescope. We appreciate the efforts of our guest editor, Dr. Sean Bentley (Gamma Theta Chapter) and the authors of the feature articles on this thrilling topic.

This issue also celebrates the winners of the 2022 IEEE-HKN Awards and Recognition program, whose contributions to the organization and profession span technical achievements, service, and teaching.

The perfect bridge between these topics is an interview with Dr. Asad Madni, who is an IEEE-HKN Eminent Member and recipient of the 2022 IEEE Medal of Honor, among many other career honors and awards. Dr. Madni is a pioneer in technology for space-based telescopes and among his creations is the control system for the Hubble Space Telescope's Star Selector System. He is also the namesake of the IEEE-HKN Asad M. Madni Outstanding Technical Achievement and Excellence Award, established in 2019 and made possible through the generosity of the family, friends, and colleagues of Dr. Madni.

The Graduate Research Spotlight content of *THE BRIDGE* magazine received a 2022 Annual APEX Award for Publication Excellence (see www.apexawards.com) in the Writing – Regular Departments and Columns category. We congratulate Katelyn Brinker and her committee for creating and managing this content! This is the ninth consecutive recognition for the magazine in various APEX categories.

We have had the privilege of serving as Editors-in-Chief of *THE BRIDGE* for the past several years. This is our final issue, as we will be stepping down in December 2022. We look forward to seeing the magazine flourish and evolve under the new leadership of Dr. Jason Hui.

IEEE-HKN strives for effective communication with members through our website, our YouTube channel, our Facebook and LinkedIn pages, and *THE BRIDGE* magazine. Please check out the website for the newest online resources and news. Remember that the current, as we ll as recent, issues of the magazine are available on the IEEE App. The Editorial Board can be contacted by e-mail at info@hkn.org.

The cover image is described on page 28.

Letter from Guest Editor

Dr. Sean Bentley, Gamma Theta, Associate Professor of Physics at Adelphi University

This issue of *THE BRIDGE* arrives almost precisely 65 years after the launch of Sputnik 1. Today we are seeing some of the most detailed images of the universe (including the one on the cover and the one here), thanks to the James Webb Space Telescope.

The "Cosmic Cliffs" region of the Carina Nebula, over 7,500 light-years from Earth, was imaged by the Near-Infrared Camera on NASA's James Webb Space Telescope, revealing much more detail than previous images of the region. Image credit: NASA, ESA, CSA, and STScI.

In the decades between then and now, significant advancements have been made in space exploration, driving innovations in engineering. Humans have walked on the moon and sent probes throughout the solar system and beyond, with Voyager 1 and 2 entering interstellar space a few years ago. Multiple rovers have explored Mars, including flying the first robotic helicopter on that planet last year. The Earth is orbited by thousands of satellites providing everything from GPS signals to weather and climate data to communication links. The International Space Station has been in orbit for over two decades, with one astronaut spending a record 355 days in orbit. Powerful space-based telescopes greatly expand our understanding of the universe with ongoing discoveries. Private spacecraft are becoming common, aiding exploration while also creating space tourism and allowing actor William Shatner ("*Star Trek's*" original Captain Kirk) to become the oldest human in space, rising to nearly 70 miles above the Earth. These advancements continue to grow, with the goal of many to send humans to Mars in the next decade.

With the high cost of space programs and the many problems to be addressed on Earth, the value of funding these programs is often questioned. From a purely scientific standpoint, much of what we know about the universe, and science itself, has been learned through the data from satellites, probes, and telescopes. While some may debate the value of fundamental knowledge, discovery remains a driving force for our species that helps define us. From a technological standpoint, a wealth of engineering advancements, from portable electronics to artificial limbs, was brought about through space programs. Many strong arguments have been made that these advancements would likely not have happened for many more years or even decades if not driven by particular requirements of a space-based mission. Perhaps most importantly, space has long inspired students to pursue STEM-related majors in college (one 2009 survey looked directly at the impact of the Apollo program on career choices of those who became scientists*). I, for one, was strongly influenced by the Space Shuttle program and originally planned to pursue a career with NASA before being drawn to a life in teaching.

In this issue, we will see three key engineering advancements for space-based technology. One looks at the Webb telescope itself, with the development of an event-driven operations architecture to maximize the use of the telescope over its lifetime. This advancement could benefit many other telescopes and probes. Another article describes designing a Lunar Environment Monitoring Station with the need for very low power consumption, overcoming a fundamental problem for many space-based missions. We also have an interview with IEEE-HKN Eminent Member Dr. Asad M. Madni, discussing his work in developing an extremely slow-motion, dual-axis servo control system for the Hubble Space Telescope that has been crucial in the over three decades of data and images collected by Hubble. These three examples highlight the impact engineers have had and continue to have on space exploration. Engineers genuinely lead the way into the final frontier.

Sean J. Bentley earned his BSEE (1995) and MSEE (1997) from the University of Missouri-Rolla (now Missouri University of Science and Technology) and his Ph.D. in optics (2004) from the University of Rochester. He is an associate professor of physics at Adelphi University, where he was awarded the Teaching Excellence Award for 2012-13. He received the 2022 David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching from the American Association of Physics Teachers. From 2014-2016, he served as director of the Society of Physics Students and Sigma Pi Sigma (the physics honor society) at the American Institute of Physics. He served as the IEEE-HKN Region 1-2 Governor for 2018-19 and has been a member of *THE BRIDGE* Editorial Board since 2021. He is a Senior Member of the IEEE.

*http://www.nature.com/news/2009/090715/full/460314a.html

Dr. Jason Hui Appointed Editor-in-Chief of *THE BRIDGE*

Dr. Jason K. Hui has been appointed as the 2023 Editor-in-Chief for *THE BRIDGE*, the official publication of IEEE-HKN, by President-Elect Sampathkumar Veeraraghavan. He will lead the Editorial Board for the magazine, which is a standing committee of the Society. He is currently a member of the Editorial Board and the IEEE-HKN Regions 1-2 Governor. Dr. Hui was inducted as a professional member of HKN by the Epsilon Delta Chapter at Tufts University. He is Senior Manager, Systems Engineering at Textron Systems and received his Ph.D. from the University of California, Los Angeles.

Dr. Hui has served widely as a volunteer, including Chair of the IEEE New Hampshire Section, Area Chair of IEEE Region 1, and board member of the IEEE Technology and Engineering Management Society. In addition to IEEE involvement, he is an Associate Fellow of AIAA, Project Management Professional (PMP)® certified, and Electrical Engineering Program Evaluator for ABET. He has extensive publication experience as a member of the "IEEE Spectrum" Editorial Advisory Board, an Associate Editor of the "IEEE Engineering Management Review," and previously a member of the AIAA Publications Committee.

A Note of Sincere Thanks from *THE BRIDGE* Family

It is with the utmost gratitude that the IEEE-HKN Board of Governors and the Editorial Board of *THE BRIDGE* thank and commend Dr. Steve E. Watkins, Professor of Electrical and Computer Engineering at Missouri University of Science and Technology (MS&T), and Dr. Sahra Sedigh Sarvestani, Associate Professor and Distance Learning Coordinator for Computer Engineering at MS&T, for their years of dedicated service to *THE BRIDGE*, IEEE-HKN's award-winning, premiere publication. Both will resign from their positions as co-Editors-in-Chief at the end of this year.

Dr. Watkins, 2018 President of IEEE-Eta Kappa Nu, served as Editor-in-Chief from 2013 to 2017 and as co-Editor-in-Chief from 2020 to present. Dr. Sedigh Sarvestani served as co-Editor-in-Chief from 2018 to present.

Their contributions to *THE BRIDGE* are immeasurable. Their dedication inspired the rest of the Editorial Board, Guest Editors, contributors, and staff to strive for excellence. The results are apparent in the nine consecutive APEX Awards for Publication Excellence the magazine received since 2013. The IEEE-HKN community is grateful that they answered the call to lead and wish them well as they each open a new chapter. Thank you, Steve and Sahra!

IEEE-HKN
2022
Student Leadership
CONFERENCE

Inspire and Be Inspired by Students at the 2022 Student Leadership Conference

Attention Alumni and friends of IEEE-HKN: Join us at the University of North Carolina, Charlotte, USA from 28 to 30 October for the 2022 Student Leadership Conference. Hands-on workshops, career and professional development sessions, an awards and recognition dinner at the NASCAR Hall of Fame, and much more will be part of the program.

IEEE-Eta Kappa Nu has a special rate for alumni and guests who wish to join us and meet tomorrow's engineering leaders:

- US$100 per person to attend the Awards and Recognition Banquet at 7 pm on 29 October 2022
- US$250 per person to join us for the full conference and attend all meals, sessions, and the Awards and Recognition Banquet

Register for the conference or purchase banquet tickets here.

If you are unable to attend the conference or dinner but wish to support our students, you may donate to the IEEE-HKN Student Leadership Conference Fund, click this link and choose this fund from the drop-down menu.

Thank you to our Conference Benefactor, the Samueli Foundation, and to all our sponsors

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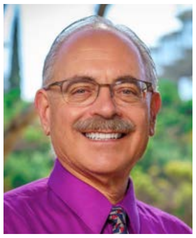
2022 IEEE-HKN Award Winners Announced

IEEE-Eta Kappa Nu (IEEE-HKN), the honor society of IEEE, is thrilled to announce the recipients of the 2022 IEEE-Eta Kappa Nu Awards and Recognition program.



Dr. Albert Pisano, Dean of Engineering, Jacobs School of Engineering at the University of California, San Diego, was named the recipient of IEEE-Eta Kappa Nu's highest honor, IEEE-HKN Asad M. Madni Outstanding Technical Achievement and Excellence Award for 2022. He was recognized "for outstanding technical achievements and seminal contributions that promote engineering to broader communities for the benefit of society." Dr. Pisano was inducted into University of California, San Diego's, Kappa Psi Chapter of IEEE-HKN.

Dr. Karen A. Panetta, 2019 IEEE-HKN President and Dean for Graduate Education at Tufts University has received the 2022 IEEE-HKN Distinguished Service Award "for outstanding contributions to the advancement of IEEE-HKN educational and professional programs." Dr. Panetta was inducted into Tufts University's Epsilon Delta Chapter of IEEE-HKN.

Dr. Thomas D. O'Sullivan, Associate Professor of Electrical Engineering at University of Notre Dame, is the recipient of the 2022 C. Holmes MacDonald Outstanding Teaching Award "for contributions to creative and inclusive teaching and mentoring in electrical engineering and bioengineering." Dr. O'Sullivan was inducted into Northwestern University's Beta Tau Chapter of IEEE-HKN and is the Faculty Advisor for Notre Dame's Delta Sigma Chapter.

Dr. Achuta Kadambi, Assistant Professor at the University of California, Los Angeles Department of Electrical and Computer Engineering, received the Outstanding Young Professional Award "for contributions to creative and inclusive teaching and mentoring in electrical engineering and bioengineering." Dr. Kadambi was inducted into the University of California, Los Angeles' Iota Gamma Chapter of IEEE-HKN.

Awards will be presented at the IEEE Educational Activities Board Awards & Recognition Ceremony in Vancouver, BC, Canada, on 18 November 2022.

The 2022 IEEE-HKN Awards program was extremely competitive, having received a total of 70 nominations.

Madni Award winner, Dr. Pisano has dedicated his career to promoting engineering as a force for the public good, according to his nominator. He is a highly visible figure nationally, in California, and on the UC San Diego campus. He is the Founding Chair of the National Academy of Engineering and the Division of Engineering and Physical Sciences of the National Academies of Sciences, Engineering, and Medicine Deans' Roundtable. The roundtable meets annually to bring together U.S. Department of Defense (DoD) leadership with U.S. engineering deans and university leaders to discuss research and engineering issues relevant to DoD. He is active in the U.S. Council on Competitiveness and is a strong proponent of a national network of innovation centers for platform technologies organized as public-private partnerships.

Professor Pisano became dean of the Jacobs School of Engineering, the largest engineering school in California, in 2013. It currently ranks No. 10 of all engineering schools, public or private, in the U.S. He also has made myriad contributions to the invention, design, fabrication, optimization, and application of microelectromechanical systems (MEMS). As Program Manager, he initiated the largest MEMS program at the Defense Advanced Research Projects Agency (DARPA). He was elected to the National Academy of Engineering and the National Academy of Inventors in recognition of these achievements.

Dr. Panetta, the recipient of the Distinguished Service Award, was the IEEE-HKN President in 2019 and continues to lead initiatives and assists in cultivating significant sponsorships including from the Samueli Foundation and donations from Apple co-founder, Steve Wozniak. These contributions propelled IEEE-HKN to new levels of giving and sponsorship and contributed to creating the first endowed HKN Award, namely, the Asad Madni Technical Achievement Award. She also created, with IEEE-HKN graduate students, the "Grad Lab" series of webinars to help prepare and support students through graduate programs. Her diverse roles in IEEE have given her keen abilities to see and build partnerships across other IEEE organizations and societies, according to her nominator.

Outstanding Teaching Award recipient, Dr. Thomas D. O'Sullivan fosters excitement, motivation, curiosity, and creativity, instilling strong technical and communication skills in his students, according to his nominator. In six years, he has taught over 300 undergraduate and graduate students, advised 12 Ph.D. students, mentored 15 undergraduate research assistants, and advised two student groups, including IEEE-Eta Kappa Nu. He strives to create an inclusive learning environment and, this year, 46 percent of students enrolled in his technical elective are women, compared with about 30 percent of electrical engineering majors overall in the program.

Outstanding Young Professional award recipient, Dr. Achuta Kadambi, has commercialized his research in computational imaging into a thriving venture, known as Akasha Imaging. Beyond the startup, Prof. Kadambi leads a lab at the University of California, Los Angeles, that is looking to understand how the behavior of circuitry and gadgets vary across demographic types, according to his nominator. For example, light-based medical devices will perform less well on darker skin tones. Dr. Kadambi works with teams in electrical engineering, at the university's medical school, and the Equity and Diversity Initiative (EDI) offices at UCLA to invent new devices that are fair. He also has taught "intro to computer science" courses at prisons to help reduce the rate of re-entry into the prison system.

Click here for more information on the IEEE-HKN Awards Program.

Patrick O. Nunally

1992 HKN Outstanding Young Electrical Engineer Award Recipient

Father of the Arbitron and Nielsen Radio ratings system

Epsilon Phi Chapter

The Power of a Supporting Community

Ever since Neil Armstrong stepped foot on the moon, a young Patrick Nunally had his heart set on becoming an engineer because he believed they had the true superpowers – they put Armstrong on the moon. And if there is one thing Nunally realized, it's that superheroes can't achieve everything on their own.

Patrick Nunally has been a successful electrical engineer for 30 years and is known to be many things: the father of the Arbitron and Nielsen radio ratings system and a pioneer of Artificial Intelligence/Machine Learning technology among them. His work has been recognized by the National Academy of Television Arts and Sciences. He was awarded the 1992 HKN Outstanding Young Electrical Engineer Award, and received a Technical Emmy for the Arbitron Portable Meter in 2009.

Throughout his successful career, and his many notable achievements, he still remains lifelong friends with the members of his IEEE-HKN community, as he credits them for being a big reason why he is where he is today.

When Nunally first started engineering school, he knew it was not going to be easy, especially since he was juggling it with a full-time job and with actively designing a telemetry system for a training mission. Instead of trying to navigate the waters himself, Nunally reached out to mentors for assistance, and they ultimately introduced him to IEEE-HKN.

"Engineering school is a big life commitment, and while you're all working hard at it, at the time, it's important to find your supporting community, and HKN was mine," Nunally says. IEEE-HKN gave him a safe place to be creative, bounce ideas around, and be himself with like-minded students who were just as in love with electrical engineering as he was, he says.

Out of all the awards and recognitions Nunally has received, he said he believes the IEEE-HKN Outstanding Young Electrical Engineer Award is the one he treasures the most. "It's great to be recognized by the government, academia, industries, but to be recognized by your peers? It's a whole other level," Nunally says. To this day, he still values those very same people and wouldn't have it any other way.

HKN had the honor to interview Patrick Nunally for a series of videos. You can check out the first one, on how he got involved with Eta Kappa Nu, on our YouTube channel. Check back for more.

Delta Omega Chapter

First Chapters Receive HKN Chapter Support Grants

The first IEEE-HKN Student Chapter Support grants have been awarded to chapters to fund programs such as chapter-building and visibility activities, a mentoring event, and an event that engaged alumni.

The officers of the Mu Chapter at the University of California, Berkeley, used the grant money to offset costs of purchasing announcement whiteboards to increase visibility and improve outreach, better spreading the word on campus and to the department about their tutoring programs and events.

Officers at the Mu Iota Chapter at Seattle University used the funds to offset the cost of hosting an ECE Mentoring Night, which was co-hosted with the ECE Advisory Board. The event provided students with the opportunities to meet with industry professionals and represented the Chapter's biggest event of the year.

The Delta Omega Chapter at the University of Hawaii at Manoa is using the grant funds to offset the cost of its annual induction ceremony and banquet, which brings students, faculty, and alumni together to recognize induction candidates' hard work throughout the school year.

The grants are made possible by the IEEE-HKN Student Chapter Support Fund, launched at the beginning of 2022. This dedicated fund was established to create new and enhance existing resources, training, and programs to help every chapter thrive. A strong chapter helps ensure that members have a fulfilling HKN experience throughout their entire careers.

The two facets of this fund include the IEEE-HKN Student Chapter Support Grant program and a supplemental Chapter coaching initiative. For the latter, HKN volunteers and staff have been coaching 18 university chapters, many of whom are working to revitalize their activities as the world emerges from the pandemic. In April, a brand new HKN Chapter was installed at Kennesaw State University in Georgia. Join us in congratulating and welcoming the Nu Epsilon Chapter!

John McDonald, Beta Chapter, and his wife, Jo-Ann, made the first gift to this dedicated Fund that provided the mechanism to launch the program. Please consider joining them and us in our mission to give every student the chance to be part of a successful chapter. You can make a contribution by choosing the Student Chapter Support Fund from the drop-down menu on the HKN page of the IEEE Foundation website.

A pictorial representation of JWST, with images on mirror segments representing various kinds of observations performed by the telescope, including direct imaging, coronagraphy, spectroscopy, and much more. Credit: STScI

Commanding the James Webb Space Telescope: OSS and Event-Driven Operations

Kyle Elliott, Senior Software Engineer, Space Telescope Science Institute (STScI)

I. Introduction

The James Webb Space Telescope (JWST) is a space-based, near- to mid-infrared observatory that follows a novel engineering design. Unlike its infrared predecessors such as the Spitzer Space Telescope and Herschel Space Observatory, JWST employs a segmented primary mirror and a sunshield the size of a tennis court. The 6.5-meter diameter primary mirror renders a light gathering power that is about 6.25 times greater than that of the Hubble Space Telescope (HST) and, coupled with the fact that it reflects infrared light, enables us to see as far back as about 250 million years following the Big Bang. Orbiting around the second Lagrange Point (L2), roughly 1.5 million kilometers from Earth, JWST enjoys a space environment that imposes fewer constraints on activities than low-Earth orbit. For instance, there is no South Atlantic Anomaly bombarding spacecraft electronics with high-energy protons or terminator transitions causing changes in the electrical and thermal environments. These features enable JWST to address fundamental questions in astronomy ranging from the evolution of protoplanetary systems, stars, and galaxies to extrasolar planetary atmospheres and the origins of life.

Given the many years spent developing this mission and the amount of ground-breaking science we stand to gain, it is crucial to note that JWST is planned for only 5.5 to10 years of mission lifetime. We must get the most out of this mission as possible. To maximize the efficiency of science observations that will address varied questions in astronomy, JWST implements an event-driven operations architecture that is predicated on the idea that each planned command should be issued as soon after the previous one as possible, even when the ground system is out-of-contact with the spacecraft or when an activity fails in a non-critical manner.

II. Absolute Time Commanding vs. Event-Driven Commanding

HST is a technological marvel that has provided the astronomy community with over three decades of data (read more in the third feature). HST is operated in a manner that befits a steady stream of observations whereby onboard activities, such as slews and filter wheel moves, are modeled and broken down into individual time-stamped commands to be uplinked to the spacecraft.

This design, called "Absolute Time Commanding," has been a standard in the industry for transforming science programs into instructions carried out by the onboard flight software. However, these instructions, or "commands," assume the worst-case timing scenario (Figure 1). Imagine a filter wheel commanded to rotate from Position A to Position B. HST's planning and scheduling subsystem knows how long this rotation should take to complete. Still, because it cannot know precisely when it ends, it adds pad time to the calculated motion time. This timestamped approach introduces many instances of overhead which, while individually small, add up to a significant amount of time lost over the mission.

Unlike HST's case, where commands must wait until their designated time for execution, JWST follows an event-driven operations paradigm. Under such operations, science activities are specified within an onboard observation plan which points to "visit" files that may be executed at any time within an allowed timeframe. These visit files describe exactly what JWST must do to meet specific program requirements. The advantage here is that these visit activities are carried out by onboard scripts written in a C-extended variant of JavaScript, collectively referred to as the Operations Scripts Subsystem (OSS). OSS breaks these visit activities into a series of low-level flight software commands. Because these scripts are onboard, they offer the following advantages: they immediately check whether the visits meet the time constraints specified in the observation plan; ensure that the visits' exposures will not lead to exceeding the solid-state recorder data volume

Figure 1: Absolute Time Commanding vs. Event-Driven Commanding. This example shows how the non-critical guide star acquisition failure causes HST to skip all its activities and wait for the absolute start time of the subsequent visit, while JWST would skip all its activities and immediately start the next visit (as long as both visit time windows overlap) [1].

threshold; provide fault management responses to off-nominal flight software telemetry; and contain embedded logic that takes advantage of access to that same real-time telemetry. If the nature of any software fault is benign (e.g., time constraint not met, guide star acquisition failure, etc.),

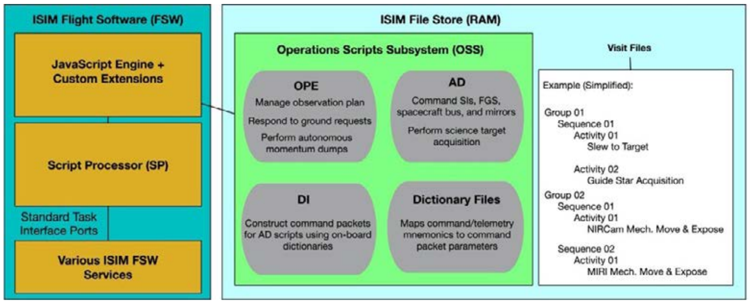


Figure 2: OSS Interface to the ISIM Flight Software [4]

then OSS can skip that visit and move on to the next one in the observation plan without delay.

During normal operations, the ground system has real-time contact with JWST for only eight hours daily, generally in two four-hour chunks. Using this event-driven operations architecture, the ground system can uplink any needed changes to the onboard observation plan within this time period. Such changes can include starting the plan, adding more visits, and removing visits, as well as stopping the plan immediately after a specified visit, or after a specific section of a visit reaches completion. In this way, the flow that starts from astronomers detailing their science programs and ending with OSS executing their programs in the form of visit files can proceed uninterrupted even with occurrences of non-critical failures. Critical failures, such as those concerning the health and safety of the hardware, could still result in a safe-haven event that requires the ground to intervene before bringing JWST back to an operational state; however, some of these failures can be contained to their source such that OSS will simply mark that source unavailable for commanding and continue along the observation plan while the ground works to resolve the contained problem concurrently [2].

III. OSS Commanding Architecture

All files required for event-driven operations reside in filestores in the Integrated Science Instrument Module (ISIM). The OSS scripts and several data files they require are permanent but can be updated as needed. Files associated with Observation Plan (OP) segments are uploaded weekly and are deleted as observations are completed. The scripts are run by a Script Processor (SP) task and executed separately by a JavaScript engine task that can support up to ten threads of execution. The interface to the SP Task, and therefore the ISIM flight software services via standard task interface ports, is provided by a set of C language extensions to the JavaScript language. The interface between the multiple threads of execution is provided by similar extensions that can set and retrieve the values of shared parameters.

OSS is categorized into three sets of scripts: the Observation Plan Executive (OPE), the Activity Description

(AD) scripts, and the Dictionary Interface (DI) scripts. The OPE scripts process visit files in the order specified in the OP segment file. They launch visit file-specified AD scripts with specified parameters to carry out the actual observations. Once invoked by the OPE, these top-level scripts carry out their functions with the assistance of various lower-level AD scripts. The AD scripts are categorized according to the subsystems that drive science the most: each science instrument (SI), which includes the Near-Infrared Camera (NIRCam), the Near-Infrared Spectrograph (NIRSpec), the Near-Infrared Imager and Slitless Spectrograph (NIRISS), and the Mid-Infrared Imager (MIRI); the Fine Guidance Sensors (FGS); the Optical Telescope Element (OTE) and spacecraft bus; and common utility scripts used by all scripts ranging from file operations to coordinate transformations. Abstracting away the specifics of CCSDS command packet construction from the AD scripts, the DI scripts serve as wrapper scripts for sending commands to various application flight software with the aid of onboard dictionary files containing the translations from mnemonics to parameters required by the Script Processor in the construction of a command packet [3].

Thus, commands or telemetry queries are communicated in the following manner:

1. OSS sends a command or telemetry query to the SP Task
2. The SP Task sends the corresponding packet to the Command Manager Task
3. The Command Manager Task notes the application ID in the packet and passes it along to the appropriate Application flight software Task (e.g., that of one of the science instruments, the mirrors, or a subsystem that is part of the spacecraft bus such as attitude control)
4. The application flight software Task generates commands to the hardware to complete the requested operation – these commands are sent back to the Command Manager Task, which then passes them to the Bus Interface Task (either 1553 or SpaceWire) to connect to the hardware being commanded physically

Commands originating from the ground, including those that interface with the OPE for adjustments to the onboard observation plan, are received by the spacecraft RF communications subsystem and transferred to the ISIM via the Command and Telemetry Processor (CTP) using the ISIM flight software CTP Interface Task and Command Manager Task [4].

IV. Visit Files – The Entry Point to OSS

Normal operations are dictated by the interplay of the Proposal Planning Subsystem (PPS), the Flight Operations Subsystem (FOS), and OSS. PPS consists of multiple subsystems, including the Astronomer's Proposal Tool (APT), which enables astronomers to request the observations they would like to execute, the Visit Planning System (VPS) for extended range visit plans, the Visit Scheduling System (VSS) for short term visit plans, and the Observation Plan Generation System (OPGS) which

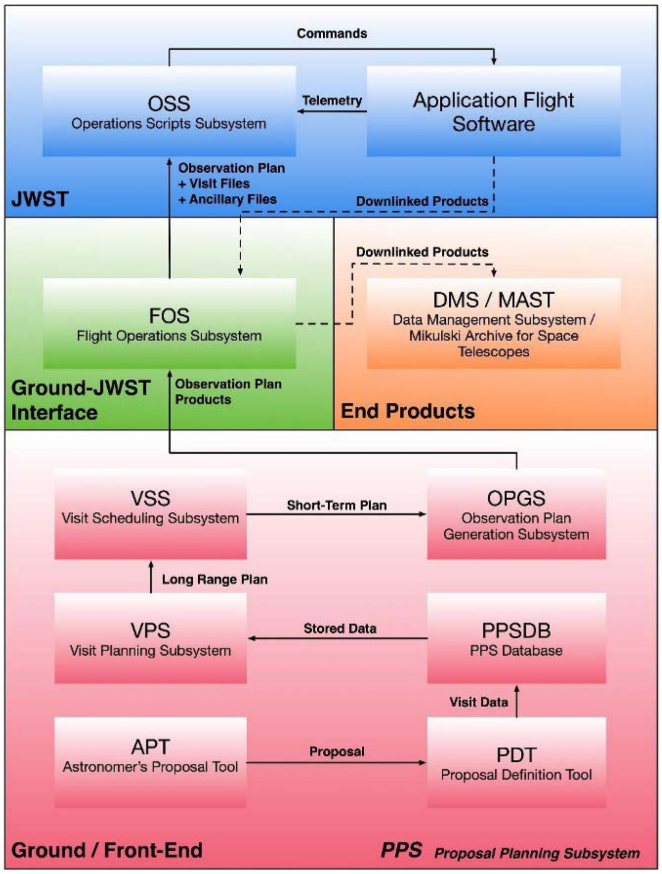


Figure 3: Science Operations Center Subsystems

generates the observation plans and visit files to be interpreted by OSS [3].

Visits have a hierarchical structure. A serial list of one or more activities constitutes a "sequence." Up to three sequences can be executed in parallel within a "group." One or more groups are executed serially within a visit. This structure facilitates proper control of activity ordering while providing the ability to perform certain activities in parallel, thus improving observing efficiency (see example visit file in Figure 2).

There are multiple types of visits: science, engineering, calibrations, and real-time handoffs.

- ***Science:*** Science visits typically include a slew to the science target, guide star acquisition, science target acquisition, mechanism moves (e.g., filter/grating wheel moves), detector and data acquisition configurations, the SI exposures, and small spacecraft pointing offsets to support dithered observations. Dithering helps improve sampling and remove cosmic rays and bad pixels from the raw images to obtain clean-looking photos that best represent the science target. The exposures are often done in parallel, where possible, for efficiency.

- ***Engineering:*** Occasionally, the ground system will need to perform various activities not part of a science program. These include detector checkouts, mirror alignments, tests specific to science instrument mechanisms such as NIRSpec's Microshutter Array (MSA), tuning analyses for all the near-infrared science instruments that use hybrid HgCdTe detectors and require readout and control via a System for Image Digitization, Enhancement, Control, and Retrieval (SIDECAR) ASIC, and the routine momentum unloading of the reaction wheels via thrusters. The OPE is capable of initiating momentum unloads autonomously, if necessary. Still, it is preferable to understand the spacecraft's momentum profile well enough to plan momentum unloads well before the OPE considers initiating one.
- ***Calibrations:*** Calibration visits typically involve internal lamp exposures to characterize pixel-to-pixel responsivities, dark exposures to characterize detector dark current and electronic bias, and optical focus adjustments.
- ***Real-Time Handoff:*** There are specific activities that are not supported by OSS and must be handed off to and conducted from the ground. One example is a station-keeping maneuver that uses the thrusters to keep JWST in its halo orbit about L2.

Some activities, particularly exposures and calibrations between more than one science instrument, are often performed in parallel (i.e., frequently, one device will be doing an external exposure while another is taking a dark exposure). Depending on the specific nature of the activities, these parallel visits may be deemed "coordinated" or "pure," whereby the former requires that there are no issues with both instruments working in parallel. The latter allows the primary instrument to continue with the rest of its activities in the visit if the secondary instrument(s) suffer a non-critical failure (and otherwise allows the secondary instruments to finish the activity currently executing if the primary non-critically fails) [5].

A. Embedded Logic

OSS can make many sophisticated decisions because it is a collection of onboard scripts that accept input from the visit files and query telemetry. One such example of efficiency involves the guide star acquisition process. At the beginning of most science visits, OSS commands a slew to the guide star identification attitude, followed by the acquisition of that guide star to establish closed-loop fine guidance control with the Attitude Control Subsystem (ACS) in support of pointing stability [6]. This process involves commanding the FGS to perform several functions. Still, OSS can skip the most time-consuming tasks if it can assess that the slew to the target will be sufficiently small through a series of matrix calculations.

Another example of significant embedded logic is target acquisition, where extremely fine pointing is achieved (beyond that of guide star acquisition and tracking) via onboard data reduction and centroiding. Some science activities, such as coronagraphy which involves pointing the telescope so that the star falls behind a fixed mask, require extremely fine pointing stability. This is achieved by taking a pre-science exposure with the instrument of interest so that the target can first be located with sub-pixel accuracy. The exposure, however, entails the presence of various sources of noise, cosmic ray hits, and bad pixels – therefore, to ensure that the target is centroided, as opposed to something brighter such as a hot pixel, it is necessary to clean up that image with a series of algorithms that includes cosmic ray removal, flat field correction, background reduction, and sometimes the merging of dithered images [7].

B. Fault Management

Since OSS can query telemetry at any time in its operations, it can support a fault management hierarchy. Every time OSS sends a command, it can check whether that command succeeded within a specific time period or failed, timed out, or was rejected by the commanded subsystem. If the command response were off-nominal, then OSS would be able to respond appropriately in a manner that considers both JWST health and safety as well as efficiency. For example, if guide star acquisition were to fail on every guide star candidate early in a visit, then the OPE would see this failure, skip the rest of the visit, and move on to the subsequent visit in the observation plan. However, if OSS encountered something more serious, such as a hardware failure, then, depending on the severity of the error, OSS may mark the associated instrument/subsystem as unavailable for commanding by OSS and skip the rest of the visit. This allows some of the remaining visits in the observation plan to run, skipping those involving the instrument marked unavailable. If the event were yet more severe, such as another subsystem communicating to OSS in a completely unexpected way, OSS would respond by throwing an exception, which brings down the OPE and puts the entire ISIM into a safe haven mode. While marking a subsystem as available for OSS commanding is not a lengthy process, recovering from ISIM safe haven is a meticulous and slow process. Still, it is in this way that OSS balances the efficiency gained by this event-driven commanding and the health and safety of JWST [3].

V. Concluding Remarks

JWST's event-driven commanding architecture is a significant leap in efficiency gain for space telescope missions. Having a collection of onboard scripts to execute activities routinely uplinked by the ground allows for seamless commanding of the Observatory and quick and appropriate responsiveness to anomalies. Complex operations are made possible or significantly easier to execute under this paradigm, rendering sophisticated science activities easier to improve and support as needed. With JWST's success under this operations model, the Nancy Grace Roman Space Telescope (RST) will also adopt event-driven operations and, in turn, lead to a new era of operations for space-based observatories.

Acknowledgments

I would like to thank our OSS development technical lead, Alan Welty, and OSS certification technical lead, Dean Zak, for their general expertise in writing this article.

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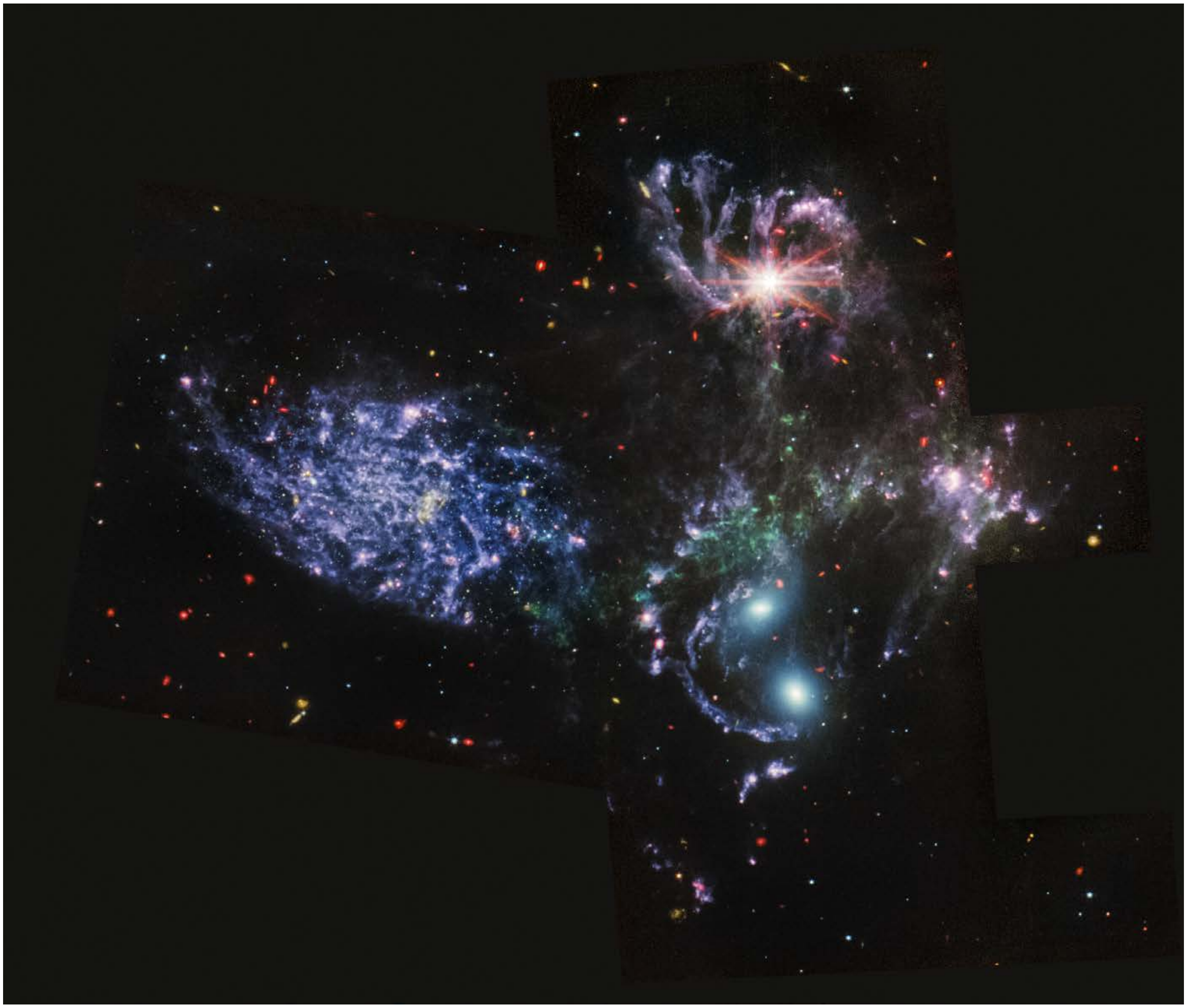
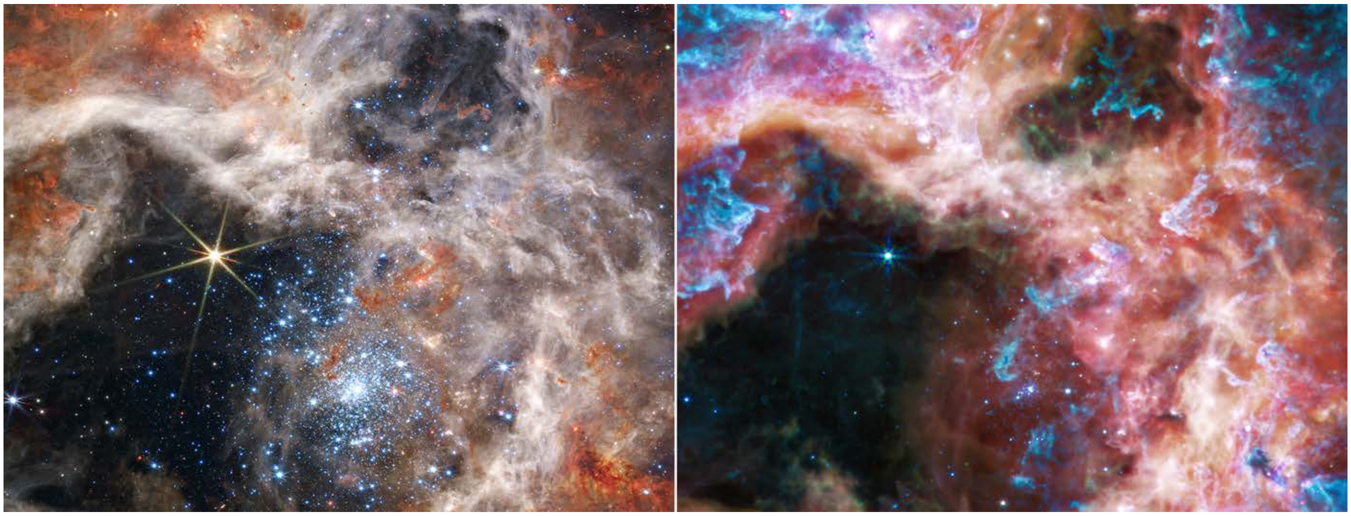
Kyle Elliott is a senior software engineer at the Space Telescope Science Institute (STScI) in Baltimore, Maryland, and has worked on the JWST mission as a member of the OSS for over five years - he currently specializes in FGS and Spacecraft Bus commanding. He has also provided development support for the Roman Space Telescope science operations. He holds an M.S. in space systems engineering from Johns Hopkins University and B.S. degrees in physics and astronomy from the University of Maryland.

Stunning Images from the James Webb Space Telescope in its Early Months of Operation

These provide much new data as well, probing the infrared (IR) portion of the spectrum which was not visible to many previous telescopes, and certainly not at this level of detail. While from an anthropic perspective these are false-color images, they have been made by mapping the IR wavelengths to visible wavelengths, giving the same effect as if the cones in your eyes responded to much longer wavelengths. This data is useful for many scientific inquiries, from the study of exoplanets to the origins of the universe, but here the images also give us a chance to again be in awe of the scope and beauty of our universe.

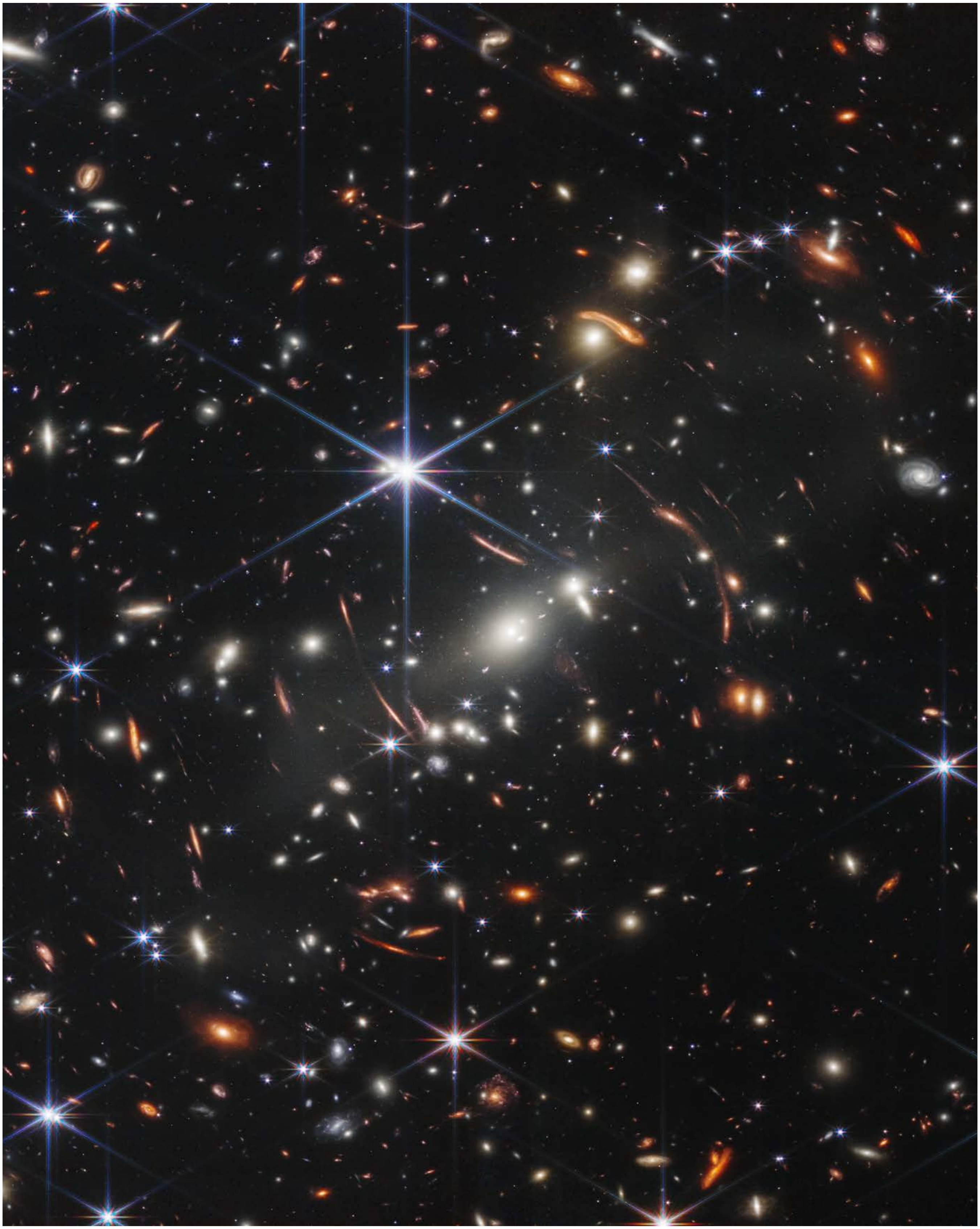


Stephan's Quintet, a group of five galaxies, as imaged by Webb's Mid-Infrared Instrument (MIRI). Four of the five galaxies are about 290 million light years away, and the fifth is 40 million light years away.
Image Credit: NASA, ESA, CSA, STScI

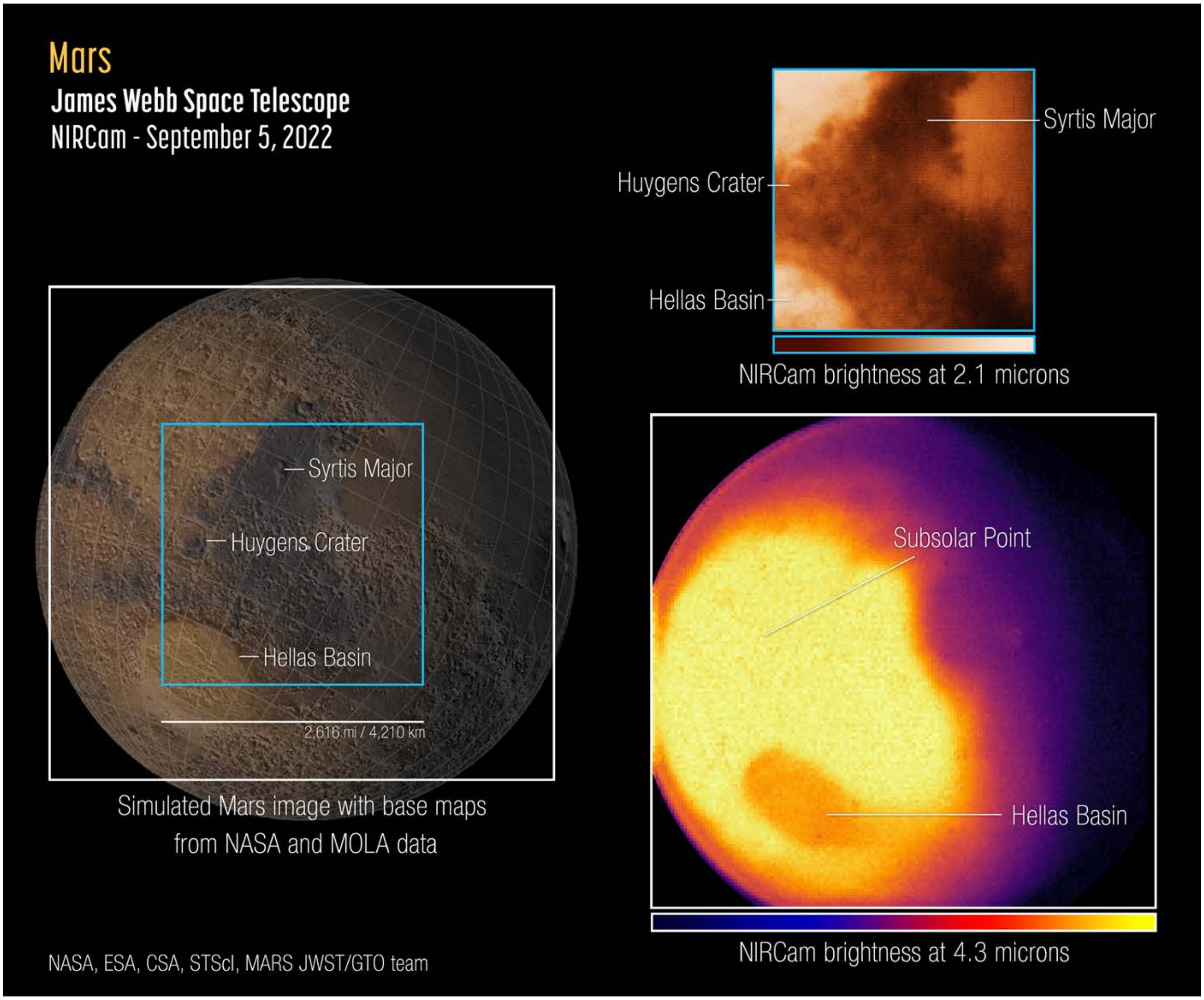


Side-by-side images of the Tarantula Nebula, imaged by Webb's Near-Infrared Camera (NIRCam, left), in which the young stars take center stage, and Webb's Mid-Infrared Instrument (MIRI, right), in which gas and dust clouds are highlighted.
Image Credit: NASA, ESA, CSA, STScI, Webb ERO Production Team

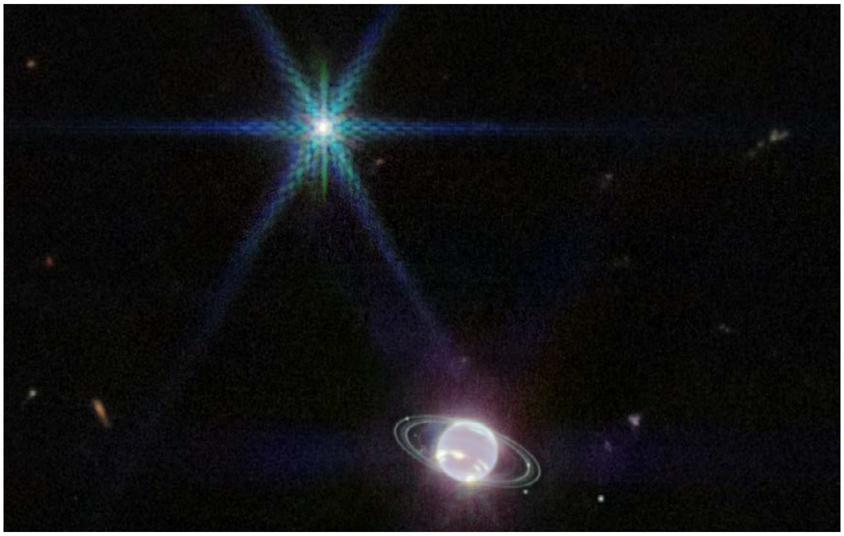
A composite image using both Webb's Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI) of the Cartwheel galaxy (along with two companion galaxies), some 500 million light years from earth.
Image Credit: NASA, ESA, CSA, STScI, Webb ERO Production Team



The one that started it all, Webb's first deep field image. This image was taken with the Near-Infrared Camera (NIRCam) of the galaxy cluster SMACS 0723, about 4.24 billion light years away.
Image Credit: NASA, ESA, CSA, STScI



Images of Mars, captured by the Webb's Near-Infrared Camera (NIRCam, upper right with 2.1 micron filter, and lower right with 4.3 micron filter; map at left gives reference positions of these photos, with outlines showing the two photo sizes). These photos can provide key data about our neighboring planet.
Image Credits: NASA, ESA, CSA, STScI, Heidi Hammel (AURA), Mars JWST/GTO Team



Neptune, along with seven of its fourteen moons, as imaged by Webb's Near-Infrared Camera (NIRCam). In visible wavelength photos, we are used to seeing Neptune as largely blue with the rings hardly noticeable, but in the IR the rings become very prominent and the planet looks mostly dark. Of the moons visible, Triton (Neptune's largest) is the very distinctive feature in the upper left of the image. The diffraction pattern seen around Triton (and other objects in this and other Webb photos) is due to the telescope's structure. The other moons are seen as small dots near the rings, with the other features in the photo being distant galaxies and a star.
Image Credits: NASA, ESA, CSA, STScI; IMAGE PROCESSING: Joseph DePasquale (STScI)

Artemis I and Orion, seen below the full moon, on Launch Complex 39B of NASA's Kennedy Space Center. A launch is planned for after the release of this issue in the next step in our return to the moon. Credit: NASA/Ben Smegelsky

Impacts of Low-Power Requirements on the LEMS HMS Design

James Olsen, an FPGA designer at NASA's Goddard Space Flight Center

Abstract

Spacecraft designs often require optimizations for low power. When low power is needed, design options become limited. The Lunar Environment Monitoring Station (LEMS) exemplifies how requirements for low power can have ramifications across a system, even impacting Field Programmable Gate Array (FPGA) design. LEMS is a standalone instrument suite concept with several that collect geophysical measurements on the moon's surface. It has completed Technology Readiness Level (TRL) 6 qualification. Continuous operation on the moon's surface has many challenges, not least of which is power management. Due to its slow rotation, lunar nighttime and daytimes last several weeks, and many science sensors have high power consumption. Designing a system that can operate during hot daytime temperatures and survive the long periods of frigid nighttime is challenging, and thus missions attempting extended duration operations on the moon are rare. To complete its science missions, LEMS seeks to survive and operate on the moon for years. LEMS utilizes a combination of techniques to solve the power management challenge. A high-efficiency battery sustains operations through the lunar night while LEMS alternates between periods of being "awake" and in "hibernation." The subsystem of LEMS that handles this switching of states is the Hibernation Management System (HMS). The HMS powers on and off the more power-hungry subsystems, such as the mass spectrometer, command and data handling, and radio, at scheduled intervals. The HMS is required to be very low power, which was paramount in the design decisions made for the HMS printed circuit board (PCB) and even in the FPGA's internal hardware description language (HDL) code.

I. Introduction

The LEMS Lunar Environment Monitoring System (LEMS) is a compact, autonomous, and self-sustaining instrument package that will operate on the moon's surface. The instruments on LEMS include a Quadrupole Mass Spectrometer (QMS) for monitoring the lunar exosphere, a Molecular Electronic Transducer (MET) Seismometer capable of continuously tracking the moon's seismic activities, a Lunar Meteoroid Monitor (LMM), and a Lunar Electrostatic Ion Analyzer (LEIA). A diagram of LEMS highlighting the different instruments and other components is shown in Figure 1. An external view of LEMS is shown on the left, and the internal layout is on the right.

LEMS was initially funded as an instrument concept by NASA's Development of Advanced Lunar Instrumentation Program. It has matured development at Goddard Space

Flight Center (GSFC) and has completed the TRL-6 qualification. This means that LEMS has completed the design, and an engineering test unit (ETU) has been built and tested in a simulated space environment. Thermal vacuum testing has been performed, and the design works as expected. A photo of the LEMS ETU is shown in Figure 2. As a TRL6 system, LEMS is ready to transition from a research and development effort to a full-fledged flight project payload. It is seeking flight project funding through a proposal to NASA's Payloads and Research Investigations on the Surface of the Moon (PRISM)[1].

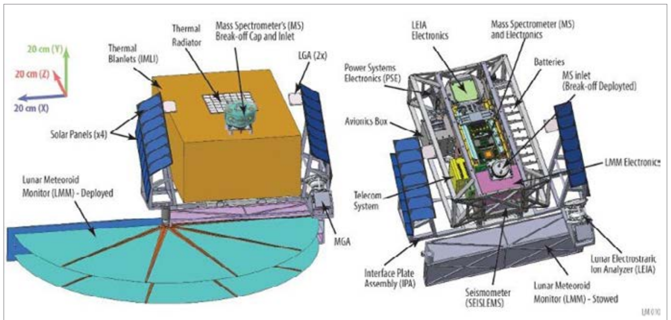


Figure 1 - LEMS Component Diagram - External (left) and Internal (right) Layouts

LEMS is designed for a minimum mission duration of two years. Designing a spacecraft that can survive and operate on the moon for this duration required solving numerous engineering challenges, including trade studies between maintaining a survivable temperature and minimizing size, weight, and power, often abbreviated as SWaP. The power concerns had ramifications in each electrical subsystem – the solar panels had to be consistently designed to charge throughout the lunar daytime, the battery had to be large enough to last the whole lunar night, and each subsystem had to minimize power as much as possible.

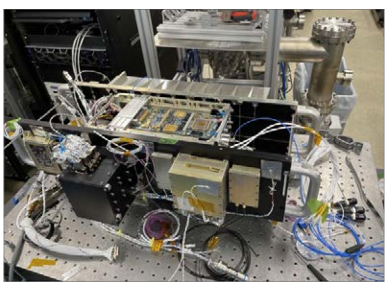


Figure 2 - LEMS Engineering Test Unit during system-level integration

II. Reducing Power as Much as Possible

LEMS is power-sufficient and does not require external power from its delivering asset to operate. Photovoltaic cells generate power during the daytime and a high-efficiency battery sustains operations at night. LEMS is also thermally self-sustained and does not require radioisotopic heaters nor active thermal dissipators to survive the hot lunar days or cold nights. LEMS manages its thermal and power states by alternating periods of low-power operations, during which the station is in "hibernation," with periods of high-power operations, during which all station subsystems are "awake" and power-demanding tasks are conducted. The balance between "hibernation" and "awake" allows LEMS to remain power-positive and within operational temperature limits. During "awake" periods, all science sensors are active and collecting data. During "hibernation," only SEISLEMS and LMM collect data. The more power-hungry systems – the Mass Spectrometer and LEIA instruments, the radio, and even the processor card which handles the command and data handling – were designed to only be active for a roughly 10- to 20-minute window once every 24 hours. A schedule over the full lunation showing estimated discharge levels of the battery and the times when each subsystem would be powered on is shown in Figure 3.

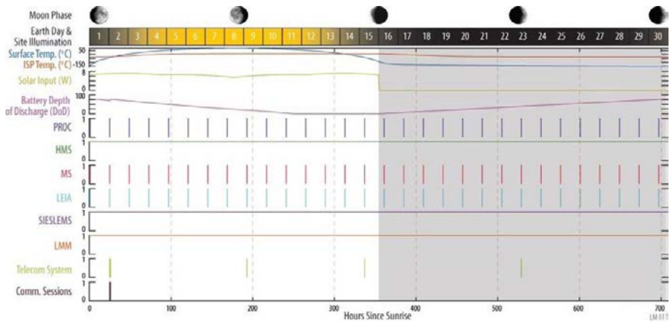


Figure 3 – Operational cycle and subsystem status estimates over one lunation

III. The Hibernation Management System

If most or all the major payload systems need to shut down, how would they turn back on? A photo of the components of the LEMS Avionics Box is shown in Figure 4. The processor card (E) in the image, manages the typical command and data handling responsibilities, such as sending commands and receiving telemetry from the other subsystems on LEMS, as well as interfacing with the radio for communication with Earth. However, as previously mentioned, even a subsystem this simple requires more power than the battery can safely provide for the long lunar night.

LEMS needed an auxiliary card that consumed very low power while managing powering on and off the other major subsystems. The HMS was conceptualized to handle this challenge and act as a "timekeeper" and a "night watcher" while the station is hibernating. The HMS will follow a schedule stored in flash memory to control inhibit signals, which act as an on-off switch to the electrical power system card (D) in Figure 4, and the processor card. With these inhibits set high, LEMS enters a low power state.

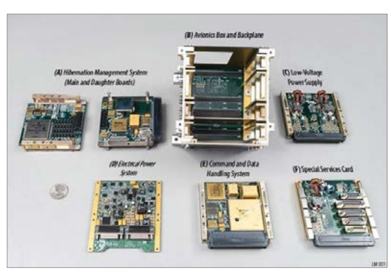


Figure 4 - LEMS Avionics Box

The HMS consists of two Printed Circuit Boards (PCBs) designated as the main card and daughter card. The main card has all the major components, such as an FPGA, low-power oscillator (used as the FPGA clock), flash memory, and a four-channel Analog-to-Digital Converter (ADC). The HMS daughter card is predominantly used for analog telemetry hardware. During the long periods of time when the major LEMS components are asleep, the HMS constantly monitors telemetry data from these thermistors.

To collect sufficient data, the seismometer on LEMS needs to remain active for the mission's duration and collect data continuously. Fortunately, the seismometer requires very low power to operate. Thus, the seismometer can remain powered on through the full lunation. Since the HMS will be the only other system awake, the HMS was also responsible for collecting and storing seismometer data in flash memory. The seismometer data is passed to the processor card when the processor card wakes up every 24 hours.

IV. Major HMS Board Components

The need for low power also influenced the components chosen for the HMS boards. This begins with the FPGA, for which the low-power Microchip ProASIC3L was chosen. While not the most powerful or recent FPGA, the ProASIC3L is a reliable, low-power FPGA with radiation-hardened options. A low-power 10 MHz oscillator drives the FPGA clock.

The ADC chosen is a low-power, four-simultaneously-read-channel, 24-bit ADC. Three of the channels are used for the seismometer, and one channel to read in multiplexed telemetry data. The HMS utilizes four independent analog multiplexers to read in telemetry into a single ADC channel. Two 16-channel MUX are set up for temperature measurements using thermistors with a current source, and the other 16-channel MUX are for single-ended voltage inputs.

Seismometer and telemetry data are stored periodically in flash memory. The flash is a 64Gbit (8GB), high-density nonvolatile CMOS NAND FLASH module. Flash acts as a low-power method of storing seismometer and telemetry data while the rest of LEMS is asleep. Since flash is nonvolatile, it also provides a way to save the HMS FPGA state information in case of a need to reset.

V. HMS FPGA Design

Jumping down to low-level hardware design, low-power optimizations were also made when it came to low-level FPGA design. A high-level block diagram of the HMS FPGA design is shown in Figure 5.

It was determined early that the FPGA design would avoid using a processor to minimize power. This is mainly because the use of a soft-core processor is usually less efficient in terms of area and power when compared with a pure HDL design. To explain this, power consumption in FPGA designs is directly correlated with transitions in flip-flop states. A processor, by its nature, must constantly read and execute instructions, which requires the transition of flip-flop states. Additionally, a soft-core processor would take up more area in the FPGA than a dedicated HDL design, allowing for a less optimal place-and-route design.

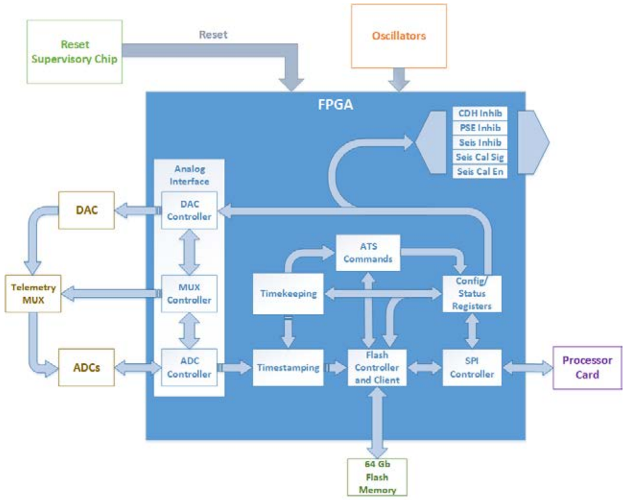


Figure 5 - LEMS HMS FPGA Design Block Diagram

The need for a processor-less, pure HDL design necessitated relatively simple requirements – both because simplicity often equates to low power (for the same reasons as noted in the paragraph above), and to allow an FPGA developer to complete the design within a reasonable timeframe. While a pure HDL design is often more efficient than a processor-based design, the development time for similar tasks can often be much longer. Thus, the HMS FPGA design requirements were designed to be simple. For example, complex data processing such as digital filtering of ADC data was left as a task to be accomplished once the data safely reached Earth.

Another early trade study for power reduction involved the selection of the 10 MHz clock frequency. Since power consumption is directly proportional to clock speed, it would seem that to reduce power, one need simply to reduce the clock speed. However, the clock speed also determines how quickly the stored seismometer and telemetry data can be sent out of the HMS to the processor card over the SPI bus. The processor card must be powered on long enough for all the data stored in the past 24 hours to be transferred. Ten MHz was selected to allow the data to be transferred in roughly 10 minutes.

In a similar vein, the limited time for transferring data to the processor card puts limitations on the data itself. The amount of seismometer and telemetry data stored in flash was capped by how long it would take to transmit all of it during the window of time when the processor card would be awake.

Seismometer data was prioritized to take up more space in the flash, being stored multiple times per second, with telemetry only being stored on the order of minutes.

An FPGA design challenge involved squeezing data into flash as efficiently as possible to optimize the efficiency of the utilized flash. Before being written into flash, ADC data needed to be timestamped. After all, the seismometer and telemetry data need a time associated with each sample to be valuable data. Instead of timestamping each ADC read, which would roughly double the number of bits per sample, only the first sample in each page of flash is timestamped, with the rest of the samples assumed to be taken at the configured sample rate. This nearly halves the time required to transmit the data to the processor.

VI. Summary

The methods by which power consumption was reduced in LEMS offer a unique insight into how high-level requirements propagate through the entire design, even affecting design choices at the lowest level. The need to allow power-hungry instruments to survive and operate continuously on the moon necessitated the development of the LEMS HMS. The need to reduce power within the HMS as much as possible necessitated choosing low-power hardware and even impacted low-level FPGA design. And, although this focuses on a deep dive into the LEMS HMS, other components of LEMS could be given the same treatment. Many hours of engineering back and forth discussion, design, and testing were required to develop LEMS from an idea into a working system, now a TRL-6 verified lunar payload.

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James Olsen has been working as a computer engineer specializing in FPGA design at NASA's Goddard Space Flight Center for five years. At Goddard, James has worked as an FPGA designer on a data encoder/decoder for the recently launched Laser Communications Relay Demonstration (LCRD), and on numerous research and development efforts. His first experience with digital design was as an undergraduate pursuing physics at Adelphi University. He acquired a BS in physics from Adelphi University and a BS and MS in electrical engineering from Columbia University. His hobbies include playing the piano and trumpet, and reading fantasy and sci-fi novels.

The Butterfly Nebula, 3400 light-years away, as imaged by Hubble in late 2019 to early 2020. Image credits: NASA, ESA, and J. Kastner (RIT).

Understanding Our Universe Through Imagery and Data: An Interview with HKN Eminent Member Dr. Asad Madni

Dr. Asad M. Madni is an IEEE-HKN Eminent Member, our Society's highest membership classification. He is an IEEE Life Fellow, and was recently awarded the 2022 IEEE Medal of Honor, adding to the many honors and awards he has earned throughout his career. He currently serves as a Distinguished Adjunct Professor/Distinguished Scientist in the Electrical and Computer Engineering Department of the University of California, Los Angeles (UCLA), a Faculty Fellow with UCLA's Institute of Transportation Studies, and a Faculty Fellow of UCLA's Connected Autonomous Electric Vehicle consortium. He previously served as the chairman, president, and chief executive officer of Systron Donner, and president, chief operating officer, and chief technology officer of BEI. Among his accomplishments at BEI was the development of the extremely slow-motion servo control system for the Hubble Space Telescope's Star Selector System.

This year has seen much excitement with the first images and data from the James Webb Space Telescope (see Feature on page 12). This leads us to reflect on the over 32 years (and still counting) of service of the Hubble Space Telescope, and its data, which have led to great advancement in physics and astronomy and generated images that have long been hanging on many of our walls or serving as our backgrounds. This success would not have been possible without the work of Dr. Madni and his team.

Q: Can you begin by giving us some context of Hubble in comparison to Webb?

The Hubble and Webb are two different types of Telescopes. Hubble is pretty close to us in low Earth orbit (150 miles), while the James Webb Space Telescope will actually orbit the Sun 1.5 million kilometers (1 million miles) away from the Earth at what is called the second Lagrange point or L2. Lagrange points are positions in space where objects sent there tend to stay put. At Lagrange points, the gravitational pull of two large masses precisely equals the centripetal force required for a small object to move with them. These points in space can be used by spacecraft to reduce fuel consumption needed to remain in position. What is special about this orbit is that it lets the telescope stay in line with the Earth as it moves around the Sun. This allows the satellite's large sunshield to protect the telescope from the light and heat of the Sun and Earth (and Moon).

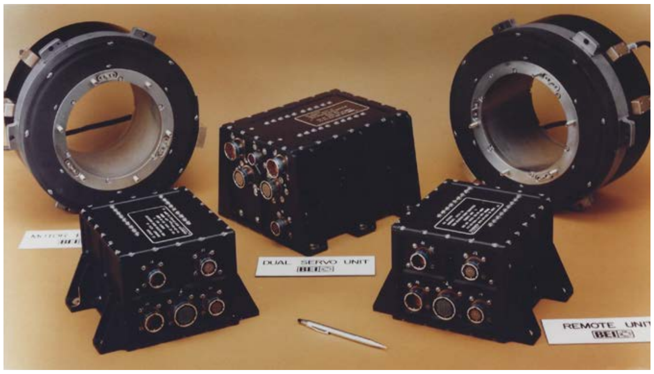
Additionally, while both Hubble and Webb are large space telescopes (though Webb is considerably bigger), the two actually "see" the universe very differently. While Hubble observes light at primarily optical and ultraviolet wavelengths, Webb is designed to detect primarily infrared light (IR) and will be able to see things that Hubble cannot. It is so powerful that it can detect heat signature of a bumble bee from the moon.

Hubble Space Telescope as seen from Space Shuttle Atlantis after Servicing Mission 4 in 2009. Image credit: NASA

The pointing systems are very different. James Webb isn't using mechanical gyroscopes like Hubble to keep it on target. Instead, it's using a different technology called **hemispherical resonator gyros**, or HRGs (The HRG makes use of a small, thin solid-state hemispherical shell, anchored by a thick stem. This shell is driven to a **flexural resonance by dedicated electrostatic forces generated by electrodes** which are deposited directly onto separate fused quartz structures that surround the shell). Similarities exist in signal processing and several electronics boards of the Hubble, which have been reduced to ASICs in the Webb. These will be used to actually upgrade Hubble during the next servicing mission.

Q: Can you tell us about the servo control system you developed for Hubble?

At our BEI Precision Space and Systems Division (PSSD), we developed an extremely slow-motion, dual-axis servo control system for Hubble Space Telescope's (HST) star selector that provided the HST with unprecedented pointing accuracy and stability, resulting in truly remarkable images that have enhanced our understanding of the universe.



Hubble Star Selector Servo System. Image credit: A. Madni

The system utilizes proprietary high-resolution optical encoders in conjunction with a patented Ultra Loc® technique to provide unprecedented accuracy & resolution. Together with integral DC torque motors, the system provides precise, digital control over a range of 0.5 arcsecond/ second (0.0333 revolution per day) to 16,384 arc second/second (0.759 revolutions per minute) and 21- bit absolute position words to an accuracy of 2.0 arc seconds peak-to-peak. In the fine tracking mode, the system provides position tracking to the order of 0.1 micro radian.

This system, which is part of the HST Fine Guidance System, allows a fine lock to the guidance system and plays a pivotal role in providing a highly stable reference required for pointing the HST and maintaining a pointing accuracy equivalent to pointing at the face of a U.S. quarter dollar as seen from 200 miles away and the pointing stability less than the width of the quarter dollar over a 24-hour period. This required development of optical encoding technology with accuracies previously unachieved (21 up to 23 bits of resolution), together with advanced actuation and signal processing techniques that would allow HST to scan a portion of the sky while orbiting earth at approximately 18000 mph. ***The system is still in use, 32 years since it was launched in 1990, with its pointing accuracy and stability resulting in over one million truly remarkable images such as the discovery of Pluto's moons and the formation of galaxies thousands of light-years away.***

Madni accepting award from Dan Goldin, NASA Administrator. Image credit: A. Madni

In the spring of 1998, BEI's success was key in having the Honorable Dan Goldin, NASA Administrator and his wife, Judy; astronaut, Dr. Stephen Hawley (who had flown on the second Hubble maintenance mission); the new Chancellor of University of Arkansas, John A. White; Arkansas Congressman Vic Snyder, and numerous dignitaries spend a day at PSSD to view first-hand the remarkable encoder and systems technology.

Q: What engineering challenges did this pose, and what was done to ensure the lifespan?

The system that we developed was designed to specifications that included size, performance, cost, radiation testing, temperature, humidity, and the most stringent environmental testing. It had to be designed with utmost care to ensure that the testing replicated the space environment that it would be operating in. The biggest challenge, however, was designing the system to meet the most stringent pointing and stability accuracy.

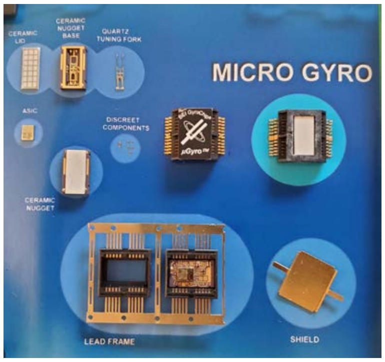
Madni (center) with the Transline Analyzer team. Image credit: A. Madni

During the servicing missions, the system would be replaced by the backup system (also developed and maintained by us) and we would then refurbish the original system together with any required upgrades and full performance and reliability testing to ensure uninterrupted performance and appropriate reliability.

Q: Beyond your work on Hubble, what are some of your biggest engineering accomplishments?

There were actually quite a few, however, I will focus on two projects that were landmark contributions. In the first, I developed industry's first standalone system capable of detecting the severities and locations of multiple faults in coaxial/waveguide transmission lines/antenna systems within inches and within minutes. This system, the Transline Analyzer® (military version AN/PSM-40) was developed for the U.S. Navy under the Combat Readiness Electromagnetic Analysis and Measurement Program (CREAM). The program was initiated to provide the fleet with capable, standardized measurement and analysis equipment and techniques and trained personnel, so that an effective Navy-wide EMC effort could be implemented and sustained. This system replaced nine instruments that took weeks to perform the measurements by highly trained personnel with much lower accuracy. It is also a critical test and measurement system for commercial passenger/cargo ships, and commercial/military aircraft. It has long become standard test equipment for the U.S. Navy while exponentially enhancing its combat readiness and that of our allies that adopted it. The digital correlation and interpolation techniques I developed in this system overcame several long-standing problems with both Time Domain and Frequency Domain Reflectometers and represented a major breakthrough for the industry.

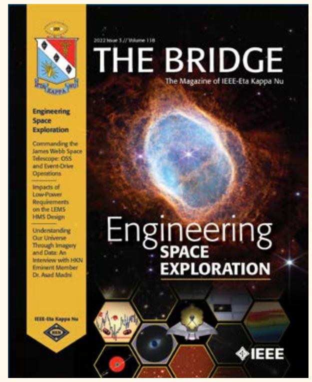
The other key project was the development and commercialization of BEI's Quartz MEMS GyroChip® technology which revolutionized navigation and stability in aerospace and automotive systems. It resulted in world's first solid-state, 6 Degrees of Freedom, Micro-Electro-Mechanical System (MEMS) Inertial Measurement Unit (IMU), a revolutionary breakthrough which required convergence of



The Micro Gyro (GyroChip). Image credit: A. Madni

micro-machining, advanced signal processing and mixed signal Application Specific Integrated Circuit (ASIC) design. It is used in over 90 types of aircraft, over 80 models of passenger cars for automotive stability and rollover protection systems, is the foundational technology for inertial heading and reference for NASA's Mars rover "Sojourner," and a multitude of other applications. Over 55 million GyroChips have been produced; their use for stability augmentation in passenger cars has saved millions of lives around the globe and continues to enhance the safety of people and transportation systems daily. Along with my and my team's related developments of MEMS accelerometers, pressure, position and torque sensors, and embedded sensors/actuators that provided unprecedented performance/reliability/cost advantages over prior art, the GyroChip® became the foundation of vehicle dynamic control and helped realize the dream of autonomous vehicles through capabilities such as electronic stability control, rollover prevention, lane change assist, autonomous cruise control, navigation, drowsy-driver detection, drunk driver detection, child seat detection, memory seat sensing, self-maintenance, and other key features.

About the Cover



Upper image: The Southern Ring Nebula, about 2000 light-years away, as imaged by Webb's Near-Infrared Camera in June 2022. Credit: NASA, ESA, CSA, STScI

Lower image: A pictorial representation of JWST, with images on mirror segments representing various kinds of observations performed by the telescope, including direct imaging, coronagraphy, spectroscopy, and much more. Credit: STScI

What is the IEEE Instrumentation and Measurement Society (IMS)?

IEEE INSTRUMENTATION & MEASUREMENT SOCIETY

The IEEE Instrumentation & Measurement Society is dedicated to the development and use of electrical and electronic instruments and equipment to measure, monitor and/or record physical phenomena.

Our mission is to:

- Provide the most comprehensive and high-quality services to our members and related professionals.
- Serve as the professional incubator for the growth of all (particularly younger) members.
- Be at the forefront of future I&M fundamental, technological, and application advances.
- Provide education in the field of instrumentation and measurement.

What do we do?

- We have 23 Technical Committees that engage in different activities, such as standards development.
- We award education-based recognitions and grants, including a Graduate Fellowship, a Faculty Course Development Award, and a Best Dissertation Award. Nominations are typically due in early February each year.
- We have distinguished lecturer (DL), video tutorial, and short course programs.
- We have chapters and student chapters around the world!
- We coordinate a mentorship program to connect students and young professionals with experts in the I&M fields.
- We present six society awards annually to recognize service, technical achievement, mentorship, and more!
- We provide comprehensive and high-quality publications to the instrumentation and measurement community, including the IEEE Transactions on Instrumentation and Measurement (the No. 1 journal in I&M among our competitors), the IEEE Open Journal of Instrumentation and Measurement, and the IEEE Instrumentation & Measurement Magazine.
- We have a flagship conference (I2MTC - Join us in Malaysia in 2023!), four major sponsored conferences, and multiple technically co-sponsored conferences!

I2MTC 2022

How can you get involved?

- Become a member!
- Attend our events, such as virtual distinguished lecturer webinars and conferences!
- Publish with us!
- Start a chapter!
- Form a Technical Committee!
- Participate in the development of an IEEE Standard!
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How can you connect with us?

- Check out our website!
- Join our Slack for students and young professionals!
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IMS West Africa Symposium

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 a new section in *THE BRIDGE* intended 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 will 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*.

New Advertising Opportunity

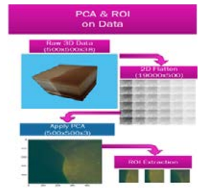
IEEE-HKN is the professional home to the world's top graduate students in electrical and computer engineering, computer science, and the allied fields of interest. Get your company or university in front of these students and HKN's undergraduate students who are considering their next steps by advertising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

William Oswald

Theta Lambda
University of South Alabama, Ph.D. Student in Systems Engineering

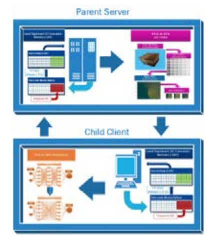
RESEARCH TOPIC
Memory Optimizations In Machine Learning Systems

It was only 2005 when Intel released its first commercial CPU to offer dual-core processing, whereas in 2020 Nvidia released a single GPU with 6912-cores of computational power, specifically to meet demands for deep learning applications. With demand ever increasing for computational performance, the entire computational system needs to evolve to meet demand. As these deep learning models increase in computational complexity, so does the demand on hardware. This hardware demand in deep learning systems remains a problem for Internet of Things (IoT) devices, spacecraft, and even large data centers; therefore, reducing the hardware demands of deep learning will affect computer systems at many different levels. Specifically, deep learning applications require a massive memory footprint which drives up power demands. These memory circuits usually consume several orders of magnitude more energy than the computational circuits. Subsequently, achieving greater energy efficiency in memory is one of the key design considerations for deep learning. Designers have developed various different low-power memory techniques, however, existing power-efficient memories usually come with a significant overhead. The deep learning systems I aim to optimize include Video Streams, and hyper-spectral imaging samples for cancer detection. I chose these systems to investigate because of the high memory demands in these two research topics.



For 3D Hyper-Spectral Images, the data can be compressed in meaningful ways before reaching the Neural Network.This shows the logical flow of data through a proposed algorithm, starting from the raw 3D data collected from the laser, to flattening, Principal Component Analysis (PCA) compression, and then Region of Interest (ROI) extraction. This is a very abstract oversimplification of the algorithm, but serves as a useful visual aid to the logical flow.

Video Stream Decoding Process, Deemed Content-Adaptable ROI-aware low-power video memory. The direction of an arrow indicates the development from one previous technique to a newer one.



A Bottom-Up example of a Neural Network Search system, including novel additions to hardware and algorithm memory optimizations. This image contains all research topics and goals of my dissertation moving forward.

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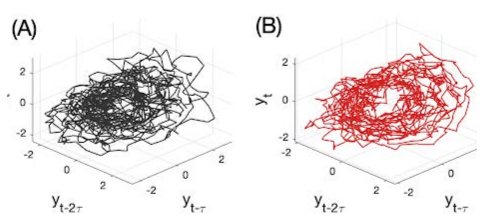
CONTACT
linkedin.com/in/william-liam-oswald-915871171

Kurt Butler

Theta Mu
Stony Brook University, Ph.D. Student in Electrical Engineering

RESEARCH TOPIC
Causal Inference and the Neuroscience of Consciousness

While the origin of consciousness has been hotly debated since the inception of humanity, modern neuroscience has revealed that the networked activity of multiple brain regions may be essential to supporting conscious experience. To develop mathematical models that describe how the network functions, it is important to distinguish causation, based on which one brain region activates another directly, from the case where both regions might both be driven by a common cause. Even with multichannel brain signal recording technologies such as electroencephalography (EEG) and local field potential (LFP), it is impossible to observe the entirety of the brain at once, and so it is important to explicitly consider hidden states when modeling brain activity. By discovering the mechanisms that underlie consciousness, researchers hope to improve the clinical treatment of patients with traumatic brain injuries or in comas.



The low-dimensional representation of a brain state is estimated (left) and the model learned using GPs reproduces similar structures in its predictions (right).

Kurt's work has focused on using machine learning, and in particular, the use of Gaussian processes (GPs) to model the complex signals that arise from the nonlinear and stochastic behavior of neural populations. His recent work has focused on detecting and quantifying the strength of causal interactions between brain regions. He also uses GPs to describe how the complicated brain signals observed by EEG and LFP can be produced by unobserved low-dimensional state spaces.

LEARN MORE
https://sites.google.com/view/kurt-butler/home

CONTACT
https://selcrec.ece.stonybrook.edu/

Ahmed Abugroun

Gamma Theta
Missouri University of Science and Technology, Ph.D. Student in Electrical Engineering

RESEARCH TOPIC
Deep Neural Networks for Real-Time Navigation and Control

A mobile robot can be made autonomous using a real-time camera for detecting and avoiding objects that are located in its environment. Deep learning is a subfield of machine learning using artificial neural networks (ANN) to process image data similar to how our human brain processes vision information. Ahmed's smart robotics research uses a special type of ANN known as convolutional neural network (CNN) to generate a model of the environment by processing image data in real-time. To create the ANN-based model, a deep lifelong learning scheme that is effective with different background environments is needed.

Ahmed developed a new lifelong learning scheme to mitigate 1) the catastrophic forgetting problem- which occurs when a CNN uses image information that is obtained from different backgrounds, and 2) vanishing gradient problem- commonly found with stochastic gradient descent (SGD)-based learning techniques that are normally employed to tune the weights of these ANN. Instead, his novel deep NN learning scheme adjusts the weights of the CNN layers directly in an offline supervised training mode first when limited image data sets are available and subsequently in real-time while navigating and collecting images. Driving simulator results for steering angle prediction at different robot speeds show that his approach performs better over widely employed SGD methods.

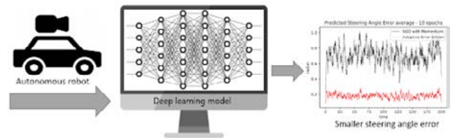


Fig. 1. The deep neural network that uses real-time data to obtain better autonomous driving

Fig. 2. A block diagram illustrating the training system of the robot.

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https://works.bepress.com/jagannathan-sarangapani/

CONTACT
aha4mb@mst.edu

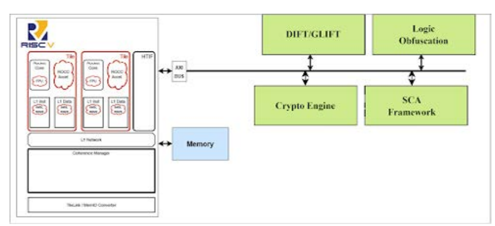
Geraldine Shirley Nicholas

Kappa Phi Chapter
University of North Carolina at Charlotte, Ph.D. Student in Electrical Engineering

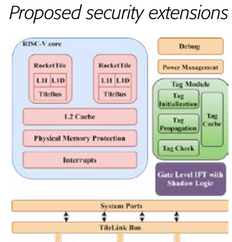
RESEARCH TOPIC
A Secured SoC Platform For Security Assessments In FPGA Using RISC-V

With the rapid increase in connected devices and SoC design architecture being used in diverse platforms, they've become potential targets to gain unauthorized access for data and privacy invasion. Security measures to protect the interfaces and data propagation through different channels are critical, and building a resilient model consists of the on-chip security factors. RISC-V architecture is used to build a robust side-channel analysis framework, as it provides a platform for custom implementation of security extensions when compared to other traditional architectures with the benefits of being an open-source ISA.

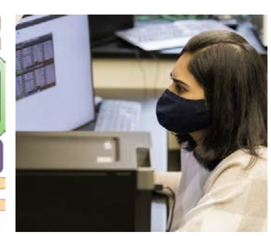
Considering a real-time network in which critical data is transferred from one node to another an adversary can modify the return address and corrupt the memory by gaining access to the system via untrusted channels and data. Tracking the data and the return addresses using the IFT model by a tagged mechanism for instruction level and shadowed logic for gate level mitigates all types of data related software attacks leveraging the RISC-V architecture benefits. An automated gate level model design tracks the information flow of specific security critical modules to detect leakage of data and triggering functionality that affects the output. The proposed IFT model is precise in securing the keys and other sensitive data. Flexibility in applying the logic to any datapath yields minimal overhead compared to other traditional models.



Proposed security extensions for RISC-V



Information Flow Tracking Model



HEAD Research Lab

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https://coefs.charlotte.edu/fsaqib/projects/

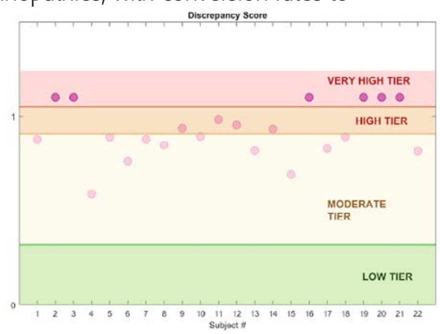
CONTACT
https://www.linkedin.com/in/geraldine-shirley-90b41266

Irene Rechichi

Mu Nu
Politecnico di Torino, Ph.D. Student in Computer and Control Engineering

RESEARCH TOPIC
Computational Analysis of Sleep for Early Detection of Neurodegeneration

Sleep plays a pivotal role in human health. There is growing evidence that poor sleep quality contributes to the onset of neurodegenerative processes, and sleep disorders are commonly acknowledged among the earliest manifestations of neurological impairment. Specifically, REM Sleep Behaviour Disorder (RBD) is a precursor of -synucleinopathies, with conversion rates to Parkinson's Disease (PD) up to 90%. In its idiopathic stage, RBD offers a window for disease-modifying interventions; therefore, early detection is pivotal for developing prevention strategies and personalized follow-up procedures. However, the diagnosis is a challenging task and nowadays relies primarily on manual scoring and clinical interviews, and many cases frequently remain undiagnosed. Irene's research encompasses a computational approach to analyzing sleep disorders, to build a lightweight framework for early detecting RBD. In more detail, her work includes the analysis of biosignals collected during sleep – that describe the electrical activity of muscles (EMG) and the brain (EEG) – and Machine Learning (ML) techniques for a faster diagnosis. Her latest work includes the automatic detection of RBD through ML with a minimal set of sensors and an index to assess and monitor the disease progression, thus leading to personalized outcomes for improving the subjects' quality of life.



The Dissociation Index and the estimated progression areas. The dots represent the subjects in the dataset; each is placed in the corresponding progression tier.

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https://scholar.google.ch/citations?user=cXK18CAAAAAJ&hl=en

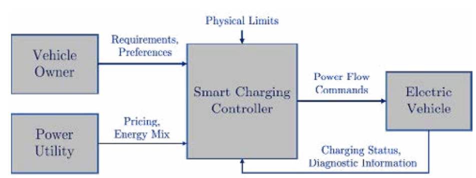
CONTACT
https://www.linkedin.com/in/irene-rechichi/

Kartik Sastry

Beta Mu
Georgia Institute of Technology, Ph.D. Candidate in Electrical and Computer Engineering

RESEARCH TOPIC
Smart Charging of Electric Vehicles

Market penetration of electric vehicles (EVs) is rising due to increasing environmental awareness, decreasing vehicle costs, regulatory pressures, and tax incentives. Left unmanaged, the corresponding increase in EV charging is expected to exacerbate the evening surge in power demand, degrade power quality, and overload power distribution infrastructure. Simultaneously, renewable energy resources (RESs) are being increasingly deployed to reduce dependence on fossil-based energy. Unlike fossil-based sources, power generation of RESs depends on natural phenomena like wind speed and solar intensity. Consequently, mismatches arise between times of high power supply (e.g. mid-day, when the sun is shining) and high power demand (e.g. evening, when people come home from work), which hinder the transition from fossil-based energy.



A smart charging controller collects various pieces of information from an electric vehicle (EV), the vehicle owner, and the power utility. This information is then used to optimally regulate power flow into the EV, based on a pre-specified optimality criterion.

Kartik's work on smart charging aims to aid the integration of EVs and RESs into today's power grid by controlling EV charging. In a smart charging session, the power flow into an EV battery is intelligently regulated such that energy demands and physical limits are satisfied, while also optimizing a performance criterion (e.g. maximizing renewable energy consumed during charging, minimizing charging time). Recent results indicate that equipping commercially-available EV chargers with smart charging algorithms may increase the number of EVs that can simultaneously charge (safely) within a neighborhood, and potentially offset costly infrastructure upgrades.

Kartik has the privilege of being advised by professors David Taylor and Michael Leamy at Georgia Tech.

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CONTACT
www.linkedin.com/in/kartiksastry/

You can choose to directly support IEEE-HKN or any of the strategically identified IEEE initiatives that help meet the world's most pressing challenges and help us to realize the full potential of IEEE.

Kyle Lady

Head of Security Engineering
Cisco Security Business Group

Beta Epsilon 2009

Kyle Lady joined HKN as an undergraduate at the University of Michigan (Beta Epsilon Chapter) in 2009 and has stayed involved in the Chapter ever since. He served as president in 2012 during his time as a Ph.D. student at Michigan. He received a BSE in computer science in 2010 and an MSE in computer science & engineering in 2012, both from Michigan. He joined Duo Security in 2015 and has followed the company's path through acquisition by Cisco Systems in 2018. Kyle was elected as the inaugural Student Governor on the IEEE-HKN Board of Governors in 2014 and 2015. He subsequently served as a IEEE-HKN Governor At-Large from 2017 to 2019. Kyle currently serves IEEE-HKN as vice chair of the Chapters & Ritual Committee and as the chair of the Outstanding Chapter Award subcommittee.

Why did you choose to study the engineering field (or the field you studied)?

I originally was interested in biomedical engineering, based on a desire to help people through science and technology. As I progressed through introductory courses, I discovered an interest and aptitude in the software engineering courses. I pursued that aptitude and latched on to the field of computer security as a way to similarly benefit humanity, as grand as it may sound.

Who do you admire and why??

I admire a number of pioneers who have thrived despite societal biases. University of Michigan professor emerita Lynn Conway has been one of the most public-facing trans women in computer science and engineering, significantly contributing to the field after having to restart her career due to prejudice. I also admire Edie Windsor, who was a systems programmer at IBM who became the public face in a 2013 U.S. Supreme Court case to fight for equal rights.

What is the most important lesson you have learned during your time in the field?

I had heard people talk about "office politics," and it was never anything positive. However, engineering is a field where collaboration outside of your team is necessary to succeed with complex projects, including non-engineering teams. I've learned that there will be "politics" whenever you need time, staff, or other resources from other teams (and whenever they need resources from you). "Politics" can be productive, as you consider what other teams' needs and perspectives are, help them proactively, and build relationships to learn who to go directly to instead of going up and down the org chart to get anything done.

What advice can you offer recent graduates entering the field?

Don't discount the value of clear technical writing. As you advance in an individual contributor role, you do less and less hands-on engineering work and more writing and meeting. Lots of folks set up unneeded meetings to make up for the fact that there isn't clear documentation readily available. In any new role, make a note of everything that you need to ask someone for help with that you could have simply read, had it been written down already. Incomplete documentation is better than no documentation, so start writing down what you figure out. Have an expert review that initial version, identify the gaps, and iterate from there.

What is your favorite Eta Kappa Nu memory?

My favorite HKN memory has to be spending my summer downtime in the Beta Epsilon office with other members who were on-campus during the summer. The small group of members who were around, mostly grad students, helped each other with technical roadblocks, played Xbox on the office couch, went on impromptu road trips for dinner, and brought in discounted grocery-store baked goods to share. My second favorite memory might be a vigorous debate on whether it takes more energy to launch a particular pop singer into the sun or out of the solar system, complete with whiteboard diagrams and orbital mechanics equations.

Why do you support IEEE-HKN?

I support IEEE-HKN because IEEE-HKN was a major part of my undergraduate and graduate careers. I met many of my closest friends to this day through HKN. I learned a lot about different ECE/CS subfields from other HKN members and gained an appreciation for the interesting aspects of fields as diverse as computer vision, control systems, and non-destructive measurement. I still don't understand MOSFETs despite trying several times, not for a lack of generous discussion from fellow members.

What are the greatest opportunities for IEEE-HKN over the next three years?

An opportunity with great potential for IEEE-HKN is building increased chapter support programs. One aspect of this is financial, but there is much more that IEEE-HKN could do to support chapters at scale. Chapters generally operate in a silo, but many are physically quite close to other chapters. It's currently a question of how much effort individual officers want to put into developing relationships outside of campus. The sense of community within IEEE-HKN could be strengthened by expanding programs to connect chapters as institutions instead of just between individual officers. Financial support would help free up bandwidth for chapters, especially smaller ones. I stay involved and donate to help build this sense of community for student members to feel a greater sense of IEEE-HKN as a whole.

HKN Chapters Inspiring K-12 Students with STEM Programs

Throughout the 2021-2022 academic year, HKN Chapters around the world spent time with children (K-12), introducing them to the wonderful world of STEM! Here is how they did it.

Chapter President Jowaria Khan, presenting a certificate to a coder

The Lambda Lambda Chapter at American University of Sharjah hosted the Toy Stories Workshop in March. In collaboration with the Community Services and Outreach Office at their university, Lambda Lambda members developed this program for children from The Big Heart Foundation, an organization that provides services to people in need.

Using a fun interactive game, Chapter members taught the basics of coding to 20 children from the Foundation. Chapter President Jowaria Khan recalls, "This STEM workshop had been a great success as the children got introduced to computer science for the first time in their lives and seemed to be quite interested in the field by the end of the workshop."

Before the coding workshop, the Chapter recruited nearly 100 student volunteers to hand-stitch soft toys to give to the children who would participate. The young coders received the handmade toys and a certificate at the completion of the workshop.

The Lambda Zeta Chapter at the University of North Texas was also hard at work getting children excited about engineering through its Future Innovators Workshops.

The Chapter collaborated with the UNT IEEE Student Branch, the IEEE UNT Signal Processing Society, the IEEE UNT Robotics and Automation Society, the IEEE UNT Computer Society, and the IEEE UNT Engineering in Medicine and Biology Society to create virtual workshops to teach K-12 students about electricity, circuits, and microcontrollers.

The Chapter and its partners shipped electronics kits to the students and walked them through completing a hands-on project. They also shared resources supporting future project ideas and exploration. Visit the Lambda Zeta website to learn more and support Future Innovators!

Chapter Vice President Rohan Mitra, assisting with the program

Celebrate HKN's 118th Anniversary!

Founders Day is a way for us to share the IEEE-Eta Kappa Nu story, raise awareness of the value that an IEEE-HKN Chapter brings to a University, show the many ways a Chapter serves fellow students and the community, and encourage industry to support us. Please find a way to tell the IEEE-HKN story to celebrate Founders Day, wherever you are in your IEEE-HKN journey!

- Invite alumni to get involved in your Founders Day celebration. Alumni reconnect with your Chapter.
- Share an HKN memory–tag us: #IamHKN, #HKNFOUNDERSDAY, @IEEE_EtaKappaNu
- Add your HKN status to your social media profiles
- Host or participate in a community service activity
- Hold a networking event
- Donate to IEEE-HKN to help us provide Chapter support, training, conferences, special events, and more

IEEE-HKN Announces Mentorship Program for Graduate Students and Professionals

IEEE-HKN's Professional to Graduate Student Mentorship Program links Graduate Student Members with a mentor who can offer their experience and insights to assist with career planning, professional development, and more.

Several HKN graduate students and professional volunteers formed a Support Working Team to support the students by pairing them with a mentor, ensuring that the time each partner contributes is mutually beneficial. Also, a member of the support team was assigned as a primary point of contact once students received their mentors. However, it was incumbent upon the mentee and the mentor to establish a mentoring agreement and encourage effective communication practices.

The first cohort will end in December, but the goal is to build mentoring connections that will last for several years. Look for updates on this program in future issues of *THE BRIDGE* and on the HKN website.

Two Books in a New Series on Reaching Your Full Career, Personal Potential Are Among Free E-Books from IEEE-USA for Members

by Georgia C. Stelluto

New E-Book on Using Self-Assessment to Visualize and Realize Your Future Self Now Available

IEEE-USA has just published *The Ultimate Upgrade Essentials: Book 2: Self-Assessment*, the second e-book in the series, by Terence Yeoh, Ph.D., PMP.

In his newest e-book, Yeoh, who offered the keynote address at the 2022 IEEE-HKN Pathways to Industry conference, outlines three failures of individuals:

1. Failure to correctly gauge your potential, thereby limiting yourself (a failure of youth).
2. Failure to adequately recognize your limitations, thereby overstretching yourself (a failure of midlife).
3. Failure to realize that balance is dynamic, and can only be achieved in motion, not stillness (a failure late in life).

Yeoh notes that it is common to look at yourself and others, and attribute successes to hard work or luck. He suggests, however, that regardless of one's life stage, successful individuals focus on their skills to expand their strengths and recognize that "'every weakness can be harnessed for even greater strength."

The first step in this exercise is self-assessment. Yeoh discusses several self-assessments, starting with a simplified personal SWOT analysis (strengths, weakness, opportunity and threats). He encourages readers to draw on their own observations, as well as the input of others (a friend, a coworker and a relative) to effectively develop a 360-degree assessment.

The Ultimate Upgrade Essentials – Book 2: Self-Assessment is available to IEEE members for free at IEEE-USA's online shop.

New E-Book for Members Explores Reaching Your Full Human Potential

"Author Terence Yeoh loves cars. The author makes it clear from the very opening paragraphs of his first book in the new IEEE-USA e-book series: *The Ultimate Upgrade Essentials Book 1: The Human Condition*. Yeoh starts by drawing parallels between cars and the human body. He notes that just like cars: "Our bodies always leave something in the back pocket," and that "Our human potential far exceeds our day-to-day performance."

In this book, Yeoh draws from both his engineering experience, and from his YouTube series, *Yeoh on the Go*, to offer suggestions on performing at peak levels. He notes that as everyone is bombarded with more and more information, we need to understand how we can process and act on information in parallel tracks, while cutting out information or tasks that are less important. The author points out that humans are generalists by nature, but are most able to become expert (or at least competent) in multiple areas. In the face of even more information and the maturing of artificial intelligence, he suggests we "strive to grow in this manner – to be more human, not less."

Members: Get your free e-book here.

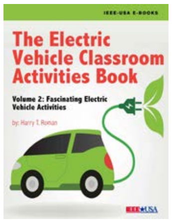
New E-Book for Members Encourages Teachers, Students, and Parents To Explore Creativity

Prolific Author, Harry T. Roman is back with a new e-book series on creativity in the classroom. *Creativity – Our Valuable Lifelong Skill – Volume 1: The Basics*, is the first of a three-book series on creativity. This book contains the basics about creativity gleaned from the author's personal readings, research, and interactions with teachers and students over decades of in-person visits and lecturing in various grade levels in public and private schools.

In *Volume 1: The Basics*, Roman outlines the four Cs necessary to prepare the next generation to be creative, and to generate the ideas necessary for the unprecedented global changes to come: creativity, curiosity, collaboration, and communication.

Creativity–Our Valuable Lifelong Skill–Volume 1: The Basics is available to IEEE members for free at IEEE-USA's online shop. Get it here.

New E-Book for Members Helps Teachers, Students Explore Electric Cars with 360-Degree View



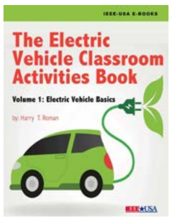
Roman is also back with a second book on electric cars: *Electric Vehicle Classroom Activities Book—Volume 2: Fascinating Electric Vehicle Activities*. Roman's newest book helps teachers lead students as they take a 360-degree look at electric cars, examining the technological, environmental, social, cultural, safety and regulatory implications of widespread electric car adoption.

The author pushes student exploration well beyond the environmental impact. For instance, he suggests students brainstorm unexpected economic impacts, such as job reductions at gas stations, and a lessened need for mechanics (electric cars with fewer moving parts need fewer repairs).

Roman also raises questions about public policy. Adopting electric cars varies greatly around the nation, the author notes, due to varying incentives offered by state governments.

Electric Vehicle Classroom Activities Book–Volume 2: Fascinating Electric Vehicle Activities" is available to IEEE members for free at IEEE-USA's online shop. Non-members pay US$2.99. Don't miss this opportunity to complete the series for your reference libraries! Get it here.

E-Book for Members Offers Educators Electric Vehicle Exploration Activities for the Classroom



In Volume 1 of IEEE-USA E-Books' new series, *The Electric Vehicle Classroom Activities Book–Volume 1: Electric Vehicle Basics*, Harry T. Roman provides teachers with discussion ideas surrounding the history of electric cars. Roman explores three areas: the operation of electric cars, electric car batteries, and electric car charging. This book provides a starting point for drafting lesson plans to help ground students in one of the most important innovations taking place in today's marketplace.

In the book's introduction, Roman notes: "All technologies have pros and cons, and electric vehicle technology is no different. It is my hope this small volume will stimulate informative exchanges among our future leaders.

Members: Get your free e-book from IEEE-USA here. No promo code necessary!

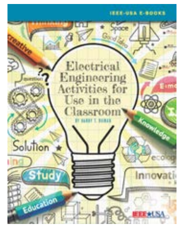
New Audiobook Explores Understanding the Engineering Gender Gap

IEEE-USA has published a new audiobook: *Free to Choose STEM: Data and Reflections on Girls and STEM Careers*. Author Pamela Cosman draws on her personal experience as a female engineer, as well as numerous studies and articles, to examine why a gap remains between the number of women and the number of men entering engineering. It raises questions about how we raise our children and influence their decisions to enter (or avoid) STEM careers.

Cosman outlines many reasons we should encourage more of our daughters to go into engineering, including that those employed as engineers have exceptionally high levels of career satisfaction, as well as steady and high-paying opportunities.

IEEE-USA's new *Free to Choose STEM: Data and Reflections on Girls and STEM Careers* audiobook is available free here.

New Audiobook Offers Guide to Excite Teachers, Students about Electrical Engineering



IEEE-USA has released a new audio edition of veteran engineer and educator Harry T. Roman's *Electrical Engineering Activities for Use in the Classroom*. The audiobook guides teachers through exercises and activities they can use to introduce students to and excite them about electrical engineering.

Roman notes that in 1905 only five engineering fields (electrical, mechanical, chemical, civil and industrial) existed. Today, we have more than 100, ranging from aeronautical and ceramic to aerospace and solar. So, there is much material to cover! The author suggests starting with students developing their own definition for electrical engineering, and exploring how engineers solve problems, what processes they use, and how these processes vary among the engineering fields.

You can download this audiobook here. The companion e-book is also available at no charge to members.

New Audiobook Discusses the Value of R&D

In his new IEEE-USA audiobook, *Do Your R&D*, author Harry T. Roman makes it clear he believes in the value of R&D, and that all too often, it falls victim to aggressive accountants or short-sighted leaders. He is also clear about who he believes corporate R&D should emulate: Thomas Edison.

Roman presents the seven-step systematic innovation process Edison pioneered: Identify a problem worth solving; evaluate market needs; identify constraints and challenges; test potential solutions; validate invention; market the invention (now a product); and develop and improve the product.

Download the new audiobook in MP3 format, here. The companion e-book is also available at no charge to members.

Georgia C. Stelluto is IEEE-USA's Publishing Manager, Editor and Manager of IEEE-USA E-Books and Audiobooks, Department Editor of @IEEEUSA for IEEE-USA's flagship publication, "Insight," and Co-Editor for *IEEE-USA Conference Brief*.

IEEE-Eta Kappa Nu Launches IEEE-HKN Career Center

IEEE-Eta Kappa Nu

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