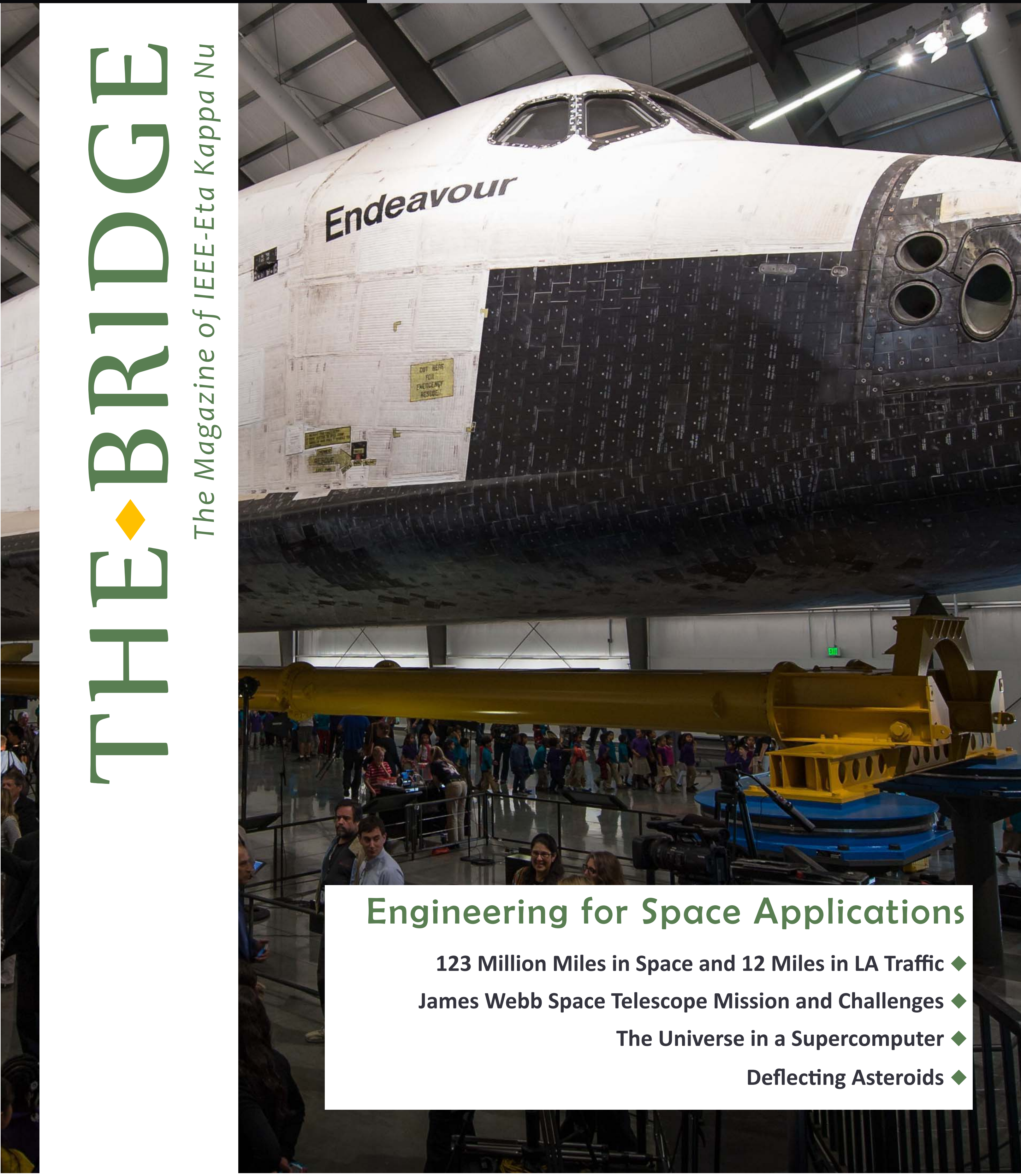
THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu



Engineering for Space Applications

123 Million Miles in Space and 12 Miles in LA Traffic ◆

James Webb Space Telescope Mission and Challenges ◆

The Universe in a Supercomputer ◆

Deflecting Asteroids ◆

March 2013 Vol. 109 / No. 1

HKN IEEE

IEEE-HKN AWARD NOMINATIONS

As an honor society, IEEE-Eta Kappa Nu has plenty of opportunities designed to promote and encourage outstanding students, educators and members.

Visit www.hkn.org/awards to view the awards programs, awards committees, list of past winners, nomination criteria and deadlines.

Outstanding Young Professional Award

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

Vladimir Karapetoff Outstanding Technical Achievement Award

Recognizes an individual who has distinguished him or herself through an invention, development, or discovery in the field of electrical or computer technology. (Deadline: 30 April)

Outstanding Student Award

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

Outstanding Chapter Award

Singles out chapters that have shown excellence in their activities and service at the department, university and community levels. Winners are determined by their required Annual Chapter Reports for the preceding academic year. (Deadline: 15 October)

C. Holmes MacDonald Outstanding Teaching Award

Presented annually to a dedicated young professor who has proven exceptional dedication to education and has found the balance between pressure for research and publications and enthusiasm and creativity in the classroom. (Deadline: 30 April)

IEEE-Eta Kappa Nu (IEEE-HKN) was founded by Maurice L. Carr at the University of Illinois 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-Eta Kappa Nu. Ideas and opinions expressed in THE BRIDGE are those of the individuals and do not necessarily represent the views of IEEE-Eta Kappa Nu, the Board of Governors, or the magazine staff.

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The Magazine of IEEE-Eta Kappa Nu

March 2013 Features

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LETTER FROM THE PRESIDENT

JOHN A. ORR

Alpha Chapter

Dear IEEE-HKN Members and Friends:

It is a great honor as well as a real pleasure to write this letter as I take on the Presidency of IEEE-HKN. Although it has been quite a few years since I joined Eta Kappa Nu, I still recall my initiation into the Illinois Alpha chapter. HKN's fundamental purpose of recognizing and celebrating academic excellence in Electrical and Computer Engineering is as valid and important now as it was in 1968 when I joined, or in 1904 when HKN was founded. However, the world is a very different place than in either of those past times. The field of electrical engineering has expanded in breathtaking fashion, so much so that we have a hard time defining the limits of our profession – and that is a good thing!

Please join me in thanking Steve Goodnick for his excellent leadership that has resulted in a strong and vibrant organization. I look forward to his wisdom and continued involvement as Past President. Our merger with IEEE has been a complex undertaking that has concluded quite successfully, thanks to the hard work and good will of many people in HKN and IEEE. While we have fond and grateful memories of the past days when a few dedicated volunteers oversaw our organization, the merger with IEEE has brought opportunities for global expansion, greatly increased financial stability, and wonderful operational resources for activities ranging from publishing THE BRIDGE to staying in contact with our chapters. Bruce Eisenstein merits our heartfelt appreciation as he completes his term as Past President. Bruce's vision and attention to all aspects of the merger have resulted in the strong position in which we find ourselves today.

Nancy Ostin hit the ground running when she joined IEEE-Eta Kappa Nu as Director, and her experience and energy are already being noticed in both large and small ways. Nancy truly shares our vision for expanding IEEE-Eta Kappa Nu both in global geographic reach and in our impact on the electrical and computer engineering profession. It is a pleasure to work with Nancy, and I hope that many of our members get the chance to meet her.

I hope that you have had time to read the latest copy of THE BRIDGE. We have moved away from paper to electronic distribution of this essential part of membership in IEEE-HKN. Our vision for THE BRIDGE is three-fold: to highlight the outstanding work of our student chapters, to help members stay in touch throughout their careers, and to help us all stay on top of our ever-expanding profession. We welcome Prof. Steve Watkins of the Missouri University of Science and Technology as our new Editor-in-Chief of THE BRIDGE.

Steve Goodnick has enthusiastically agreed to chair an ad hoc committee to develop a new strategic plan for IEEE-Eta Kappa Nu. The time is right now that our transition to IEEE-HKN is complete and we have every reason to look forward to an incredibly exciting global future! My own vision for IEEE-HKN centers

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President's message continued...

on four aspects: first, to excel at our founding mission of recognizing and promoting academic excellence by students studying electrical and computer engineering and related disciplines; second, to expand this mission globally; third, to use the leadership that was demonstrated as students to advance the profession for the good of society; and fourth, to find ways to enhance the fellowship that begins at initiation time and can grow and strengthen throughout our careers. Within this broad outline, our Strategic Planning Committee will identify specific goals and strategies.

Steve, Nancy, and I are eager to hear your thoughts as we embark on this project. Please email any or all of us with your comments: s.goodnick@ieee.org, n.ostin@ieee.org, j.orr@ieee.org. Three groups represent essential contributors to IEEE-HKN's success: (1) the students in each chapter, and in particular the officers; (2) the faculty chapter advisors, department chairs, and other faculty who support the chapters; and (3) the alumni members. I think there is great opportunity for more interaction among all of these groups across our chapters. During this year, we want to investigate means to accomplish this.

During my time as the President of IEEE-HKN, I hope to have the opportunity to visit many of our chapters, install new chapters, work with our Faculty Advisors, and the Board of Governors. I pledge to listen to your ideas and suggestions, and welcome your input on ways to continue our traditions while expanding and offering services and an experience to benefit the students and professionals today, and for those of our future.

Very best wishes,

Phone + 1 508-831-5273
Email: j.orr@ieee.org

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LETTER FROM THE EDITOR-IN-CHIEF

DR. STEVE E. WATKINS

Dear IEEE-Eta Kappa Nu Members,

Welcome to the first issue of THE BRIDGE magazine for 2013. I am pleased to be starting my duties as Editor-in-Chief. I have been involved with Eta Kappa Nu for most of my professional life as a student member, as a faculty advisor, and as a board member. The organization has undergone significant changes throughout its almost 109 years, but it continues to promote the profession, to recognize excellence within the profession, and to support member development and education, especially during the student years.

The magazine is a collaborative effort of Catherine Slater (Editorial Board), Stephen M. Williams (Editorial Board), Nancy Ostin (Director, IEEE-HKN), and Joanne Van Voorhis (Senior Manager, IEEE Educational Activities) with the support of other IEEE-HKN staff. Please let us know what you like about the magazine and what you want to see in future issues. We invite submissions for our technical features, chapter happenings, member profiles, etc. Contact any of the Editorial Board or the IEEE-HKN staff for assistance in preparing submissions.

This issue is being published the same month as the 2013 Student Leadership Conference at Arizona State University. These conference events are valuable venues for networking, for sharing information, and for building career skills. I urge your chapter to take advantage of such opportunities for chapter and personal development. We will give an overview of the conference in our next issue. Chapters should consider applying to host the conference for the next available year. Watch for information on the 2014 conference in coming issues.

Best regards,

Steve E. Watkins

Phone + 1 573-341-6321

Email: steve.e.watkins@ieee.org

Did you Know?

The Greek letters HKN were chosen from the 1st, 4th, and last letter of the Greek word for amber or electron:

ΗΛΕΚΤΡΟΝ

LETTER FROM THE DIRECTOR

NANCY M. OSTIN, CAE

Dear Friends of IEEE-Eta Kappa Nu,

Buckle your seatbelts…it's going to be an exciting ride! In our first issue of THE BRIDGE for 2013, I am happy to share with you some very interesting and intriguing projects we are working on in the coming year.

The IEEE-HKN Student Leadership Conference (SLC), held 15-16 March at Arizona State University, exceeded our expectations in every way. We had stunning student attendance and chapter representation, witnessed brilliant collaboration, listened to passionate speakers, and participated in excellent workshops...making this year's SLC a huge success! The conference is offered at no charge to IEEE-HKN students. We provide a small travel stipend to make sure everyone has the opportunity to attend; however, exceeding our expectations also means we exceeded our budget. Please consider contributing to IEEE-HKN, and allow us to cover our costs and fund future events for students and Chapters in 2013! A donation of US$114 supports the attendance of one student; a donation of US$250 can help provide a travel stipend for an entire Chapter! Donations should be directed to the IEEE Foundation, a tax exempt 501(c) (3) organization in the U.S., designated to the IEEE-HKN Student Leadership Conference Fund. For ease of donation, please use the IEEE Foundation's secure site at www.ieee.org/donate and select the IEEE-HKN Student Leadership Conference Fund. Please look for photos from the Conference, and information on our virtual conference scheduled for the fall of 2013 on our website at www.hkn.org.

We are excited to announce our Alumni Reconnect project! This is a call to all HKN and IEEE-HKN alumni to update your contact information. Learn more about how you can continue to be involved with IEEE-HKN, and benefit as a professional, at www.hkn.org today.

Updates about our exciting plans for Founders Day, to be held on 28 October, will be available at www.hkn.org shortly. We plan to celebrate our rich history and the contributions of our members in a big way! Plan to share your best Eta Kappa Nu stories, accomplishments, and memories. Take part and participate in envisioning what IEEE-HKN should be today, and in the decades to come.

Finally, there are many opportunities to serve on committees, the Board of Governors, or work directly with students and chapters. If you are interested in learning more, please contact me at n.ostin@ieee.org or +1 732 465 6611. I welcome your involvement, and look forward to speaking with you and hearing your great ideas. Look out 2013; it's going to be a busy year!

Phone + 1 732 465 6611

Email: n.ostin@ieee.org

IEEE-HKN PLEDGE

"I sincerely promise that I will live up to ... in word and in deed ... the principles for which IEEE-Eta Kappa Nu stands ... To the members now and to those to come after ... I bind myself to the faithful observance of these promises ... I give my solemn word of honor."

123 Million Miles in Space and 12 Miles in LA Traffic

Engineering the Final Journey of the Space Shuttle Endeavour

(Image Credit: NASA/Bill Ingalls)

By Burton Dicht

THE FINAL JOURNEY

In the mid 1970's, engineers at Rockwell International's Space Transportation Systems Division in Downey, California, were tasked with developing the Space Shuttle Orbiters as part of NASA's new Space Transportation System. They confronted many technical challenges and overcame them with creativity and innovation as they pushed the boundaries of technology to design the world's first reusable spacecraft.

Today, more than thirty years later, those same engineers would have been impressed with the engineering effort and ingenuity that was required to complete the final mission of one of their creations, the Space Shuttle Orbiter Endeavour. On October 14, 2012, Endeavour arrived at its final home, the California Science Center, after a twelve mile journey that started at the Los Angeles International Airport (LAX) and wound through the streets of Inglewood and Los Angeles.

In planning, preparation and execution, Endeavour's final journey, which was labeled, "Mission 26: The Big Endeavour," rivaled any of its twenty-five space missions. Endeavour is about the size of a DC-9 jetliner, with a length of 122 feet, a wingspan of 78 feet, a vertical height of 58 feet and a weight of 145,000 pounds. On Endeavour's arrival at the Science Center, Los Angeles Mayor Antonio Villaraigosa commented, "Nothing like this has ever been attempted before, and nothing like this will ever be attempted again. This was not just a once in a lifetime event, this was a once event."

PRESERVING THE SPACE SHUTTLE LEGACY

Endeavour's journey to the Science Center had its origins in a December 2008 announcement that NASA was seeking ideas from science and aerospace museums on how to preserve the legacy of the space shuttle orbiters at the

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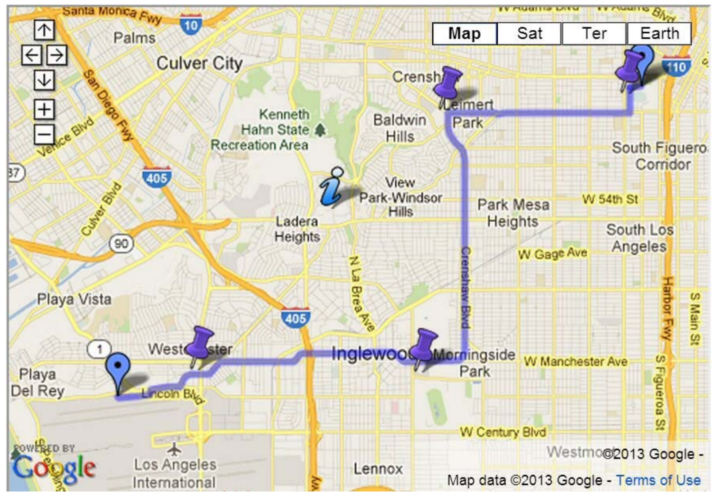
conclusion of the Space Shuttle Program in 2010 or 2011. The Science Center joined 20 other museums and submitted proposals to acquire one of the three retiring orbiters: Discovery, Atlantis or Endeavour. The prototype orbiter Enterprise, which never flew in space, was also available for display. (Five orbiters were constructed with Columbia and Challenger lost in accidents.)

In an April 12, 2011 announcement that coincided with the thirtieth anniversary of the shuttle program's first flight, NASA administrator Charles Bolden announced that Endeavour would be displayed at the Science Center. Of the other orbiters, Discovery would go to the Smithsonian's National Air and Space Museum Steven F. Udvar-Hazy Center in Virginia, Atlantis to the Kennedy Space Center Visitors Complex in Florida, and Enterprise to the Intrepid Sea, Air and Space Museum in New York City.

TAKE THE FREEWAY OR SIDE STREETS: DETERMINING THE BEST ROUTE

In making the award, NASA assumed the responsibility for transporting the orbiter to an airport near the host museums. Each museum was then responsible for the final delivery of the orbiter to its own facility. Kenneth Phillips, the Science Center's curator for aerospace science, indicated that questions for delivery of the orbiters were not addressed in the proposal to NASA. Phillips added, "In fact, we didn't even know whether NASA would fly the orbiter into LAX or Edwards Air Force Base. So, it was not possible at that time to develop a plan."



LAX to Science Center Route.
(Photo Credit: Google Map Created by the California Science Center)

Located south of downtown Los Angeles in Exposition Park, the Science Center had experience in transporting aircraft and spacecraft through urban areas to the facility. The Lockheed A-12 Blackbird, the Gemini 11 Capsule, the Apollo-Soyuz Command Module and a United Airlines DC-8 passenger jet are several examples. The DC-8, with a 150 foot length, 143 foot wingspan and a 43 foot vertical tail was towed along city streets to the Science Center from Long Beach in June 1984. With the wings and tail removed, the DC-8's journey took about 6 hours. However, the challenges to the Science Center staff in transporting Endeavour would be far more daunting.

Following the April 2011 award, the Science Center was required to submit a report to NASA within 45 days detailing the logistics of transporting Endeavour from LAX to the Exposition Park facility. Knowing that cars are king in L.A., using the freeways seemed a logical first option. The freeways were wide enough to accommodate the orbiter's wingspan and weight.

The showstopper for the freeway option was the overpasses. The orbiter's height and 58 foot vertical tail made it impossible for it to pass through the average 16.5 foot overpass vertical clearance. Phillips noted, an option that they discussed was lifting the orbiter at each overpass and translating it horizontally across the road and then lowering the orbiter back to the transport trailer. The problem was, no system existed that was capable of carrying out those movements. NASA's orbiter lift system only provided for vertical lift, so this option was never considered.

Many also asked why the orbiter's wings and tail were not removed, which is typically done when transporting aircraft in order to make the transportation simpler. Displaying the orbiters as intact as possible to their flying configurations was a priority. Removing the wings and tail would mean cutting and permanently damaging the Thermal Protection System (TPS) tiles. Plus, removing and re-attaching the wings and tail required a complicated infrastructure that was only available in the Orbiter Processing Facility (OPF) located at the Kennedy Space Center. Once disassembled, it would have been impossible to reassemble Endeavour to its original state.

The best options were surface streets. Phillips noted, "The great thing about Los Angeles is that it has very wide boulevards." To assist in the planning and logistics of the move, Science Center officials brought in Parsons, an engineering and construction firm headquartered in Pasadena. Working as a subcontractor to Parsons and donating their engineering services, Psomas, a California based consulting and engineering company that specializes in transportation challenges, was tasked with identifying potential routes. Using satellite technology and onsite surveying,

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the Psomas engineers reviewed seven possible routes that were later analyzed to determine the optimal path. "We were looking for grades that did not exceed 5% and the minimum number of other obstacles like power lines, trees and traffic and street lights," says Phillips. The route that was chosen would start at LAX and travel over several major thoroughfares including La Tijera Boulevard, Manchester Avenue, over the 405 Freeway, Crenshaw Boulevard and Martin Luther King Boulevard before ending at the Science Center.


An artist rendering of the Space Shuttle Orbiter on the Overland Transporter with the Self-propelled Modular Transporters (SPMT). (Photo Credit: California Science Center)

THE OVERLAND TRANSPORTER, SPMTs AND ASSORTED ITEMS

With the route selected, the question was how to actually move Endeavour? Following their assembly at Air Force Plant 42 in Palmdale, California, the orbiters had to be transported 35 miles on surface roads to Edwards Air Force Base (EAFB) for the ferry flight to the Kennedy Space Center (KSC). NASA developed a specially fabricated frame called the Overland Transporter (OT) to perform this task. The OT had one forward and two aft fittings that mirrored the connections used to attach the orbiter to the external tank for launch and the Shuttle Carrier Aircraft (SCA) for the orbiter ferry flights.

The OT had last been used in April 1985 to transport Atlantis to EAFB. As the final orbiter to be assembled, Endeavour was flown directly from Plant 42 to the KSC and never used the OT. Luckily, the OT had been kept in storage in an EAFB hangar. After a thorough inspection by NASA for corrosion and structural integrity, it was determined to be in good shape to carry Endeavour from LAX to the Science Center. Because of the tight spaces along the route, the OT and Endeavour could not be towed and instead they would rest on top of Self-propelled Modular Transporters (SPMT) supplied by the Sarens Group.

The Sarens Group is a Belgian company that specializes in heavy lifting and engineered transport. The SPMTs, manufactured by KAMAG, were comprised of four independent, multi-axle, computer-controlled wheeled vehicles. The configuration chosen for Endeavour consisted of two 4-axle units at the front and two 6-axle units at the rear that were coupled together side-by-side respectively. In total, there would be 80 wheels on the vehicle that would be synchronously steered using only one remote control. The electronic multi-mode steering together with a steering angle of +130°/-100° enables the SPMTs to be extremely flexible and maneuverable, making them particularly suited for the tight bends that would be encountered on Endeavour's urban journey.

A single operator, using the remote joystick and walking alongside the orbiter controlled the movements. The operator was assisted by spotters positioned near the nose, tail and wingtips to enable precision maneuverability. Voicing the importance of their company's contribution, Jim Hennessy, Sarens North America's marketing manager said, "This may not be the largest or heaviest object we have transported, but it is certainly one of the most important in our company's history. The Endeavour is a national treasure and we are honored to play a key role in its final mission in route to the California Science Center where it will be put on display for all to see."

Having identified the route and transport plan, the Science Center submitted the logistics report to NASA in late May. In July 2011, a NASA team arrived to review the plans, scout the route and to meet with officials from the Science Center. NASA also met with the Los Angeles World Airports, the managers of LAX, to alleviate concerns about the space required to demate the orbiter from the SCA and for the storage and security of Endeavour. After six weeks of negotiations, the details were finalized. United Airlines donated the use of one of its hangars to store Endeavour while the final preparations for the move were completed. The decision was also made to conduct the demating of Endeavour immediately after the conclusion of the arrival ceremony in hopes of lessoning the disruption to the airport.

ORBITER TRANSITION AND RETIREMENT

Concurrent with the planning and preparations for Endeavour's ground move, engineers and technicians from NASA and the United Space Alliance (USA), the consortium of companies that maintained and processed the shuttles, began the Transition and Retirement (T&R) phase for the three orbiters. The main objectives were to make the orbiters safe and ready for public display and to remove selected hardware for possible use in future NASA programs.

All of the orbiters had their Space Shuttle Main Engines (SSME) removed. The SSMEs are the first reusable rocket engines and remain the most advanced engines ever designed. NASA plans to use the SSMEs as part of the new Space Launch System heavy-lift rocket. In place of the SSMEs, technicians installed actual engine nozzles that had been flown or tested. The nozzles were then cosmetically treated to look weathered in order to simulate normal flight wear and tear. Also removed were the Orbital Maneuvering System (OMS) pods and the Forward Reaction Control System (FRCS).

The OMS pods and the FRCSs used hypergolic propellants for orbital insertion and maneuvering. Hypergols, as they are called, are also very toxic. Exposure to humans would be very dangerous. To ensure the orbiters were safe for public display, the OMS pods and the FRCSs were sent to the White Sands Test Facility in Las Cruces, N.M. for cleaning and servicing. The FRCSs were returned to the KSC to be reinstalled into the orbiters. The OMS Pod nozzles were replaced with real-life replicas to be reinstalled after the orbiters arrived at their display sites.

Specifically for Endeavour, technicians removed some additional equipment that would be on display to provide the public with a better understanding of the space experience. They included: 1) One of Endeavour's three fuel cell power plants, which generated electricity from chemical reactions using hydrogen and oxygen; 2) The Galley, which gave astronauts the tools they needed to rehydrate and heat food; and 3) The Waste Collection System (or zero-g toilet) that used air flow to pull waste away from the astronauts' bodies and into the collection chamber.

As the sun rises at the Shuttle Landing Facility at NASA's Kennedy Space Center in Florida, preparations are under way to back NASA's Shuttle Carrier Aircraft, or SCA, away from the Mate-Demate device. Space shuttle Endeavour has been fitted with an aerodynamic tailcone and secured atop the aircraft for its ferry flight. (Photo credit: NASA/Frankie Martin)

The work to de-service and de-commission Endeavour was completed in August 2012, more than a year following its 25th mission, which landed at the KSC on June 1, 2011. "Endeavour's preparations have gone extremely well. Since its last flight, we have been de-servicing the vehicle instead of servicing it," said Stephanie Stilson, NASA's flow director for orbiter transition and retirement. The final step was to close out the crew module. This was handled as carefully as it would have been for any space mission. "For flight we had to carefully make sure everything was in place for a mission. We are making sure everything is secured for Endeavour's flight to the museum in California," said Bobby Wright, a senior aerospace technician with USA.

The preparations for the ferry flight began on September 14, 2012, as Endeavour was towed to the Shuttle Landing Facility (SLF) to be mated to the SCA. The SCA is a modified 747 that has three attach fittings on the top of the fuselage that connect and secure the orbiter. NASA used a device called the Mate-Demate Device (MDD) to lift the orbiter onto the SCA. The MDD is a structure that has a self-contained crane, which lifted the orbiter vertically from a sling that was attached to the fuselage. The SCA would then be towed into position under the orbiter, which was then lowered and attached to the support assemblies on the SCA fuselage. This was typically a two day process.

PREPARING THE ROUTE

Space shuttle Endeavour secured to the Overland Transporter (OLT) meets nose to nose with the Shuttle Carrier Aircraft (SCA), at Los Angeles International Airport.
(Photo Credit: NASA/Scott Andrews)

As Endeavour was undergoing its T&R phase, efforts were continuing in Los Angeles to prepare for the transport through the city streets. The route, which had been determined to best accommodate the orbiter's dimensions and weight was thoroughly reviewed for obstacles. The Cordoba Corp. and David Evans and Associates, both from Los Angeles, teamed up to provide high-definition 3D laser scanning services. They produced a list of all the obstructions including: trees, traffic signals, light poles, street signs and parking meters. A team from Plump Engineering of Anaheim also scanned public work documents to identify sewer and storm drains that the orbiter would pass over.

During the move, the SPMTs would straddle each side of the boulevard medians to maximize the curb-to-curb clearance. In probably the most controversial aspect of the plan, more than 390 trees had to be removed, the majority of which were located in the medians. Restoring the communities to their original state prior to the move was a priority to the Science Center. Working with the cities of Inglewood and Los Angeles, they made a commitment to plant four trees for every one that was removed. Another important task, performed by the workers from the Department of Water and Power and Southern California Edison, was to extend power and telephone poles to allow for raising power transmission lines as the orbiter's 58 foot vertical tail passed through.

ENDEAVOUR'S FINAL FERRY FLIGHT

The space shuttle Endeavour atop the 747 shuttle carrier aircraft is seen flying over the Hollywood sign in Los Angeles during the final portion of its tour of California.
(Photo Credit: NASA/Jim Ross)

After more than a year of intense planning, engineering and review, Endeavour was ready to begin its final mission. But planning is still not a match for Mother Nature. Rain along the ferry route postponed the September 17 departure date. Delayed for two days, the space shuttle Endeavour finally took to the air from the Kennedy Space Center for its final ferry flight and a trip to its new home atop the Boeing 747 SCA at 7:22 am EDT on September 19, 2012. It began a 3-day, 2-night trip that included a farewell tour to several NASA sites across the country and would end in Los Angeles, just 20 miles from the Downey plant where Endeavour was designed.

The first leg of the ferry flight included a series of 1500 foot flyovers above Florida's Space Coast, the Stennis Space Center near Bay St. Louis, Miss., and the Michoud Assembly Facility in New Orleans. The flight plan then took Endeavour over Houston, Clear Lake and Galveston before landing at Ellington Field near NASA's Johnson Space Center. On September 20, following a refueling stop at the El Paso's Biggs Army Airfield, the SCA did flyovers of the White Sands Test Facility and Missile Range in New Mexico and Tucson, Arizona before landing at EAFB to spend the night.

The last leg of Endeavour's journey began on the morning of September 21 at NASA's Dryden Flight Research Center at Edwards Air Force Base. The four-hour, 34-minute flight included low-level flybys over many California cities and

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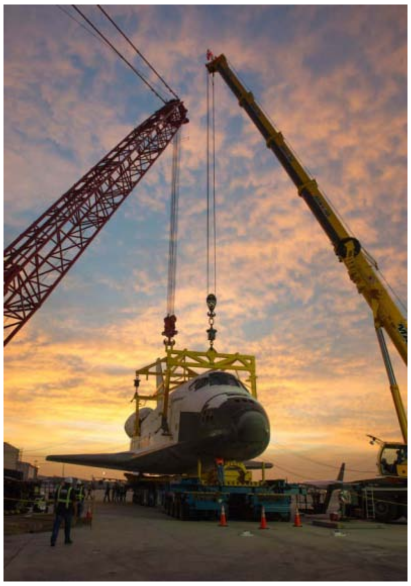
landmarks, several of which had direct ties to NASA's Space Shuttle Program. The 747, with Endeavour riding piggyback, left a memorable image as they passed over such landmarks as the State Capitol in Sacramento, the Golden Gate Bridge in San Francisco and NASA's Ames Research Center at Moffett Field north of San Jose. Finally, after passing by Vandenberg Air Force Base on the California coast, the SCA entered Los Angeles airspace. It made passes by Griffith Observatory, the Hollywood sign, Dodger Stadium, NASA's Jet Propulsion Laboratory, Malibu, Santa Monica, Disneyland, The Queen Mary, the USS Iowa, the Science Center, and several low-level flyovers over Los Angeles International Airport before touching down on Runway 25L at 12:51 p.m. PDT.

THE FINAL DEMATE PROCEDURE



Space shuttle Endeavour is secured to the Overland Transporter in the early morning hours of September 22, 2012, at Los Angeles International Airport. (Photo Credit: NASA/Paul E. Alers)

The next major milestone was to demate Endeavour from the SCA and place it on the Overland Transporter. The MDD device used at the KSC was a fixed structure and only two existed, the other being at EAFB. In the event the orbiter did not land at either KSC or EAFB, NASA developed a mobile lift system, consisting of two large cranes, a sling similar to the one used in the MDD and four stabilizing masts to prevent any lateral movement. The mobile system enabled the demating of the orbiter in about 10 hours.

Several weeks before the ferry flight, a NASA and USA team of 45 engineers and technicians headed to Los Angeles to prepare for the orbiter separation from the SCA. That included sending the mobile lift system, which was comprised of 20 truckloads of equipment. The separation began in the early morning hours of September 22, in an effort to minimize the noise disruption generated from landing and departing jet aircraft, which could have interfered with crew communication during the operation.

By midmorning, Endeavour had been demated, placed on the OT and moved into the United Airlines hangar to undergo additional preparations prior to its move to the Science Center. This would be the last time an orbiter would be demated from the SCA. And in a reminder of the stark finality of the close of the shuttle program after thirty years of operation, 135 flights and more than 530 million miles traveled in space, this was also the final mission of the SCA.

Shuttle Carrier N905NA, which flew 70 of the 87 operational ferry flights and all three of the ferry missions to deliver Discovery, Enterprise and Endeavour, was also being retired. Originally earmarked to serve as a spare part donor for NASA’s Stratospheric Observatory for Infrared Astronomy (SOFIA), NASA 905 is now slated to be on public display at NASA’s Johnson Space Center in Houston and share in Endeavour’s new role of preserving the shuttle legacy.

Workers prepare to remove the tail cone off of the space shuttle Endeavour in a hangar at Los Angeles International Airport, September 24, 2012. Photo (Credit: NASA/Bill Ingalls)

PREPARING FOR TRANSPORT AND DISPLAY

Inside the hangar, technicians had several major tasks to complete. The first was to remove Endeavour’s tail-cone, which was used on all ferry flights to reduce the aerodynamic drag and turbulence. With the tail-cone removed, technicians reconfigured Endeavour’s SSME nozzles to a launch mode. They had been gimbaled in a close-in configuration for the ferry flight. Also, reinstalled were the OMS pod replica nozzles to replace the originals, which had been removed for cleaning and decontamination. A final preparation included entering the crew compartment, as the technicians configured the flight deck and mid-deck for display. (Disclaimer: None of the orbiters on display will allow for entry into the crew compartment.)

An important decision made by the Science Center officials was to keep the landing gear retracted and have Endeavour displayed on the overland transporter. To house Endeavour, the Science Center constructed the Samuel

The space shuttle Endeavour, sitting on the Overland Transporter and the Self-Propelled Modular Transporter, moves out of the Los Angeles International Airport and onto the streets of Los Angeles. (Photo Credit: NASA/Carla Cioffi)

Oschin Space Shuttle Endeavour Display Pavilion. Once the move was completed to the Samuel Oschin Pavilion, the OT and Endeavour will rest on seismic isolation pedestals to protect against the threat of earthquakes. As curator Phillips noted, "This display is only temporary as we are planning for a new facility in 2017 that will enable us to display Endeavour in a launch mode, with the orbiter attached to solid rocket boosters and an external tank." For the future display, the Science Center will use real solid rocket boosters that are currently in storage at the Dryden Flight Research Center at EAFB and they will construct a replica external tank.

Phillips added, "We had to anticipate the equipment and strategy for five years . . . how do you handle the orbiter five years down the line without the NASA infrastructure and logistic support that existed to help with this move?" Having Endeavour's landing gear retracted would eliminate many future processes and the required support equipment, making it just a little easier to prepare for the complicated maneuvers that will be required to place the orbiter into a vertical position without NASA's assistance.

With the move to the Science Center set for October 12, a last minute requirement surfaced from city engineers. There was great concern that the combined weight of the orbiter, OT and the SPMTs, which was more than 300,000 pounds, might damage underground utilities. To better distribute the combined load, steel plates had to be placed on the most vulnerable parts of the roadway. The plates used were either 1 or 1 ½ inches thick and most were 8 feet by 10 feet. In all, they used about 2600 plates rented from almost every outlet on the west coast. This was just another preparation that had several key objectives: 1) Move the orbiter safely and securely, 2) Ensure the safety of the public, and 3) Protect the city infrastructure.

A NEW HOME AND MISSION: ANOTHER TWELVE MILES TO GO

After all of the preparations, Endeavour left the LAX security gate at 2:00 am PDT on October 12, and moved onto the city streets for its 12 mile journey to the new Samuel Oschin Pavilion. Accompanying the orbiter was a team of almost one hundred people that included several astronauts. Preceding Endeavour was an advance team who had responsibility for clearing obstacles. They removed light posts and traffic signals, trimmed trees and raised power lines in order to let Endeavour pass. More than 200 street fixtures were removed and 100 power lines were raised. Taking up the rear was another team that replaced the removed street fixtures and restored the thoroughfare to its original state.

Power lines are hoisted upwards by a crane in order to allow the space shuttle Endeavour to traverse on its path to the California Science Center, October 12, 2012 in Inglewood. (Photo Credit: NASA/Carla Cioffi)

The procession was designed to move no faster than 2 mph, but it was apparent from the start that this would be an intricate technical ballet. The SPMT operator using a remote controlled joystick, slowly moved the large spacecraft forward and performed numerous zigzags as the orbiter passed only inches from the roadway obstacles. An early challenge for the Shuttle Delivery Team was the Manchester Boulevard Bridge which passed over the 405 Freeway.

The California Department of Transportation would not allow the use of the SPMTs on the overpass. So the delivery team had to perform a delicate switch-over. Prior to reaching the overpass, a dolly was slipped between the SPMTs and then raised to lift and support the OT. The SPMTs were moved out of the way and the dolly was attached to a Toyota Tundra pick-up, which towed Endeavour across the overpass. It was only a 100 yard trip that took about 3 minutes, but the Tundra had gone through extensive practice sessions towing a 300,000 pound load and performed its task effortlessly. Once over the bridge, the process was reversed and the OT was placed back on the SPMTs to continue its journey to the Science Center.

A technician for the Overland Transporter signals how much room is available between a tree and the orbiter's wing, (Photo Credit: NASA/Carla Cioffi)

The original plan had Endeavour arriving at the Science Center on the evening of October 13. Built into the schedule were several public celebrations at the Inglewood Forum and at Crenshaw Plaza. But just as with the intricacies and unexpected occurrences of space travel, Endeavour encountered similar experiences on its street travels. The Shuttle Delivery Team had to slow the transport down multiple times as the orbiter zigzagged around several obstacles and conduct additional maintenance breaks to keep the SPMTs functioning perfectly. Finally, at about 2 pm PDT on October 14, about 15 hours later than scheduled, Endeavour reached its new home at the California Science Center's new Samuel Oschin Pavilion.

More than 1.5 million people viewed some portion of Endeavour's final journey through Los Angeles neighborhoods. It was a once in a lifetime event, made possible with more than a year of planning and through the hard work of hundreds of dedicated and highly skilled individuals. These individuals were representing the Science Center, NASA, USA, the cities of Inglewood and Los Angeles and more than twenty other companies.

Many donated time and resources to ensure that Endeavour's final journey was a safe one so that current and future generations can enjoy, learn and be inspired by the many contributions of the space shuttle program. The Samuel Oschin Pavilion opened on October 30, 2012, and the Space Shuttle Orbiter Endeavour is now on display. For the shuttle designers, the thousands of skilled individuals who took part in operating the shuttle program over thirty years, and all of those who contributed to Endeavour's final journey, they can be assured that its legacy will be preserved and cherished.

About the Author:

Guests walk around space shuttle Endeavour after the grand opening ceremony for the California Science Center's Samuel Oschin Space Shuttle Endeavour Display Pavilion. (Photo Credit: NASA/Bill Ingalls)

Burt Dicht is currently Director of IEEE University Programs where he is involved in engineering education accreditation activities and developing programs for faculty and students. During his career, Burt held engineering positions at NASA's KSC (Intern), Rockwell Space Transportation Systems Division and Northrop Grumman. He has worked on projects such as the F-5E Tiger II, the F20A Tigershark, the F-18E/F Super Hornet, the YF-23A Advanced Tactical Fighter and the Space Shuttle. Burt is a member of IEEE, AIAA, and an ASME Fellow. As a member of ASME, Burt was instrumental in having the Apollo Command/Service Module, the Apollo Lunar Module and the Voyager Spacecraft designated ASME Historic Mechanical Engineering Landmarks. Burt has published multiple articles on aerospace history and is a frequent guest speaker on aviation and space topics. He currently serves as a volunteer exhibit explainer for the Intrepid Sea, Air and Space Museum in New York City.

CHAPTER INDUCTIONS

IEEE-HKN Chapter (Lambda Xi) at Hofstra University

Alexander Milliken, Michael Lasher, Dr. Sleiman Ghorayeb (Advisor), Nicole Companion (Corresponding Secretary), Steven Prince (President), Navid Paknejad (Vice President), Arik Adhami (Treasurer), Jordan Smith, and Marissa Castoro.

The IEEE-HKN Chapter (Lambda Xi) at Hofstra University was founded on 5 December 2012 with a ceremony that included all of the members of the new Chapter. Under the guidance of faculty advisor Dr. Sleiman Ghorayeb, the Hofstra Chapter of IEEE-HKN looks poised to thrive. "The Hofstra Chapter is off to a great beginning, thanks in large part to Dr. Ghorayeb's excellent leadership," said Dr. John A. Orr, IEEE-HKN President. The installment of this new Chapter came alongside the newly established School of Engineering and Applied Sciences and recent ABET accreditation. In discussions with the students after the induction ceremony, Chapter President Steven Prince noted plans for instating an alumni contact database, archiving notes, textbooks, and other study materials for classes at Hofstra. There is even potential for founding a Senior Design funding account that could provide extra money to students for their engineering design projects, a pre-requisite for graduation at Hofstra. "This would be a huge draw for those talented students who are passionate about their work. When freshman students come see our Senior Design presentations, they'll see that IEEE-HKN funding sponsored many of the projects, and they will want to know how they can produce something of a similar caliber. We'll tell them to join IEEE-HKN" added Prince. In a supportive comment, Navid Paknejad (Chapter VP) said "We want this Chapter to serve a function for the students, not just to be a resume-padder." Hofstra is already making the news about the Presidential Debates, the School of Medicine, and now the new School of Engineering and Applied Sciences; IEEE-HKN will be a major force behind this movement.

IEEE-HKN President, John Orr presents the Charter to Steve Prince, President of the Lambda Xi Chapter.

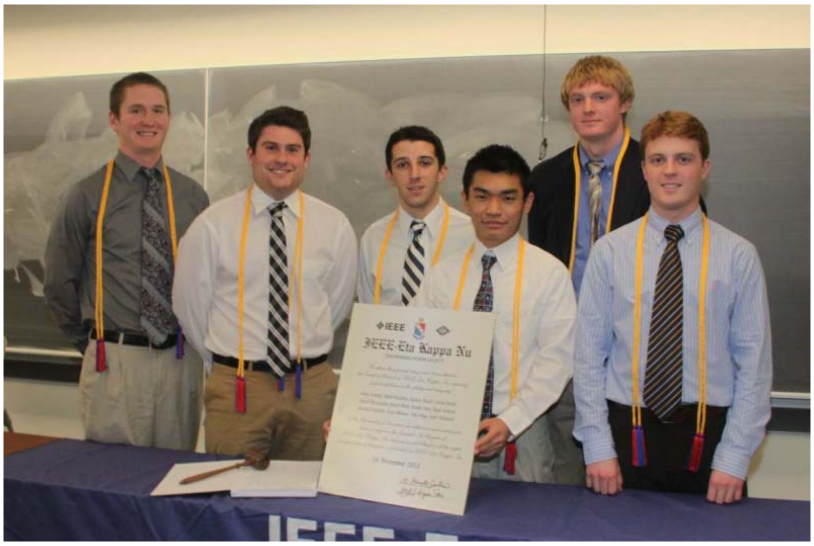

Lambda Xi Chapter members take the IEEE-HKN Pledge.

IEEE-HKN Chapter (Lambda Nu) at University of Scranton

On 28 November 2012, the Lambda Nu Chapter of IEEE-Eta Kappa Nu was installed at the University of Scranton. The induction ceremony was held in the University's new Loyola Science Center. In attendance were Lambda Nu's sixteen charter members, Dr. Harold W. Baillie, the Provost and Senior Vice President of Academic Affairs, and Dr. Brian Conniff, the Dean of the College of Arts and Sciences. Lambda Nu's Charter members are composed of twelve students and four faculty members. The faculty advisors for this Chapter are Dr. Christine Zakzewski and Dr. W. Andrew Berger. The induction ceremony was led by Dr. W. Kenneth Jenkins, a member of the IEEE-Eta Kappa Nu Board of Governors, and Nancy Ostin, IEEE-HKN's Director. The ceremony concluded with a dinner for those present in the atrium of the science center.

University of Scranton - Lambda Nu Chapter Installation and Induction 28 November 2012.
All new inductees sign the Chapter Signature Book, the official record of each Chapter.

Joshua Javitz, President IEEE-HKN of the Lambda Nu Chapter signs the Signature Book.



University of Scranton student officers:
Kerry Williams, Pat McLaughlin, Josh Javitz, Ardy Wong, Ryan Robeson, and Walter Checefsky.

The Mission and Engineering Challenges of the James Webb Space Telescope

Sunshield template. Image Credit: NASA

By Jonathan Arenberg

The James Webb Space Telescope (JWST) is NASA's flagship astrophysics mission for the next decade. I am with Northrop Grumman, a key member of the worldwide team designing, building, testing, and ultimately delivering the world's next-generation space observatory. As engineers, we face some great challenges in making JWST happen. To achieve this goal, we must understand JWST's mission, its design, and the technical challenges it presents.

The Mission of JWST

JWST's primary scientific goal is to see the very first luminous objects in the history of the universe — namely to see the earliest stars and galaxies that formed within the first few hundred million years after the Big Bang, when the universe was only a few percent of its current age. Prior to this epoch, the universe was either ionized plasma and opaque, or after recombination, the primordial hydrogen had not collapsed to form the first stars. These objects are over 13 billion years old and are receding from us at a high velocity, red shifting their ultraviolet and visible radiation into the infrared.

In addition to the detection of first light, JWST is also intended to achieve other scientific objectives. JWST will study the formation and evolution of galaxies throughout the universe. Its intra-galactic objectives include the study of star formation, extra-solar planets, and objects within our own solar system. To achieve these scientific goals, JWST must be a highly sensitive, stable, and large infrared observatory, capable of pointing anywhere in the sky, Figure 1.

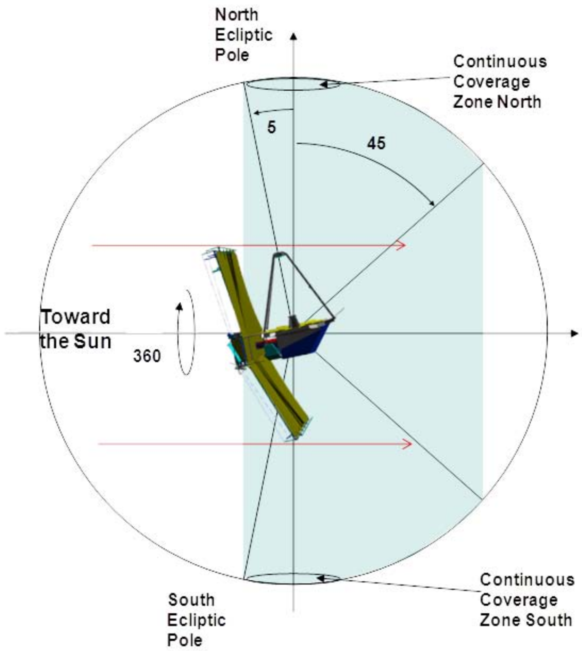


Figure 1. JWST's sunshield allows it to pitch 5 degrees forward and 45 degrees backward, and 360 degrees around the sun line. JWST sees ~39%. Image Credit: NASA

The team designing, building, testing, and delivering JWST is an international one from government, academia and industry. JWST team members are located in the United States, Canada and throughout Europe. NASA is partnered with the Canadian and European Space Agencies to make JWST a reality.

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JWST's Mission Architecture

JWST is designed to be a highly efficient, long-lived scientific resource. JWST will operate 1,000,000 miles away from Earth, orbiting in the Second Lagrange point or L2, Figure 2. This will enable JWST to have an orbit that is free from the destabilizing influence of the Earth's radiated heat, eclipses and blockage of the observable sky. However, this location is close enough to allow high-rate communication without excessive commitment of mass. JWST will achieve this orbit by a direct injection trajectory, similar to that used on the European Space Agency's (ESA) Herschel/Planck mission. This orbit is affected by the gravity of the Earth in such a way that even though JWST is 94,000,000 miles from the sun, it completes its annual revolution in approximately one year. This means that the Earth is in approximately the same position at all times throughout the mission, facilitating command and communication.

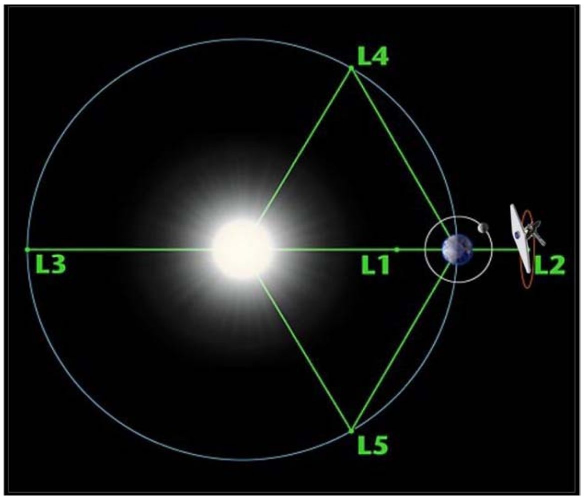

Figure 2. Lagrange points and JWST's orbit. Image Credit: NASA

The Design of JWST

JWST consists of three segments. The first, the flight segment, contains the optical telescope element, the sunshield, a spacecraft bus and the integrated science instrument module, Figure 3. The second segment is launch and is provided by ESA in the form of the Ariane V launch vehicle. The third segment is the ground segment, which will process the scientific proposals, generate commands for the flight segment, control spacecraft operations and archive and disseminate scientific data. The operations of JWST will be controlled through the Space Telescope Science Institute, just as the Hubble telescope is operated and its data are managed.

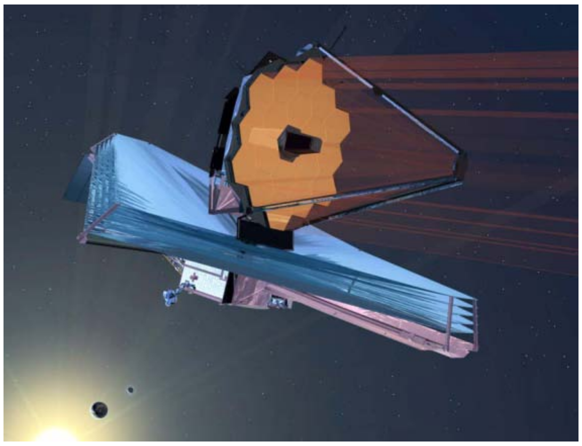

Figure 3. Artists rendition of deployed JWST. Image Credit: Northrop Grumman Aerospace Systems

The optical telescope element collects and focuses the light from the target down into the science instruments. The optical system consists of beryllium mirrors coated with a protected gold coating to enhance their infra-red reflectivity, Figure 4 shows six of the mirrors ready for test. The primary mirror consists of 18 hexagonal mirror elements each individually actuated in seven degrees of, three in translation, three in rotation, and one to alter the radius of curvature (if required). The secondary mirror is also made of beryllium and is also actuated in six degrees of freedom. The light is then directed to the tertiary mirror, the only fixed mirror in the optical train, and is then sent to the fine-steering mirror, which directs the light into the instruments. The mirrors have all completed manufacture and coating, and are being delivered to NASA's Goddard Space Flight Center (GSFC) for storage prior to integration. Ball Aerospace in Boulder, Colorado has led the efforts to manufacture the mirrors, actuators and control system, with major subcontractors Axsys, Tinsley Laboratories and Quantum Coating.

Figure 4. Six Primary Mirror Segment Assemblies ready for test a Marshall Space Flight Center, Huntsville, AL. Image Credit: NASA

The optical elements are held in their proper places by a high-performance structure. This high-

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performance structure, designed and built by ATK in Magna Utah, is primarily a graphite composite construction. It must be dimensionally stable to the order of nanometers per Kelvin.

The Integrated Science Instrument Module (ISIM), made by NASA's Goddard Space Flight Center, consists of a structure, international instruments, command and data handling systems, and electronics necessary to operate the instruments. JWST's suite of instruments comes from the United States, Canada, and Europe. The Near Infrared Camera, NIRCam, is provided by the University of Arizona with main industrial partner Lockheed Martin, and is the workhorse shortwave imager and wavefront sensing instrument. The Fine Guidance Sensor and Near Infrared Imaging Slitless Spectrometer, FGS/NIRISS, provided by the Canadian Space Agency, is the instrument that allows JWST to achieve its exquisite pointing performance and also offers science capability. The Near Infrared Spectrograph, NIRSpec, is provided by the European Space Agency with main industrial partner EADS. This instrument allows JWST to take hundreds of spectra in a single field, necessary for separating objects by red shift. The final instrument, the Mid-Infrared Imager, MIRI, is the only actively cooled instrument on JWST. MIRI provides the longwave, 5-27+ µm, capability for JWST, both as an imager and spectrometer. MIRI's focal plane is actively cooled using a cryo cooler provided by the Jet Propulsion Laboratory (JPL) through a contract with Northrop Grumman Aerospace Systems. The ISIM is beginning flight integration with its graphite composite structure completed and the initial flight instruments delivered.

Figure 5. Northrop Grumman Lead Venting Analyst Dan McGregor with a sunshield test article as it is placed in the vacuum chamber at Aerospace Systems' test facility in Redondo Beach, CA. Image Credit: Northrop Grumman Aerospace Systems

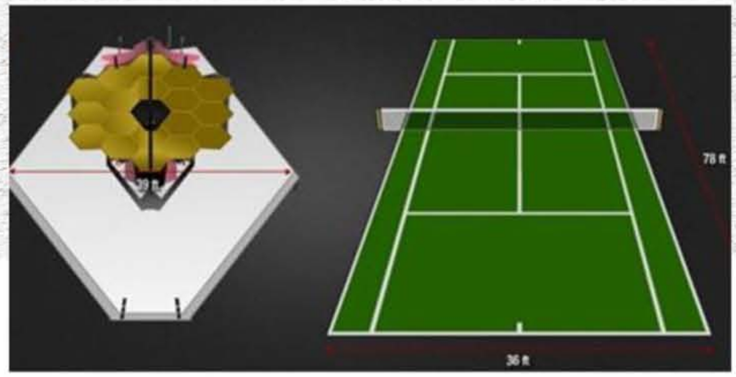

Figure 6. JWST sunshield and a doubles tennis court. Image Credit: NASA

The sunshield enables the mission of JWST by casting a deep, dark shadow in which the telescope lives, allowing it to radiate its heat to space and achieve the necessary cryogenic temperatures passively. For the sunshield to provide the necessary thermal attenuation of the approximately 200,000 W incident on its sunward facing surface, five precisely shaped membranes are used. These membranes must be stowed and restrained during the turbulence of launch, and subsequent depressurization to allow for deployment. The sunshield is approximately the size of a doubles tennis court, Figure 6.

The sunshield has been tested to demonstrate its thermal performance using a one-third scale model that is over 22 feet in length and 12 feet in width. In this test, solar simulators for incident on the sunward side and the temperatures of the membranes facing the telescope were measured and compared to prediction. This test validated thermal analyses and showed that the design of the JWST sunshield will meet requirements.

Learning how to stow and deploy the membranes is a major effort requiring technological extremes. The finite element models that predict the shape of the membranes under tension are highly complicated, containing many hundred thousand degree of freedom models that press the state of the computational art. Determining the location of the holes that are used as part of the restraints to manage the membranes through launch is done using full-scale models. The holes must line up when stowed, but they cannot line up when deployed for control of stray light and thermal management. This kind of analysis is not easily done using current computer based tools, so full scale mock-ups are needed.

In order to ensure that the membrane manufacturing processes account for handling and integration processes, a set of template membranes are being manufactured by membrane contractor Nexolve at their facility in Huntsville, Alabama. To date, three of the five template membranes have been completed. The sunshield structure — the large pallets that deploy forward and aft and contain the membranes for launch

— are being designed and manufactured by Northrop Grumman. The mid-booms that push the membranes out from the sides of the spacecraft are being manufactured by Astro Aerospace, a Northrop Grumman subsidiary, located in Carpinteria, California.

The last element is the spacecraft bus, which is beginning the final design phase ahead of its planned critical design review at the end of 2013. The spacecraft bus houses the traditional spacecraft subsystems, such as propulsion, electrical power, command and data handling and attitude control. It also contains the room-temperature electronics and compressors for the MIRI cryo cooler. The spacecraft has all of the usual challenges when designing a high performance spacecraft, including the need to be mass efficient, stable and easy to manufacture. The JWST bus has the additional challenge that there is no "cold side" that can dump heat. The sunshield and temperature-sensitive telescope and instruments prevent radiation of the heat toward the cold side of the observatory, and furthermore, the sunshield directs a large infrared load onto the spacecraft. The spacecraft is making excellent progress toward its planned review, and is being designed and manufactured by Northrop Grumman Aerospace Systems.

To build and test these extremely large flight systems requires similarly large and complex ground support and test equipment. The program is also making excellent progress in these critical areas. The support equipment to assemble the optical telescope in the clean room at GSFC has been built and delivered, see www.jwst.nasa.gov/webcam.html. The ambient optical assembly stand weighs over 140,000 pounds. Additionally, the robot arms that will be used to precisely install the primary mirror segment assemblies and the secondary mirror have been developed and are currently being tested. Both the assembly stand and robot arms are being designed and built by ITT Excelis of Rochester, New York. JWST is also planning a system-level test in vacuum at cryogenic temperatures, where light will go through the entire optical system to assure proper assembly and workmanship. This test will take place at Johnson Space Center (JSC) in Houston, Texas in historic Chamber A, the location of the Apollo environmental tests, Figure 7.

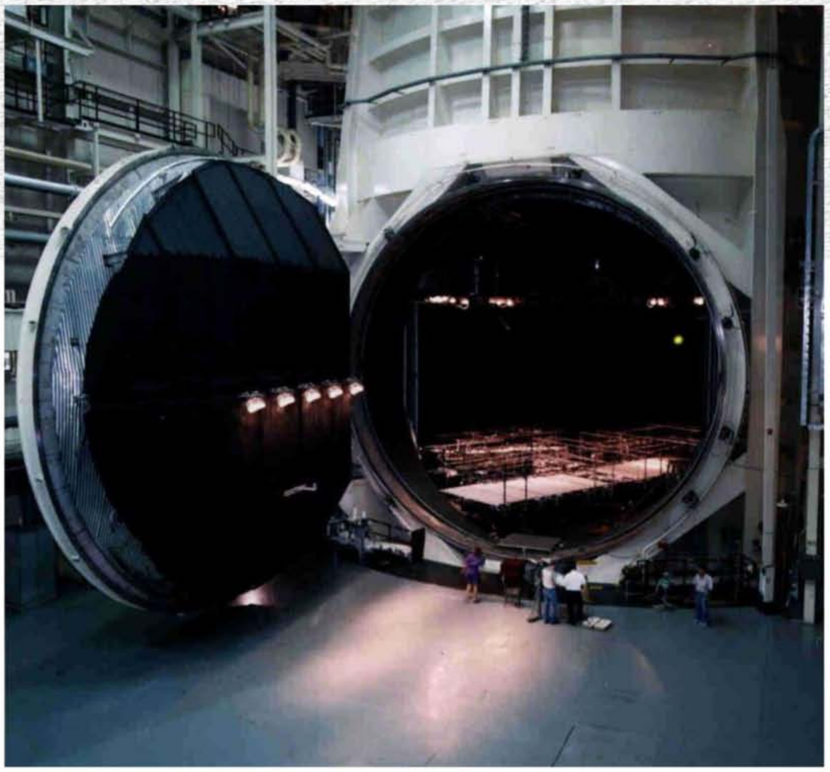

Figure 7. Chamber A with door open, note people at bottom of door for scale. Image Credit: NASA

Bringing Chamber A up to date and making it a modern, clean cryogenic optical test facility is being undertaken by a team at JSC. All of the 1960s era equipment in the chamber has been removed, the air handling pipes and manifolds have been cleaned and coated consistent with clean room operations, and the two-stage cryogenic shrouds have been installed. The renovated Chamber A passed its first vacuum and cryogenic temperature tests earlier this year.

JWST is a complex mission with challenges for every engineer on the program, and promises to return ground breaking science. The JWST team is extraordinarily capable and is making excellent technical progress. The entire team is focused on mission success and looking forward to launch in late 2018.

About the Author:

Jonathan Arenberg has been with Northrop Grumman Aerospace Systems since 1989, having started with Hughes Aircraft Company. His work experience includes optical, space and laser systems. Dr. Arenberg has worked on such astronomical programs as the Chandra X-ray Observatory, James Webb Space Telescope, and helped develop the New Worlds Observer concept for the imaging of extra-solar planets. He has worked on major high-energy and tactical laser systems, laser component engineering and metrology issues. He is a member of the ISO sub-committee charged with writing standards for laser and electro-optic systems and components, SPIE, American Astronomical Society, and AIAA. Dr. Arenberg holds a BS in physics and an MS and PhD in engineering, all from the University of California, Los Angeles. He is the author of many conference presentations and publications, and holds one European and 11 U.S. Patents in a wide variety of areas of science and technology. He is currently the Chief Engineer for the James Webb Space Telescope Program (www.jwst.nasa.gov) and is a Charter Member of the Iota Gamma Chapter of Eta Kappa Nu.

BOARD OF GOVERNORS

Welcome to our new members of the IEEE-HKN Board of Governors

Volunteers play an indispensable role in setting the direction and vision of our organization. The dedicated members of the IEEE-HKN Board of Governors give of their time, talents and are our most generous supporters. We welcome three new members in 2013, Evelyn Hirt as our Vice-President, Tim Kurzweg as Governor-at-Large and David Jiles as Governor-at-Large, West Central Region. There are opportunities to work on a Board level committee, or an ad hoc such as strategic planning and communications and membership committees. Open to students and professionals, contact info@hkn.org to learn more about these and other ways to be involved.

Evelyn H. Hirt

Evelyn H. Hirt

Evelyn H. Hirt is Principal Engineer, Operational Systems Directorate, at the Pacific Northwest National Laboratory, which is operated by Battelle, for the U.S. Department of Energy. For over 38 years, Ms. Hirt's career has focused on the expert delivery of technology-based solutions to address customer needs. She has a Bachelor of Electrical Engineering, cum laude, from the University of Detroit, and both a Masters in Engineering Management and a Certificate in Project Management from Washington State University. Her 35-year career in engineering is multidisciplinary, however, her interests center on systems and controls, and engineering management. Her multi-disciplinary career in engineering has provided employment and professional experiences that bridge the industrial, government, and academic communities, as well as leadership positions in professional technical societies and service organizations. She has advanced from the engineering ranks into risk-based project and team management. "At a time when few women were in the engineering profession and were not always well received, my induction into the Beta Sigma Chapter of Eta Kappa Nu gave me confidence in my future role in the engineering profession." Her honors include listings in ten "Who's Who" directories, membership in Eta Kappa Nu, and thirteen outstanding performance awards while working for three different employers. She has published works in the application of laser ablation, test program requirements management, fault-tree-generation methodology, and time dissemination using the Global Positioning System (GPS). She has been a technical contributor and has had responsibilities for staff, technical, and day-to-day operations as well as project/program management. Ms. Hirt currently serves as the Vice President of IEEE-HKN, and is a member of six IEEE societies as well as IEEE Women in Engineering, Order of the Engineer, National Society of Professional Engineers (NSPE), and the International Council on Systems Engineering (INCOSE). In July 2007, she began a three-year term as the Member-at-Large on the Board of Governors of Eta Kappa Nu (HKN), the Electrical and Computer Engineering Honor Society.

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David C. Jiles

David C. Jiles

David C. Jiles is the Palmer Departmental Chair in Electrical and Computer Engineering (ECpE) and Anson Marston Distinguished Professor at Iowa State University. Previously, he was the director of the Wolfson Centre for Magnetics and Professor of Magnetics at Cardiff University in the United Kingdom. His research interests include nonlinear and hysteretic behavior of magnetic materials; magnetoelasticity, magnetostriction, and magnetomechanical effects; development of novel magnetic materials; and applications of magnetic measurements to nondestructive evaluation. He has authored more than 550 scientific papers, has published three books, and holds 19 patents. He has served as editor-in-chief of *IEEE Transactions on Magnetics* since 2005. He is a Fellow of the APS, IEEE, and the Magnetics Society in the U.S. He is also a Fellow at IET (Formally IEE), Institute of Physics, Institute of Materials, and Institute of Mathematics and its Applications in the UK. He was educated in the United Kingdom and earned a DSc from the University of Birmingham, PhD from the University of Hull, MSc from the University of Birmingham, and BSc from the University of Exeter. In the fall of 2011, David became an honorary member of IEEE-HKN, and was given the opportunity to serve as a Governor on the Board. A key goal in the strategic plan of the ECpE Department is to not only emphasize fundamental engineering principles in educating our students, but also to encourage and facilitate the development of leadership and supporting skills. With the importance of preparing well-rounded students at Iowa State University for a career in engineering, it was a natural decision to participate in this organization to serve as an example of both leadership and service. “Engineers, of course, need a solid base of understanding of engineering principles. This provides them with the foundation on which they can build their careers. But they also need leadership skills. I feel that we as faculty have a responsibility to provide good role models to engineering students through IEEE-HKN, an organization that exemplifies leadership.”

Timothy Kurzweg

Timothy Kurzweg

Timothy Kurzweg is an Associate Professor in the Electrical and Computer Engineering Department at Drexel University, Philadelphia, PA. He obtained his BS degree from Penn State University and MS and PhD from the University of Pittsburgh. He joined Drexel in 2002, and was appointed the Assistant Department Head of Undergraduate Affairs in 2010, as well as Assistant Dean in the College of Engineering, and Director of the Bachelor of Science in Engineering Program. He is the recipient of the 2011 C. Holmes MacDonald Outstanding Teacher Award from IEEE-HKN, and the Drexel University Christian R. and Mary F. Lindback Award for Distinguished Teaching in 2009. In 2009, he co-founded MetaTenna LLC, a startup that spun out of funded research at Drexel in transparent, flexible antennas . His technical interests are in the area of micro-optical systems for biological sensing, communication, and imaging. Kurzweg is the IEEE Region 2 Director-Elect in 2013-14, and will serve as Region 2 Director in 2015-16. Dr. Kurzweg accepted membership into Eta Kappa Nu in 1994 with the Epsilon Chapter as an undergraduate Electrical Engineering student at Penn State University. Since 2005, he has been the Faculty Advisor of the Beta Alpha Chapter at Drexel University. “My favorite memory of HKN is becoming the faculty advisor of an organization that had four (yes, 4!) members. We were able to grow our HKN Chapter to where we were inducting approximately 50 students a year. I have personally seen the ebb and flow of membership and popularity of our honor organization. We need to encourage our students, faculty, and industry leaders to become IEEE-HKN members and get involved!“

IEEE-HKN PRESENTS AWARDS

Outstanding Chapter Award

Presented March 2013

Congratulations to a record-breaking twenty-four Outstanding Chapter Award winners for the 2011-2012 academic year. The awards are determined by a calculation of service hours, recruiting and retention efforts, and the overall report score. Chapters are required to file the Annual Chapter Report by 30 June of the same academic year. Outstanding Chapter Award submissions are accepted by 15 October for the preceding academic year.

2011-2012 OUTSTANDING CHAPTER AWARD RECIPIENTS:

Alpha	**University of Illinois at Urbana-Champaign**
Beta	**Purdue University**
Beta Kappa	**Kansas State University**
Beta Mu	**Georgia Institute of Technology**
Beta Tau	**Northwestern University**
Beta Theta	**Massachusetts Institute of Technology**
Delta Omega	**University of Hawaii, Manoa**
Epsilon Beta	**Arizona State University**
Epsilon Kappa	**University of Miami**
Epsilon Sigma	**University of Florida**
Gamma Chi	**New Mexico State University**
Gamma Mu	**Texas A&M University**
Gamma Rho	**South Dakota State University**
Gamma Theta	**Missouri University of Science and Technology**
Gamma Xi	**University of Maryland, College Park**
Iota Gamma	**University of California - Los Angeles**
Lambda Eta	**Bharati Vidyaeeth's College of Engineering**
Mu	**University of California - Berkeley**
Nu	**Iowa State University**
Psi	**University of Texas at Austin**
Sigma	**Carnegie Mellon University**
Theta Mu	**Stony Brook University**
Theta Tau	**University of Michigan - Dearborn**

IEEE-HKN HISTORY SPOTLIGHT

ROGER IVAN WILKINSON, NU '24 AWARD FOUNDER

Roger Ivan Wilkinson (1903 - 1985)

Roger Wilkinson graduated with honors in electrical engineering from Iowa State University in 1924. There he was elected a member of Eta Kappa Nu, Tau Beta, Pi, Phi Kappa Phi, and Pi Mu Epsilon. At graduation he joined Northwestern Bell Telephone Co., and later the Department of Development and Research for AT&T. In 1934 he joined Bell Laboratories. During World War II he was a consultant to the War Department and earned the Presidential Medal of Merit for his studies of radar under combat conditions. He was elected a Fellow of the IEEE "for contributions to the application of probability and statistics in the engineering of communications systems." Roger was presented the Eta Kappa Nu Distinguished Service Award for his years of dedicated contributions to the society. He will be remembered for his unique legacy -- the Eta Kappa Nu Outstanding Young Electrical Engineer Award.

CHAPTER MANAGEMENT NEWS

New On-line Forms

There are new on-line forms for Chapter management, they are:

- Annual Chapter Report — now due 30 June
- New Member Requisition — for each Induction
- Notice of Election of Officers — due upon election
- New Pledge Form — optional
- Order Stoles & Cords — order early!!

These new forms can be completed and paid with a credit card completely online; eliminating the need to attach documents or send separate spreadsheets. If you are paying with a check, please submit online and then print and mail the form to IEEE-HKN Headquarters with your check. You can attach additional documents if necessary, such as letters of support for graduate students, or to induct a professional into your Chapter.

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Note: Submissions for the Outstanding Chapter Award will be accepted until 15 October. Please submit your Annual Chapter Report by 30 June.

The Universe in a Supercomputer

To understand the cosmos, we must evolve it all over again.

By Joel R. Primack

When it comes to reconstructing the past, you might think that astrophysicists have it easy. After all, the sky is awash with evidence. For most of the universe's history, space has been largely transparent, so much so that light emitted by distant galaxies can travel for billions of years before finally reaching Earth. It might seem that all researchers have to do to find out what the universe looked like, say, 10 billion years ago is to build a telescope sensitive enough to pick up that ancient light.

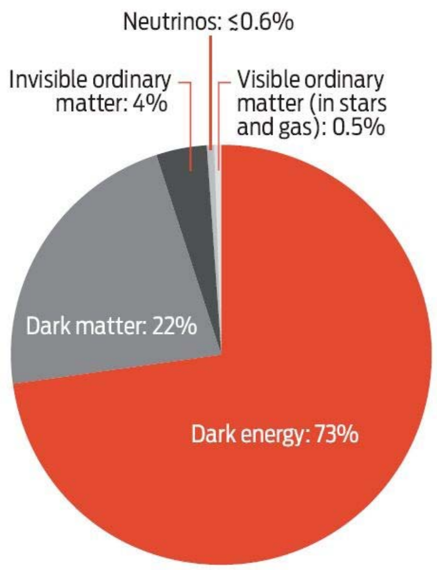
Actually, it's more complicated than that. Most of the ordinary matter in the universe — the stuff that makes up all the atoms, stars, and galaxies astronomers can see — is invisible, either sprinkled throughout intergalactic space in tenuous forms that emit and absorb little light or else swaddled inside galaxies in murky clouds of dust and gas. When astronomers look out into the night sky with their most powerful telescopes, they can see no more than about 10 percent of the ordinary matter that's out there.

To make matters worse, cosmologists have discovered that if you add up all the mass and energy in the universe, only a small fraction is composed of ordinary matter. A good 95 percent of the cosmos is made up of two very different kinds of invisible and as-yet-unidentified stuff that is "dark," meaning that it emits and absorbs no light at all. One of these mysterious components, called dark matter, seems immune to all fundamental forces except gravity and perhaps the weak interaction, which is responsible for some forms of radioactivity. We know dark matter must exist because it helps bind rapidly moving stars to their host galaxies and rapidly moving galaxies to even larger galaxy clusters. The other component is "dark energy," which seems to be pushing the universe apart at an ever-increasing rate.

To identify these strange dark substances, cosmologists require more than just the evidence collected by telescopes. We need theoretical models of how the universe evolved and a way to test those models. Fortunately, thanks to progress in supercomputing, it's now possible to simulate the entire evolution of the universe numerically. The results of these computational experiments have already been transformative, and they're still only in their early days.

My colleagues and I recently completed one such simulation, which we dubbed Bolshoi, the Russian word for "great" or "grand." We started Bolshoi in a state that matched what the universe was like some 13.7 billion years ago, not long after the big bang, and simulated the evolution of dark matter and dark energy all the way up to the present day. We did that using 14 000 central processing units (CPUs) on

MOSTLY DARK: If you add up all the matter and energy in the universe, you'd find little that is familiar. The stars and gas that astronomers see in their telescopes make up just 0.5 percent of the cosmos. Just 0.01 percent of the universe is made of elements heavier than hydrogen or helium. Because of uncertainties, the numbers in this chart do not add up to 100 percent.



the Pleiades machine at NASA's Ames Research Center, in Moffett Field, California, the space agency's largest and fastest supercomputer.

Bolshoi isn't the first large-scale simulation of the universe, but it's the first to rival the extraordinary precision of modern astrophysical observations. And the simulated universe it produces matches up surprisingly well with the real universe. We expect Bolshoi's computer-generated history of the cosmos to improve the understanding of how the Milky Way (the galaxy we live in) and other galaxies formed. If we're lucky, it might just reveal crucial clues to the nature of the mysterious dark entities that have steered the evolution of the universe and continue to guide its fate.

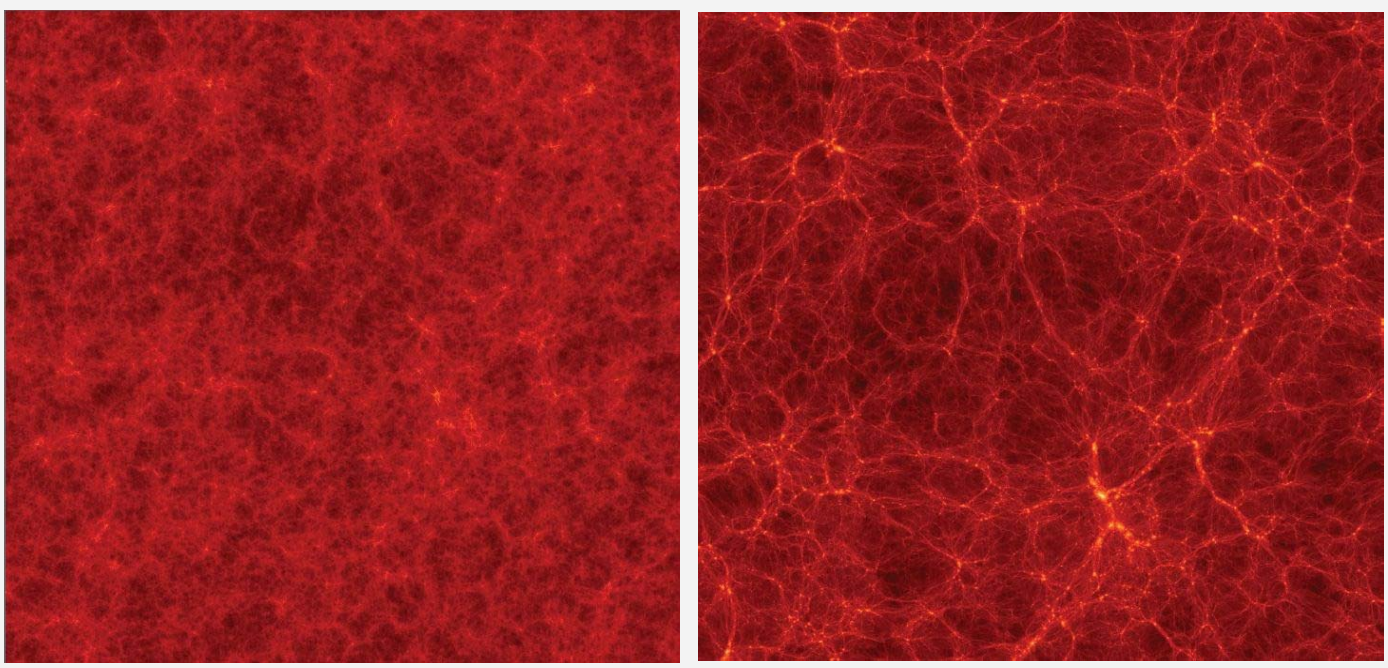
Cosmology took a dramatic turn in 1998. That's when two teams, both studying light from past stellar explosions, showed that the universe isn't expanding as expected. Astronomers have been aware of the overall expansion of the universe for many decades, but most figured that this expansion must either be slowing or coasting along at a steady rate. So they were astonished to discover that the cosmos has, in fact, been expanding faster and faster for the past 5 billion years, pushed apart by a mysterious pressure that pervades space.

Although nobody knows what the dark energy that creates this pressure is, its discovery has actually been a boon for cosmology. It helped clear up a lot of old contradictions, including indications that some of the stars in our galaxy were older than the universe itself.

Nowadays, cosmologists have settled on a basic picture of a universe — one that's still full of mysteries but is at least quite self-consistent. The universe is about 13.7 billion years old and dominated by dark stuff: roughly 22 percent dark matter and 73 percent dark energy. Although dark energy strongly shapes the universe today, dark matter was more influential early on. It clumped up, producing a weblike scaffold that drew in ordinary matter and enabled the formation of all the galaxies as well as larger structures, including the galaxy groups and clusters we see today.

Telescopes on the ground and in space, like NASA's Wilkinson Microwave Anisotropy Probe (WMAP), launched in 2001, provided key evidence for developing this basic understanding of the universe. But cosmologists couldn't have arrived there without computer simulations to verify their interpretation of what they were seeing.

The most influential such simulation so far has been the Millennium Run, which was developed by a team led by Volker Springel, who is now at the University of Heidelberg. Completed in 2005, the



Cosmic Web: The Bolshoi simulation models the evolution of dark matter, which is responsible for the large-scale structure of the universe. Here, snapshots from the simulation show the dark matter distribution at 500 million and 2.2 billion years [left] and 6 billion and 13.7 billion years [right] after the big bang. These images are 50-million-light-year-thick slices of a cube of simulated universe that today would measure roughly 1 billion light-years on a side and encompass about 100 galaxy clusters.

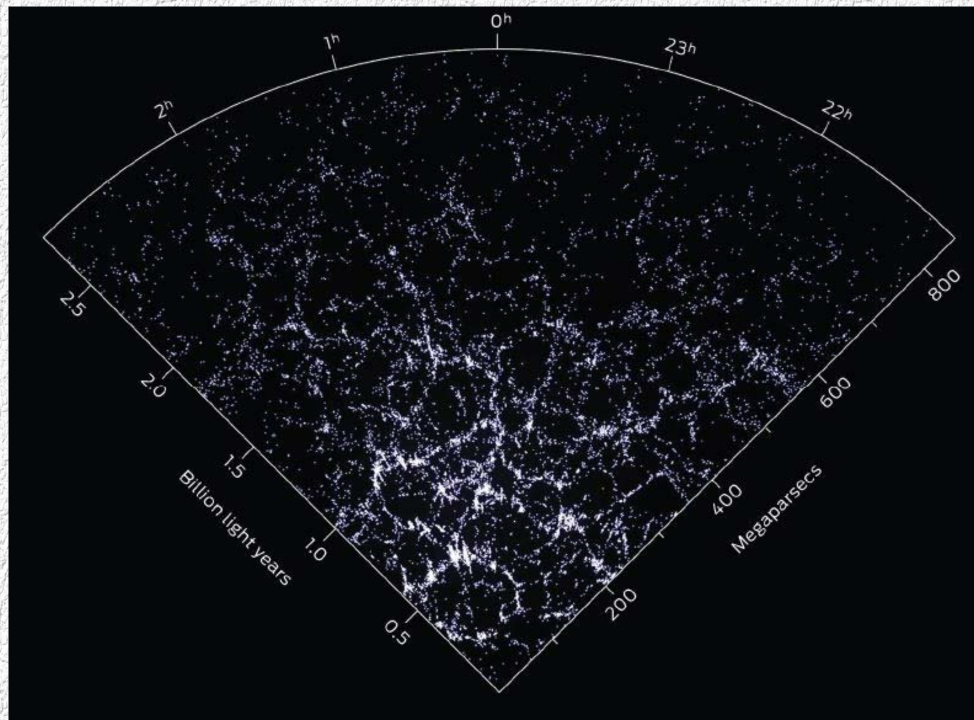
Sources: Simulation, Anatoly Klypin and Joel R. Primack; visualization, Stefan Gottlöber/Leibniz Institute for Astrophysics Potsdam

Millennium simulation was the first to be big enough and detailed enough to model the evolution of an entire population of galaxies from their birth, 70 million or so years after the big bang, up to the present day. (Galaxies are the tracer particles in cosmological simulations. By comparing the simulated population with astronomical observations, cosmologists can see how well their models of the universe match reality.)

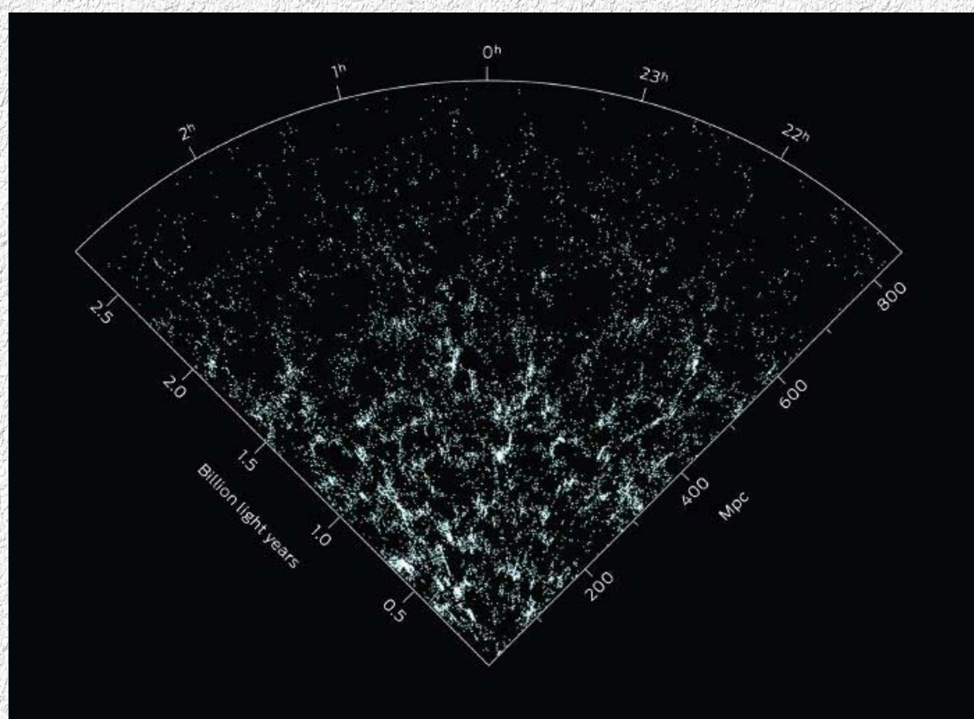
The Millennium simulation was a big step forward, and it's been the basis for more than 400 research papers. But that simulation had a few nagging shortcomings. For one thing, Millennium — as well as a later, smaller, but higher-resolution simulation called Millennium II — used very early WMAP results. Released in 2003, those data were from the first year of the telescope's operation, and they weren't very precise. As a result, the Millennium simulation made some predictions about galaxy populations that don't match very well with observations. What's more, although Millennium II had enough resolution to model the dark matter component of smaller galaxies (like the Milky Way's nearby companion, the Large Magellanic Cloud), it didn't simulate a large enough volume of space to enable precise predictions about the statistics of such satellite galaxies.

To help remedy this situation, my team at the University of California, Santa Cruz, partnered with Anatoly Klypin's group at New Mexico State University, in Las Cruces. Our aim was to improve on Millennium's size and resolution and to

Sloan Digital Sky Survey



Bolshoi Simulation



LARGE-SCALE STRUCTURE: These wedges show the distribution of galaxies in a slice of the sky. Because the speed of light is finite, looking deeper into the sky shows objects that are older and farther away. Here, telescope observations made by the Sloan Digital Sky Survey are compared with the distribution of galaxies calculated based on the Bolshoi dark matter simulation. They show a good match statistically.

Sources: Nina McCurdy/Un iversity of California, Santa Cruz; Ralf Kaehler and Risa Wechsler/ Stanford University; Sloan Digital Sky Survey; michael busha/University of Zurich incorporate the very best knowledge of key cosmological parameters, derived in part from the latest WMAP results.

To simulate the universe inside a computer, you have to know where to start. Fortunately, cosmologists have a pretty good idea of what the universe's first moments were like. There's good reason to believe that for an outrageously brief period — lasting far less than 10^{-30} second, a thousandth of a trillionth of a femtosecond — the universe ballooned exponentially, taking what were then minute quantum variations in the density of matter and energy and inflating them tremendously in size. According to this theory of "cosmic inflation," tiny fluctuations in the distribution of dark matter eventually spawned all the galaxies.

It turns out that reconstructing the early growth phase of these fluctuations — up to about 30 million years after the big bang — demands nothing more than a laptop computer. That's because the early universe was extremely uniform, the differences in density from place to place amounting to no more than a few thousandths of a percent.

Over time, gravity magnified these subtle density differences. Dark matter particles were attracted to one another, and regions with slightly higher density expanded more slowly than average, while regions of lower density expanded more rapidly. Astrophysicists can model the growth of density fluctuations at these early times easily enough using simple linear equations to approximate the relevant gravitational effects.

The Bolshoi simulation kicks in before the gravitational interactions in this increasingly lumpy universe start to show nonlinear effects. My colleagues and I began by dividing up a cubical volume of the simulated universe into a uniform, three dimensional grid, with 2048 lines running in each direction. We placed a simulated dark matter particle at each of the resulting 8.6 billion grid-line intersections.

In the real universe, there are likely to be far more dark matter particles than in a single cubic kilometer of space. But using a realistic number would overwhelm even the largest supercomputer. So we used this relatively small set, setting the mass of each simulated particle quite high so that it represents a huge amount of matter. We found that we could get pretty good results using these ultramassive placeholders, each set to about 100 million times the mass of the sun, about a hundredth of a percent of the total mass of dark matter in the Milky Way. After laying out one of these particles at each grid point, we shifted each starting location slightly to match our theoretical estimate of the primordial density fluctuations in the early universe.

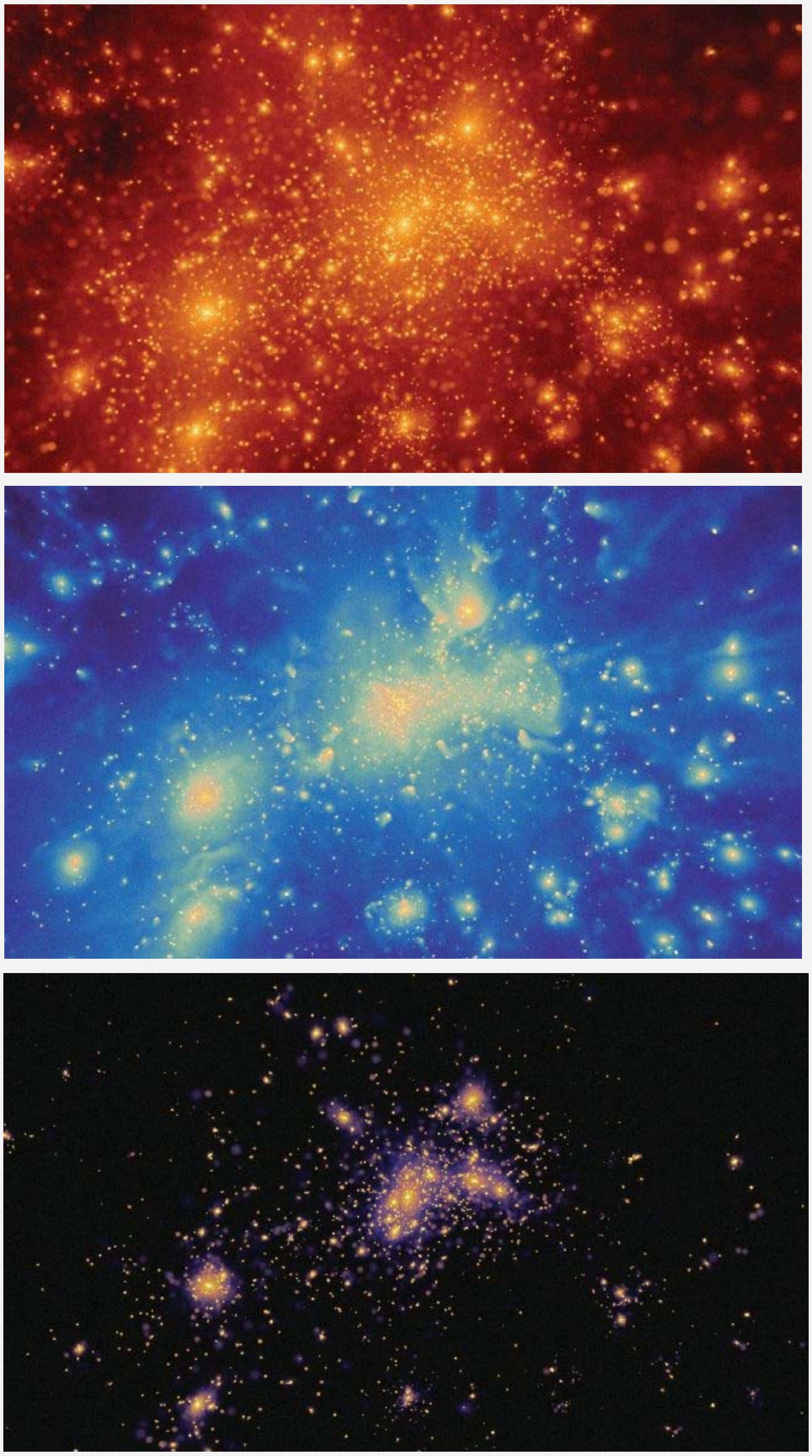
Because our simulation was supposed to model boundary-less space and not a walled patch of universe, we followed the convention that's used in many video games, including that old classic Asteroids, where if a player's ship goes off the right edge, for example, it reemerges from the left side. In this way, we made our simulation represent a random, borderless chunk of the universe.

The last thing we did before setting the simulation in motion was to prime all the particles by assigning them initial velocities depending on the degree to which each particle was shifted away from a grid intersection. Then we flipped the switch and, like a divine watchmaker, sat back and watched what happened next.

Once the simulation began, every particle started to attract every other particle. With nearly 10 billion (1010) of them, that would have resulted in roughly 1020 interactions that needed to be evaluated at each time step. Performing that many calculations would have slowed our simulation to a crawl, so we took some computational shortcuts. One was an algorithm called adaptive mesh refinement, which adjusts the resolution of the simulation depending on how closely particles are grouped together. If there are too many particles in a single cell, this approach divides that cell into eight smaller cells and calculates the interactions between particles with finer time and spatial resolution. This algorithm allows the simulation to dedicate most of its computational power where it's needed: in those small regions of the simulation where particles tend to cluster.

As Bolshoi ran, we logged the position and velocity of each of the 8.6 billion particles representing dark matter, producing 180 snapshots of the state of our simulated universe more or less evenly spaced in time. This small sampling still amounts to a lot of data — roughly 80 terabytes. All told, the Bolshoi simulation required 400 000 time steps and about 6 million CPU-hours to finish — the equivalent of about 18 days using 14 000 cores and 12 terabytes of RAM on the Pleiades supercomputer. But just as in observational astronomy, most of the hard work comes not in collecting mountains of data but in sorting through it all later.

To make sense of Bolshoi's output, the first thing my colleagues and I did was to analyze each snapshot in search of what in the real universe corresponds to galaxies. We did this by identifying distinct groupings of dark matter particles bound together by gravity. Astronomers call these bound clumps "halos" because they seem to be rather fuzzy clouds that extend in all directions beyond the visible boundaries of galaxies. In Bolshoi, these halos numbered up to 10 million at each time step. We characterized them in many different ways, measuring such properties



Cluster Structure: These three images show the distribution of matter in a cluster of galaxies from a small region of the BigBolshoi simulation. This region was resimulated, this time also taking into account the ordinary matter. The dark matter distribution [left] forms the gravitational scaffold for gas [center] and stars [right]. All the matter distributions were simulated over the age of the universe but are shown as they would appear today. The dimensions of each image are about 38 million by 50 million light-years.

Sources: Resimulation, Gustavo Yepes/Universidad Autónoma de Madrid; visualization, Kristin Riebe/Leibniz Institute for Astrophysics Potsdam

as size, shape, orientation, mass, velocity, and rotation.

The Bolshoi simulation would be just an expensive fantasy if it didn't match observations of the real universe. The simplest way to make a comparison is to assign basic galactic properties to each of the Bolshoi dark matter halos. We know from observations that the more luminous a galaxy is, the faster its stars move. So we rank the halos by how rapidly the dark matter particles move in them, and we rank observed galaxies by their luminosity, and then we match the two distributions.

This process gives each simulated halo a likely galactic identity. We don't expect each galaxy to be a literal match, but we would hope that the overall statistics of the simulated galaxy population corresponds to what we see in the night sky.

One way to find out is to examine the probability of finding a galaxy within a given distance of another galaxy. To our delight, we found the Bolshoi simulation agrees quite well with astronomical observations in this regard. It did much better than the Millennium simulation, which ended up, for example, with about twice as many pairs of Milky Way-size galaxies separated by up to 3 million light-years as have actually been observed.

We performed other checks as well. For example, using the halo data from the Bolshoi simulation, Risa Wechsler's group at Stanford calculated that about 5 percent of the time, a Milky Way-size galaxy should host two satellite galaxies as bright as our galaxy's Large and Small Magellanic Clouds. We also calculated how often there would be just one such bright satellite galaxy and how often there would be none at all. When we compared those statistics with data collected by the ground-based Sloan Digital Sky Survey, we found remarkable agreement.

Yet another way to compare simulations with observations is to consider the number of galaxies with their stars and gas moving at various velocities. Here we found a good match with astronomical observations. But we also found a problem: The Bolshoi simulation ended up with many more galaxies containing relatively slow-moving stars than have actually been observed. It remains to be seen whether this is a serious issue. Perhaps it hints at an undiscovered property of dark matter. Or it could just represent astronomers' inability to detect the faintest galaxies. Deeper surveys are now under way that could help answer this question.

One of the most important products of our early analysis of the Bolshoi output — one that we expect will become an important resource for the astrophysical community — is the "halo merger tree." This tree describes the history of each halo, showing how each one formed from mergers with other halos all the way back to the beginning of the simulation.

We can use this merger tree to feed an improved model for the formation of galaxies, one that describes in a few equations basic properties like mass, luminosity, shape, stellar age, and elemental abundances. So far, my research group and others with early access to the Bolshoi results have found very good agreement between our models and the observed properties of nearby galaxies. We are also finding that these models can help make sense of Hubble Space Telescope images that show what galaxies looked like just a few billion years after the big bang.

As you might imagine, no one simulation can do everything. Each must make a trade-off between resolution and the overall size of the region to be modeled. The Bolshoi simulation was of intermediate size. It considered a cubic volume of space about 1 billion light-years on edge, which is only about 0.00005 percent of the volume of the visible universe. But it still produced a good 10 million halos — an ample number to evaluate the general evolution of galaxies.

In addition, my colleagues and I have also run a larger, lower-resolution simulation, called BigBolshoi, which models a cube 4 billion light-years across, a volume 64 times as great as that shown by Bolshoi. The BigBolshoi simulation allowed us to probe the properties of galaxy clusters: clumps of galaxies that typically span about 10 million light-years and can have masses more than 1000 times as large as the total mass of the Milky Way. And we are running another simulation on NASA's Pleiades supercomputer called miniBolshoi, to focus in more detail on the statistics of galaxies like the Milky Way.

As supercomputers become more powerful, astrophysicists would like to run a large-scale, high-resolution simulation of the universe that includes the complex interplay within galaxies of gas, stars, and supermassive black holes. These sorts of simulations could be used to create a sort of field guide that could help astronomers interpret their telescope images, by telling them what galaxies should look like at various stages of their lives. With today's supercomputers and codes, though, it is possible to do such high-resolution simulations in only relatively small regions containing one or at most a few large galaxies.

One of the biggest hurdles going forward will be adapting to supercomputing's changing landscape. The speed of individual microprocessor cores hasn't increased significantly since 2004. Instead, today's computers pack more cores on each chip and often supplement them with accelerators like graphics processing units. Writing efficient programs for such computer architectures is an ongoing challenge, as is handling the increasing amounts of data from astronomical simulations and observations.

Despite those difficulties, I have every reason to think that numerical experiments like Bolshoi will only continue to get better. With any luck, the toy universes I and other astrophysicists create will help us make better sense of what we see in our most powerful telescopes — and help answer some of the grandest questions we can ask about the universe we call our home.

About the Author:

Joel R. Primack is a physics professor at the University of California, Santa Cruz, and director of UC's High-Performance AstroComputing Center.

Visit the Bolshoi simulation website at http:// hipacc.ucsc.edu/Bolshoi.

MEMBER PROFILE

Harley Myler

Harley Myler is Professor and Chair of the Phillip M. Drayer Department of Electrical Engineering at Lamar University in Beaumont Texas. He is also the inaugural holder of the William B. and Mary G. Mitchell Endowed Chair in Electrical Engineering. The Mitchell Chair in the College of Engineering was made possible by a gift of $1.2 million by the alumni couple to the Lamar University Foundation. Mr. Mitchell is a former Vice-Chairman of Texas Instruments, Inc. Dr. Myler's research interests are in digital video processing with an emphasis on broadband and broadcast distribution. This includes source and destination display and presentation technologies, channel efficiency considerations, compression and coding, Internet and intranet issues, multimedia formats and video quality analysis and investigation.

Dr. Myler came to Lamar from the University of Central Florida, Orlando, where he was a professor of electrical engineering. He began his college education at the Virginia Military Institute and received a double-major bachelor's degree in electrical engineering and chemistry in 1975. After serving as a missile systems officer in the Army, he began graduate studies at New Mexico State University (NMSU) in 1979 and earned the MSEE in 1981 and the Ph.D. in electrical engineering in 1985. He began his academic career as an instructor at NMSU before joining the faculty at the University of Central Florida in 1986. He is a registered Professional Engineer in electrical engineering in both Florida and Texas.

Dr. Myler has received several awards for teaching excellence from honor societies and other entities, including Computer Engineering Educator of the Year at UCF and a Fulbright Specialist Grant to teach engineering in Tunisia. Recently he was selected as one of three Lamar University Outstanding Faculty Members. He has published numerous books and articles and has obtained patents and copyrights for his work, in addition to securing more than $3.2 million in research grants.

Why did you choose to study the engineering field?

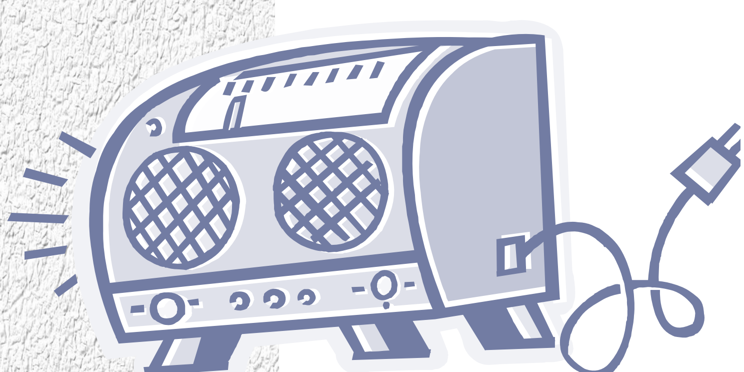
I built my first radio when I was about 10 years old. My father taught vocational electronics so I had a bit of help and I think that was what set me on the path to EE.

What do you love about engineering?

The abstraction of the problems to be solved. I get a great delight in manipulating electrons and photons--those of us that know how to do it form an exclusive club.

What don't you like about engineering?

The fact that engineering is a profession - no different than law or medicine - yet we do not enjoy the same level of recognition that those fields do.



Whom do you admire, and why?

Tesla, Edison and Armstrong. They were the pinnacle, in my opinion, geniuses of our discipline. Each a bit different type of electrical engineer, but EE's no matter how you look at it.

How has the engineering field changed since you started?

The complexity of the problems. The team is now far, far more important than that lone engineer tinkering away on a project. Our projects are mind-boggling!

What direction do you think that the engineering field is headed in the next 10 years?

I side with the authors of the NAE report "The Engineer of 2020", the need for engineers is just going to increase, the complexity of the problems and their scale is increasing and the technologies available to us are now in regimes relatively unknown a decade ago. We are the solution to the world's ills once we put politics and cultural issues aside. The global engineering economy is going to be intensely competitive and put significant demands on the skills and abilities of tomorrow's engineers.

What is the most important thing you have learned in the field?

That engineering is a community and that we transcend gender, race, and culture. An engineer, is an engineer, is an engineer. Once you are trained as an engineer, once your mindset is on engineering, you enter into a special world where the collective goal is to move us all forward and do it cleanly, efficiently and cost effectively. We can literally do anything that we put our minds to--a great feeling.

What advice would you give to recent graduates entering the field?

"Pay no attention to the man behind the curtain." Now that we live in a world where telecommunication is near ubiquitous, it is easy to get caught up in what simply amounts to noise. The noise I am talking about comes from those who do not realize the power of engineering and what it can do, and what it has done, to change the world. There is a bright future out there for you, with significant challenges to test your mettle--embrace it and let's get to work!

If you were not in the engineering field, what would you be doing?

I simply can't imagine it--probably science.

Finish this sentence: "If I had more time, I would…

…restore antique radios. Very relaxing and fulfilling.

Deflecting Asteroids

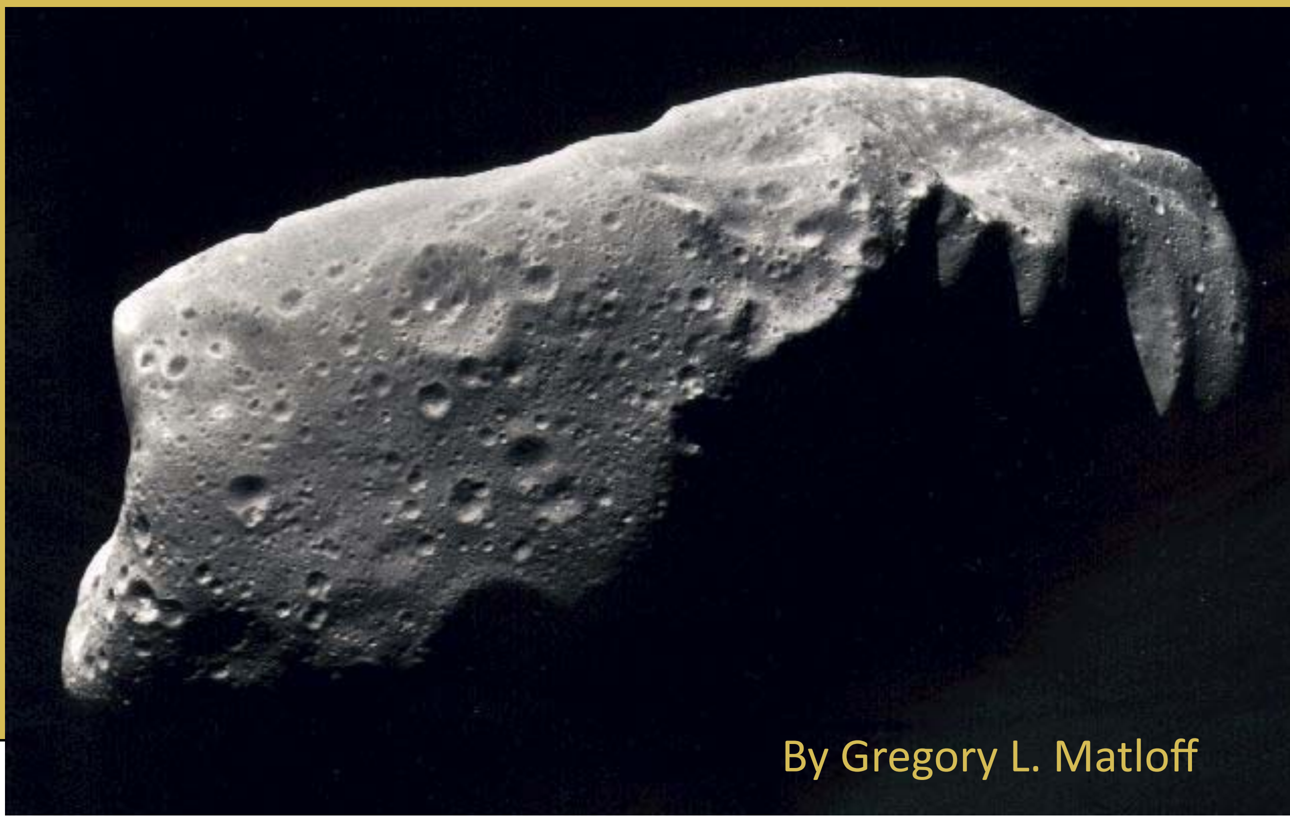


Image Credit: NASA

A solar sail could use light to nudge an earthbound rock into an orbit we could live with...

Sixty-five million years ago, a Manhattan-size meteorite traveling through space at about 11 kilometers per second punched through the sky before hitting the ground near what is now Mexico's Yucatán Peninsula. The energy released by the impact poured into the atmosphere, heating Earth's surface. Then the dust lofted by this impact blocked out the sun, bringing years of wintry conditions everywhere, wiping out many terrestrial species, including the nonfeathered dinosaurs. Birds and mammals thus owe their ascendancy to the intersection of two orbits: that of Earth and that of a devastating visitor from deep space.

We humans need not wait, like dinosaurs, for the next big rock to drop. We have an advanced understanding of the heavens and a spacefaring technology that could soon enable us to alter the orbits of any celestial object on a collision path with us. That capability just might come in handy.

We got a taste of the challenge in December 2004, when scientists at NASA and the Jet Propulsion Laboratory (JPL), in Pasadena, Calif., estimated there was a nearly 3 percent chance that a 30-billion-kilogram rock called 99942 Apophis would slam into Earth in 2029, releasing the energy equivalent of 500 million tons of TNT. That's enough to level small countries or raise tsunamis that could wash away coastal cities on several continents. More recent calculations have lowered the odds of a 2029 impact to about 1 in 250 000. This time around, Apophis will probably miss us—but only by 30 000 km, less than one-tenth of the distance to the moon.

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But let's not rejoice too quickly. We know next to nothing about that asteroid's porosity, composition, and tensile strength. It's possible that tidal stresses during its 2029 approach could cause it to break apart, adding to the odds of an Earth impact during another rendezvous further down the line.

There is some disagreement about the best course of action. In the United States, experts tend to want to experiment with various deflection techniques by first sending robots or even astronauts to asteroids that do not threaten Earth. But in Russia, many asteroid watchers believe the risk of a collision between Apophis and Earth has been underestimated. These analysts contend that we should therefore concentrate our experiments on this particular asteroid.

To be sure of diverting any interplanetary intruder, we would need several strings to our bow. A method that could swiftly deflect a hunk of iron might blow an icy rock into several parts, each of which could then become a danger. And the gentler method now being discussed — to vaporize part of the surface of the asteroid, creating an outpouring of gas that would generate a propulsive force — would do no more than warm a meteorite made of iron. So we'll doubtless need to devise several strategies for dealing with threatening asteroids.

So I have investigated a new tool, one that would use the pressure of light to nudge threatening objects into safe trajectories. That I've been asked to explain it at all in a magazine article shows that there's indeed one thing we can rejoice in: the enhanced awareness of the problem. The mention of killer asteroids no longer raises jeering comparisons to the cries of Chicken Little, now that we know celestial impacts are far more common than once thought.

The largest and most famous Earth impact in historical times occurred in Tunguska, Siberia, in 1908, when an object perhaps 30 meters wide entered the atmosphere and exploded aboveground, with the strength of several megatons of high explosive. It leveled forests and dispersed reindeer herds, and the dust it kicked up produced colorful sunrises and sunsets throughout Europe. Fortunately, the devastated area was sparsely populated, so few people were hurt.

Astronomers now know a good deal about the nature and location of objects posing threats of both the Yucatán and Tunguska kinds. Some of these objects are comets — celestial icebergs that spend most of their time in the depths of space far from the planets. At intervals of 100 000 years or more, stars may approach our solar system closely enough to disrupt the solar orbits of some of these comets, pushing them sunward. They would then swoop through the inner solar system at great speed. It is not impossible that such a comet is what destroyed the dinosaurs.

The main threat comes from what are known as near-Earth objects. They usually reside between the orbits of Venus and Mars, although their orbits aren't very stable. Most are eventually flung out of the solar system, but replacements wandering in from the main asteroid belt maintain their population. Some 7000 near-Earth objects have been identified so far. As many as 100 000 more, all larger than the Tunguska object, may await discovery. This guesstimate, by analysts at JPL, is based on the assumption that astronomers are far better at spotting mountains than molehills.

NASA, now joined by the European Space Agency and other space agencies, has been conducting systematic searches for these objects. The agencies hope that by 2020 they will be able to discover 90 percent of those near-Earth objects wider than 140 meters. Both terrestrial and space telescopes are involved in the effort, and amateur astronomers equipped with small, dedicated telescopes also contribute.

Most of our information on the physical properties of these objects comes from low-resolution radar images created using such devices as the 300-meter William E. Gordon Telescope at the Arecibo Observatory, in Puerto Rico. This radio telescope can reveal rotation rates and shapes, at least for the nearer objects, although there is much we must still learn. What we do know, from meteorite samples in museum collections, is that some of the interplanetary objects that strike Earth are metallic, consisting largely of iron, and that some are rocky,

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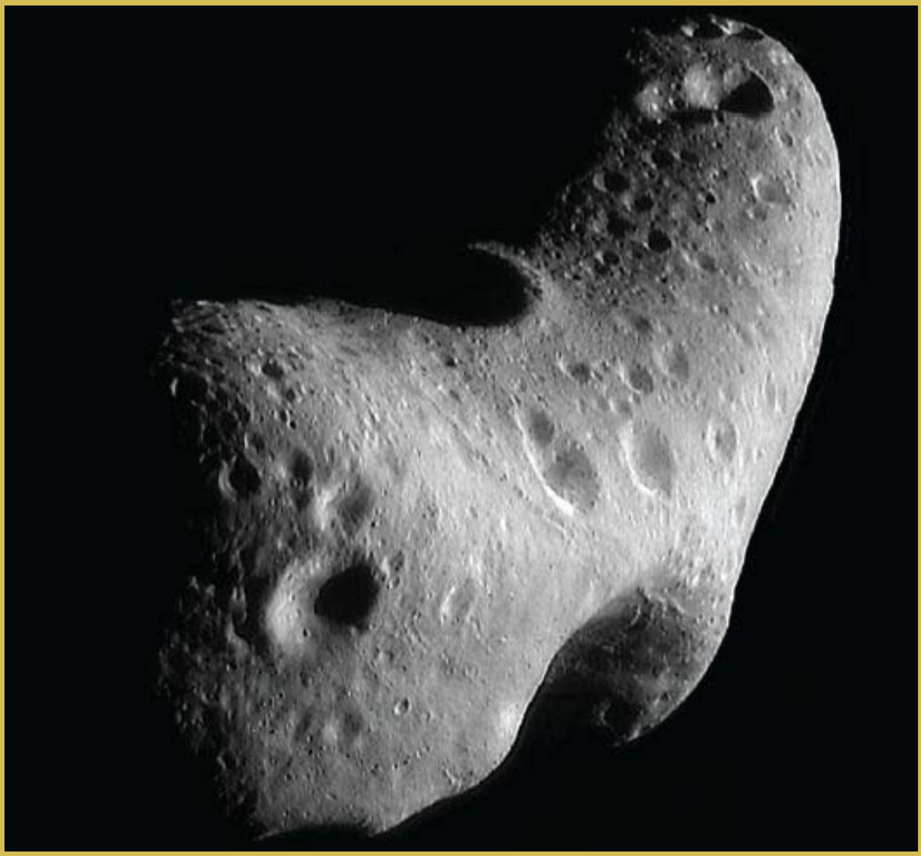
consisting largely of silicates. Then there are extinct comet nuclei, in which rocky layers are interleaved with volatile material—ice made of water or methane, for example.

An additional asteroid category has recently been added to the list. The Japanese space probe Hayabusa (formerly called Muse-C) arrived at asteroid Itokawa in September 2005. In a cliffhanger of a mission, the probe landed on the asteroid and retrieved samples of the surface, returning with them to Earth in June 2010.

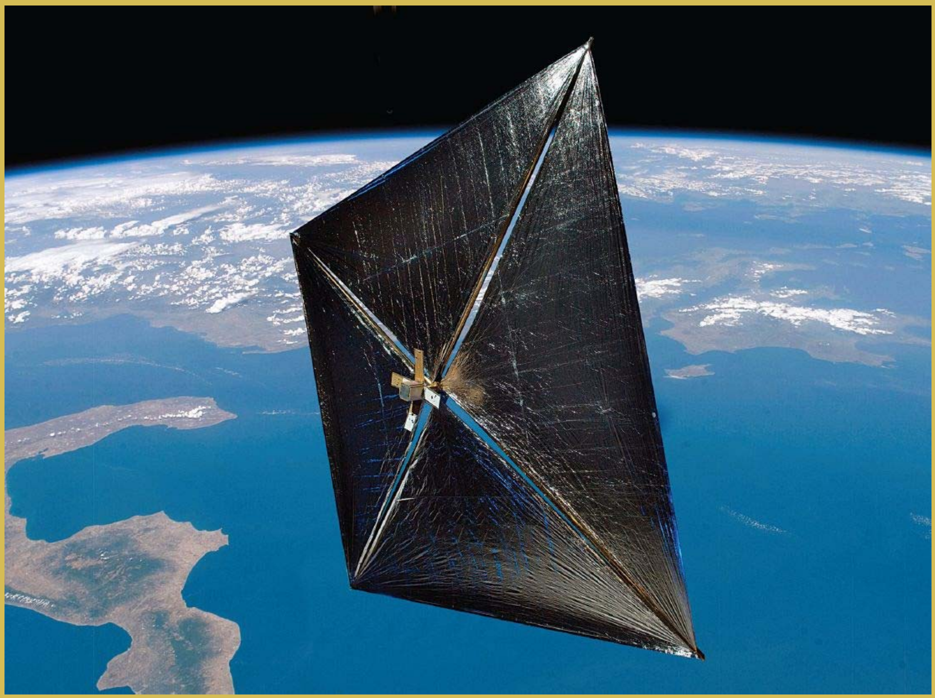
In early 2007, I took part in a NASA Marshall Space Flight Center study of proposed deflection techniques that could be ready for use by the end of 2020. My colleagues and I assumed that by that point we'd have a heavy-lift booster capable of sending 50 000 kg or more on an Earth-escape trajectory.

We considered several strategies. The most dramatic — and the favorite of Hollywood special-effects experts — is the nuclear option. Just load up the rocket with a bunch of thermonuclear bombs, aim carefully, and light the fuse when the spacecraft approaches the target. What could be simpler? The blast would blow off enough material to alter the trajectory of the body, nudging it into an orbit that wouldn't intersect Earth.

But what if the target is brittle? The object might then fragment, and instead of one large body targeting Earth, there could be several rocks — now highly radioactive — headed our way. Also, a lot of people might object to even the mere testing of any plan that involved lobbing 100-megaton bombs into space. The nuclear option might then be limited to a last-ditch defense of Earth, should we get little warning of an impending impact.



Asteroid Eros: The first space rock observed from close quarters [above] is itself a potential threat to Earth. A solar sail [artist's conception, below] might focus light onto such an object, heating ice into water vapor that would serve as a propulsive jet. (Image Credits: NASA)



Another idea is to use the "kinetic" method, which essentially uses one bullet to hit another. It requires sending a small spacecraft into an orbit around the sun in the opposite direction of that of the planets and most other objects. You then maneuver this spacecraft to hit the target head-on. It would take months to accelerate something into such a retrograde orbit. Still, the job could be done using either a solar-electric (ion) engine or a solar sail, which would use the tiny pressure that sunlight exerts on it to maneuver through space. A craft that hit the Earth-threatening rock with a relative velocity of about 60 km/s would impart a kinetic energy of 1.8 billion joules per kilogram. If the aim was perfect (no small feat at such a relative velocity), the collision could significantly alter the orbit of an asteroid — one that's sturdy enough to take the impact without falling apart. Of course, the thing could fragment, which might just make things worse.

But if we had several decades to plan the intervention, we could apply force more gently and with better control. We could wrap a solar sail around the offending object, like aluminum foil around a potato, changing the degree to which it reflects light and thus the effective pressure that sunlight exerts on it. In this fashion, the sail could gradually alter the object's orbit around the sun, converting an impending Earth impact into a near miss. This wrapping method ought to work for any kind of asteroid or comet.

Apollo 9 astronaut Rusty Schweickart and Bong Wie of Iowa State University have proposed yet another universally applicable solar-sail technique, called the gravity tractor. Here a solar sail would maintain position near the threatening body for decades, exerting a small but significant gravitational attraction on that object, which over time would alter its course. The sail would move into position and remain there using the pressure of solar radiation to maneuver. This method has the advantage of working equally well on all classes of objects — metallic, stony, or rich in ice. It would take a very long time, however, to do the job.

For the 2007 NASA Marshall study I began working on yet another scheme, called the solar collector. H. Jay Melosh of the University of Arizona and Ivan V. Nemchinov and Yu. I. Zetzer, both then affiliated with the Russian Academy of Sciences, first proposed this approach in 1994. For this strategy, the spacecraft would deploy a large parabolic ref lector that would always face the sun. Although the reflector would resemble a typical solar sail, its purpose would be solely to concentrate sunlight onto a smaller flat mirror, known as a thruster sail. The thruster sail would direct concentrated sunlight onto the offending asteroid. If the object contained volatile material, the intense beam would heat things up enough to vaporize part of the surface. The gas shooting into space as a result would, over time, impart enough momentum to nudge the body's solar trajectory away from a projected impact with Earth. It wouldn't take much of a push, because with asteroids, unlike horseshoes, a near miss doesn't count

The version of this approach that I worked on for the NASA Marshall study in 2007 assumed that gas would shoot off the asteroid at a velocity of about 1 km/s. This estimate drew on an experiment Melosh and his colleagues had done long before, using a pulsed laser to heat a simulated chunk of rocky intrasolar debris. But I had some suspicions that this number was too high — that it overestimated the efficiency of this approach. So I later looked into the thermodynamics of the problem more closely.

As I described in 2008 and 2013 papers in Acta Astronautica, it turns out that much of the energy in the concentrated beam of light would simply get conducted through the rock, away from the hot spot. The beam would have to be quite powerful to ensure that the hot spot could evaporate enough volatile material to really do the job. I found that what really mattered was how deep the concentrated sunlight penetrates. Existing studies showed that most soils here on Earth allow light into just the top 100 micrometers, but measurements on extraterrestrial samples were lacking.

As an associate at the Hayden Planetarium at the American Museum of Natural History, in New York City, I was able to collaborate with Denton Ebel, curator of meteorites there. He graciously prepared two samples of the Allende meteorite, which slammed into Mexico back in 1969. It's a carbonaceous chondrite, as are about a third of all near-Earth objects. The first sample consisted of a 30-µm-thick section epoxied to a transparent slide; the second was a finely ground simulated minimeteorite weighing just a few grams. Both samples were loaned to the physics department at the New York City College of Technology, in Brooklyn, where I teach. There, Lufeng Leng and her student Thinh Le shone two laser beams onto the samples, one at a wavelength of 532 nanometers, in the green part of the spectrum, and the other at 650 nm, in the red part. It turned out that both samples had about the same light-penetration depths you'd expect to find in terrestrial soils. I presented those results at a meeting of the Meteoritical Society in July 2010.

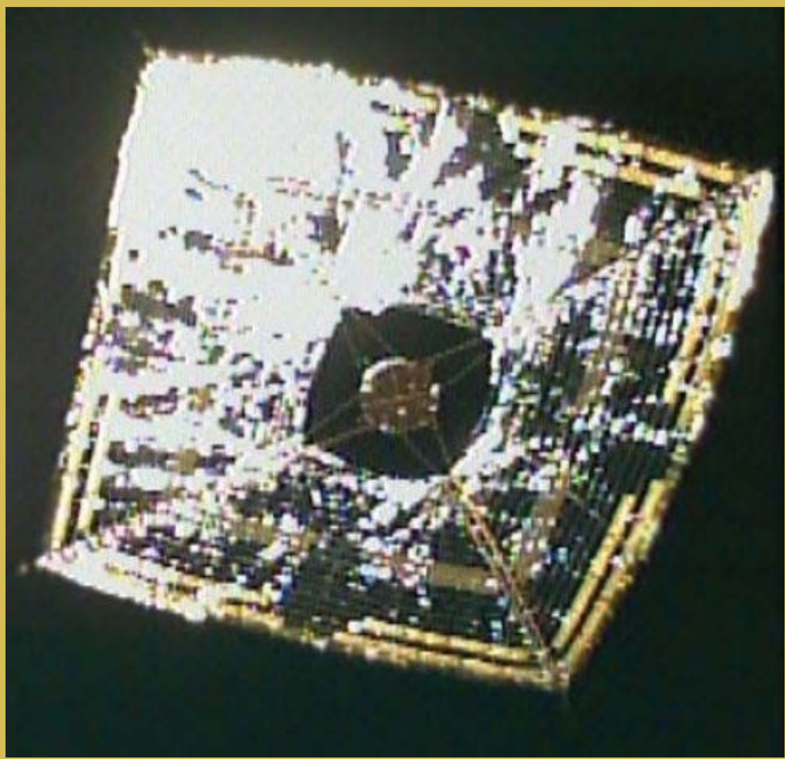
Such measurements must be repeated at other wavelengths and on samples of other meteorites and, ultimately, on samples retrieved from the moon and from asteroids. That way we will be able to test extraterrestrial material that could not have been modified by a meteorite's white-hot passage through Earth's atmosphere.

At this stage of the analysis, it is difficult to determine how big a solar collector would be required for this strategy to work. The device would probably have to measure more than 50 meters. Building it from a thin plastic film would keep its mass down to no more than a few hundred kilograms. It would remain tightly folded on the voyage out and be unfurled only near the standoff point, at least a few hundred meters from the Earth-threatening rock. Electric propulsion would probably be necessary to maintain the collector's position during the months or years it would take to divert the rock. Autonomous robotic control seems necessary, although astronauts could certainly monitor the process. And it might prove easier to use a number of smaller solar collectors rather than a single large one.

These are early days for designing such delicate space hardware, space sails included. But that solar sails can be manipulated in orbit and used for various purposes is no longer in doubt.

In 2010, two such sails flew in space. The more ambitious one, a square about 14 meters on a side, was launched by the Japanese space agency on an interplanetary trajectory between Earth and Venus. Called IKAROS, for Interplanetary Kite-craft Accelerated by Radiation Of the Sun, it proved that solar radiation pressure can be used both for primary propulsion and for attitude control. A follow-on craft, planned for around 2020, would use its solar sail during a close pass of the sun. There it could gain enough momentum from light pressure to swing into an orbit that would take it all the way out to explore the Asteroids --called the Trojans--that trail Jupiter in its orbit.

NASA's Nanosail-D2, approximately the same size as IKAROS but lighter, went up in late 2010 and deployed in January 2011, when the craft unfurled its sail in an Earth orbit low enough for amateur astronomers to see it. It was



Venus, Ho: In late 2010, Japan's IKAROS became the first spacecraft to use a solar sail for interplanetary travel. (Image Credit: Japan Aerospace Exploration Agency)

also low enough for atmospheric drag to affect the orbit. In this case, that was a feature, not a bug, because the point of the mission was to clean up space junk by docking with it and then using the sail to drag it down to a fiery disposal in the lower atmosphere.

It's a good thing that solar sails have many possible uses. This helps to defray the costs of developing a technology that's likely to be valuable should we ever discover a rogue asteroid headed our way. It also helps in overcoming the all-too-human reluctance to begin working on a problem that requires a planning horizon measured in generations or even centuries.

As with other approaches to asteroid deflection, the solar collector would not work well on all classes of interplanetary rock. If you tried to use it on an iron asteroid, the metal would instantly conduct the heat away from the hot spot. Besides, there would be no volatile material there to vaporize anyway. The asteroid would just continue on its merry way, undisturbed. A rocky body without any volatiles would also be impossible to shift in this way. So, clearly, other techniques for dealing with those kinds of asteroids must also be developed.

It does seem, though, that a solar collector could divert a 300-meter water-ice object enough to prevent an Earth impact, and while remaining on station for just a few months. Even more ambitious is the notion of using such deflection techniques to steer smaller water-ice-bearing objects into high Earth orbit, where we could mine them for materials for rocket fuel, life-support systems for space habitats, cosmic-ray shielding for such habitats, the construction of satellites to beam solar power to Earth, and other purposes. In 2010, President Obama directed NASA to prepare to send astronauts to explore near-Earth objects by the year 2025. While on that mission or on succeeding ones, astronauts could test a solar collector and other deflection techniques.

We have plenty of time to study the matter. But we do not have all the time in the world.

About the Author

Dr. Greg Matloff is a leading expert in possibilities for interstellar propulsion, especially near-Sun solar-sail trajectories that might ultimately enable interstellar travel. He is an emeritus and adjunct associate astronomy professor with the physics department of New York City College of Technology, CUNY, a consultant with NASA Marshall Space Flight Center, a Hayden Associate of the American Museum of Natural History, and a Member of the International Academy of Astronautics. He co-authored with Les Johnson of NASA and C Bangs "Paradise Regained" (2009), "Living Off the Land in Space" (2007) and has authored "Deep-Space Probes" (edition 1: 2000 and edition 2:2005). As well as authoring "More Telescope Power" (2002), "Telescope Power" (1993), "The Urban Astronomer" (1991), he co-authored with Eugene Mallove "The Starflight Handbook" (1989). His papers on interstellar travel, the search for extraterrestrial artifacts, and methods of protecting Earth from asteroid impacts have been published in *JBIS*, *Acta Astronautica*, *Spaceflight*, *Space Technology*, *Journal of Astronautical Sciences*, and *Mercury*. His popular articles have appeared in many publications, including *Analog*.

In 1998, he won a $5000 prize in the international essay contest on ETI sponsored by the National Institute for Discovery Science. He served on a November 2007 panel organized by Seed magazine to brief Congressional staff on the possibilities of a sustainable, meaningful space program. Professor Matloff is a Fellow of the British Interplanetary Society and a Member of the International Academy of Astronautics. He has chaired many technical sessions and is listed in numerous volumes of *Who's Who*. In 2008, he was honored as Scholar on Campus at New York City College of Technology. His most technical recent book, co-authored with Italian researcher Dr. Giovanni Vulpetti and Les Johnson, is "Solar Sails: A Novel Approach to Interplanetary Travel," Springer (2008). In 2011, he collaborated with his artist wife C Bangs on a self-published artist's book, "Biosphere Extension: Solar System Resources for the Earth," which has been collected by the Artist's Book division of The Brooklyn Museum. In addition to his interstellar-travel research, he has contributed to SETI (the Search for Extraterrestrial Intelligence), modeling studies of human effects on Earth's atmosphere, interplanetary exploration concept analysis, alternative energy, in-space navigation, and the search for extrasolar planets. His website is www.gregmatloff.com.

CHAPTER SPOTLIGHT

Lambda Eta Chapter Joins Forces with IEEE Student Branch in New Delhi for Fevour 2012

The Lambda Eta Chapter of Bharati Vidyapeeth's College of Engineering (BVCOE) in New Delhi, India, was established in February of 2012, and has been busy keeping their Chapter members engaged and involved by organizing 21 activities and events, known as Fevour 2012.

Fervour 2012 live logo

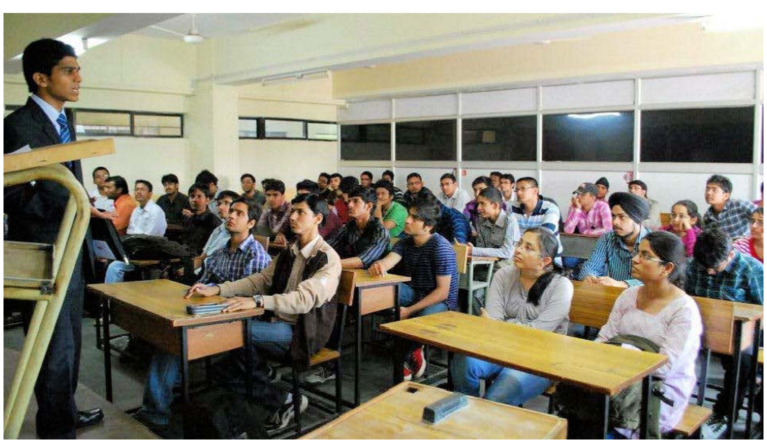
Working together with their local IEEE Student Branch, these events had immense participation from over 15 colleges, and awarded cash prizes to the winners. Lambda Eta was able to offset the costs of these events thanks to sponsorships obtained from companies such as Aricent, Engineers India Limited, Airtel, Oriental Bank of Commerce, Punjab National Bank, GAIL, Indraprastha Gas Limited, Mahavir Jain Academy, Aptech, Everonn IT and others. Some highlights from Fevour 2012 included:

National Student Symposium

The National Student Symposium was aimed at stimulating and fostering student research, providing a forum for exchanging new ideas, and highlighting student research accomplishments. BEML Limited was the exclusive sponsor for this event. The theme was "Innovation Engineering for Global Security", and papers were received from over 15 colleges in India. Fourteen research papers were presented and published, and prizes were awarded for the best papers.

Bits-N-Bytes

"Bits-N-Bytes" was an algorithm intensive programming contest which aimed to provide a platform for programmers to showcase their problem-solving and programming skills. The event consisted of quiz



Chapter President, Akshay Gupta, giving a talk on IEEE-HKN

Paper presentation at National Student Symposium round and a programming round, in which participants needed to show off their exquisite programming skills and submit code with the most efficient use of keywords and tokens.

The event saw a huge amount of participation from a variety of premier schools including Delhi University, GGSIPU, Amity University, Jaypee University and other colleges. In all, 150 teams of two participants each were registered, and the top 20 teams from preliminaries made it to the second round. Cash prizes were awarded to the winners.

Students at Round 1 of Bits-n-Bytes

Digital Fortress

Digital Fortress was an event based on Cryptography, or codes for security purposes, such as ciphers, anagrams, jumbled words, and others. The event occurred on 13-14 March 2012 under the direction of IEEE-Eta Kappa Nu. Digital Fortress generated huge Interest and team slots for both days were filled within hours! Premier business schools such as IIMs, Delhi University, GGSIPU, and other colleges from across the nation competed. 100 teams of two participants each were registered, and the top 20 teams from preliminaries made it to the second round. Cash prizes were awarded to the winners. The event was such a huge success that the organizers were flooded with praise and compliments; participants requested that similar events be held in the future.

Chapter Vice-President, Anurag Garg, giving a talk on IEEE-HKN

During Fevour 2012 and throughout the year, members from Lambda Eta Chapter connected with many IEEE Student Branches in Delhi, informing them about the ease of forming an IEEE-HKN chapter and how much it could help their branches in the future.

Fervour 2012 Closing Ceremony

Lambda Eta is currently planning a presentation on IEEE-HKN Chapter formation at this year's Women in Engineering meeting in India!

IEEE-Eta Kappa Nu Reminders

Order your IEEE-HKN Graduation Stoles and Cords

Graduation is a special time; you deserve to be recognized for your accomplishments. Order your stoles and cords now for graduation! Early ordering ensures your stoles and cords are available and that you receive them in a timely manner. Order online at www.hkn.org/store, or use this link: https://fs25.formsite.com/ieeevcep/form7/secure_index.html.

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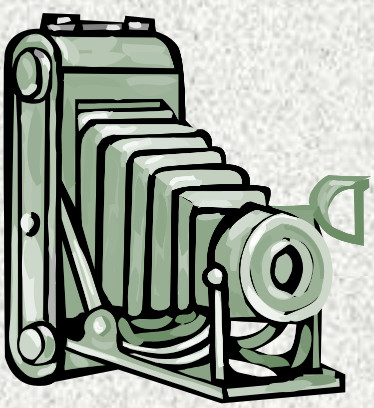

Do you have an historical photo or document that relates to IEEE-HKN that you would like to share in THE BRIDGE? We welcome your memories or memorabilia, which we may feature in the new IEEE-HKN History Spotlights section of THE BRIDGE. Just email your contributions to info@hkn.org.

Nominate an Outstanding Colleague for an IEEE-HKN Award

As an honor society, IEEE-Eta Kappa Nu has plenty of opportunities designed to promote and encourage outstanding students, educators and members. Go to hkn.org/awards to view the awards programs. Nominations due by 30 April for the Outstanding Student, Outstanding Young Professional, Outstanding Teacher and the Karapetoff Awards.

New Member Requisition, Election of Officers Online Forms

Find our new online forms on the Documents and Forms page under the Chapter tab at hkn.org. You can submit and pay online. You can attach a document or a spreadsheet. If you are paying by check, please submit online, and mail the check along with a copy of the paperwork.

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