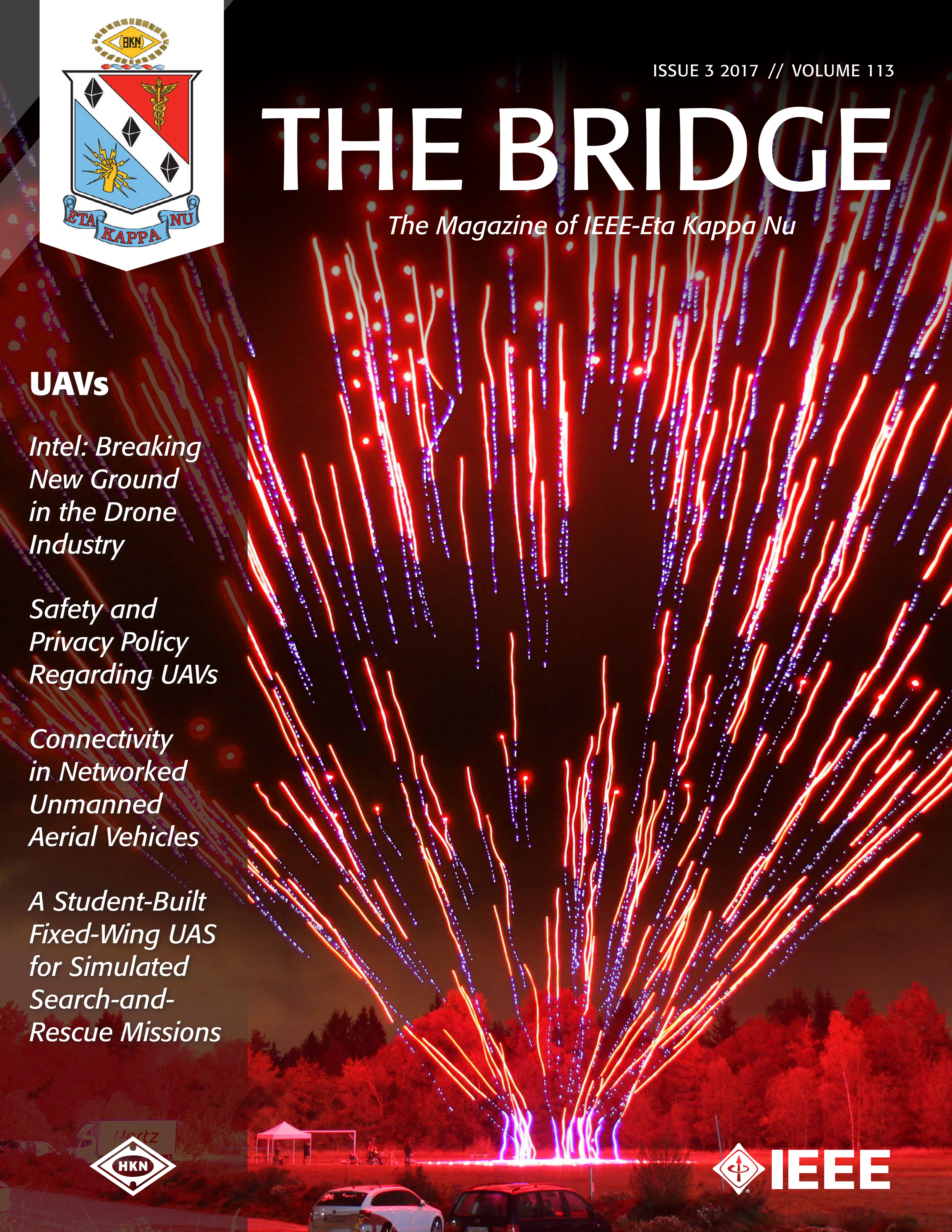
ISSUE 3 2017 // VOLUME 113

THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu



UAVs

Intel: Breaking New Ground in the Drone Industry

Safety and Privacy Policy Regarding UAVs

Connectivity in Networked Unmanned Aerial Vehicles

A Student-Built Fixed-Wing UAS for Simulated Search-and-Rescue Missions

IEEE-HKN AWARD PROGRAM

As the Honor Society of IEEE, IEEE-Eta Kappa Nu provides opportunities 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.

Alton B. Zerby and Carl T. Koerner Outstanding Student Award (OSA)

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

C. Holmes MacDonald Outstanding Teaching Award (OTA)

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

Distinguished Service Award

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

Outstanding Chapter Award (OCA)

Recognizes chapters for excellence in activities and service at the department, university and community levels. The award is based on the content contained in their Annual Chapter Report for the preceding academic year. (Deadline: Monday after 30 September)

Outstanding Young Professional Award (OYP)

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

Vladimir Karapetoff Outstanding Technical Achievement Award

Recognizes individuals who have distinguished themselves through an invention, development, or discovery in the field of electrical or computer engineering. (Deadline: Monday after 30 April)

IEEE-Eta Kappa Nu

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

Get in touch with Eta Kappa Nu
Twitter: ieee_etakappanu
Facebook: IEEE-HKN

THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

Issue 3, 2017 – UAVs

FEATURES

DEPARTMENTS

IN THE SPOTLIGHT

NEWS AND UPDATES

MEMBERS AND CHAPTERS

IEEE-HKN INTERNATIONAL HEADQUARTERS
Editorial inquiries: IEEE- Eta Kappa Nu, 445 Hoes Lane, Piscataway, NJ 08854, USA
US Toll Free: +1 800 406 2590 | Outside US: +1 732 465 5846 | Email: info@hkn.org | www.hkn.org
Subscription address and email changes: IEEE Contact Center US Toll Free: +1 800 678 4333 | Outside US: +1 732 981 0060
Fax: +1 732 562 6380 | Email: contactcenter@ieee.org

Our Cover
See page **10** for details about cover image

Timothy P. Kurzweg
Epsilon Chapter
kurzweg@ieee.org

Welcome to the October 2017 issue of THE BRIDGE

Fall renews excitement in our IEEE-HKN world. Many of our chapters are planning events for the upcoming academic year; many of our Chapters are finding and inducting new members and many of our Chapters are making a difference in their university and community. As I reflect on the promise and potential of HKN, I am reminded that the success of the organization starts with our members. Let's all be re-energized by the enthusiasm of the new academic year. Students, engage with new and past members to strengthen your chapter. Faculty guide and lead our chapters to new levels. Alumni, reach out to a local chapter and see what you can do to help. Together, we are the Honor Society that leads, trains, supports, and networks with engineering leadership around the world. This is just HKN doing what HKN does best.

I had the pleasure to attend IEEE's Sections Congress in August and spread the good word about IEEE-HKN. I had the opportunity to give multiple presentations to IEEE Section Leaders from around the globe. I challenged our IEEE Sections to reach out to HKN chapters in their areas and engage the students and chapters to participate in their IEEE Section events. One of the benefits of IEEE and HKN merging together in 2010 was the opportunity for HKN to be involved and supported by their local IEEE Sections and technical societies. I believe that we will continue to improve these relationships, and I hope that through the Section Congress meetings, the Sections will be more aware of HKN and understand how we can mutually support each other. Chapters, if you do not hear from your IEEE Sections, please connect and introduce yourselves!

Can you say four-peat? THE BRIDGE has been selected for a 2017 APEX Award, making it the fourth year in a row to receive this prestigious award. Congratulations to the entire BRIDGE team for their time, effort, and amazing publication! We will celebrate this award, as well as the IEEE-HKN Outstanding Teaching Award and the IEEE-HKN Young Professional Award during the IEEE Education Activities Board (EAB) Awards Ceremony in November.

As this is my last BRIDGE letter as President of IEEE-HKN, let me conclude with words of thanks. Thank you to our Board of Governors who care and plan for our strategic direction and growth. Thank you to our IEEE-HKN staff that make the operation run so smoothly and efficiently. However, I save the last thanks for you, our HKN member. It does not matter when you were inducted, be it 5 days or 70 years ago. IEEE-HKN members are smart, thoughtful, and caring. We are engineers that serve and make a difference in our community. I am proud to be an IEEE-HKN member, and I know you are as well.

To a wonderful rest of 2017, and beyond,

Tim

Timothy P. Kurzweg
2017 IEEE-HKN President

Steve E. Watkins

Gamma Theta Chapter

steve.e.watkins@ieee.org

Dear Eta Kappa Nu Members and Friends,

The theme for this issue of THE BRIDGE is "UAVs" for unmanned aerial vehicles. This multi-disciplinary technology is providing many opportunities and challenges for the technical, educational, and commercial community. The features discuss cooperative operation of multiple UAVs, student UAV design, and related public policy issues. Many of our authors are current students or recent graduates. Also, we thank Intel for our cover image of a UAV light show. Their recording-setting work illustrates the creativity and skill of engineers.

While the public commonly associates UAVs with military and hobby applications, UAVs are finding many roles as commercial and scientific tools. For instance, NASA has used a civilian version of the General Atomics Predator B for over a decade. This aircraft, named Ikhana after the Choctaw word for to know or to be aware, is shown in the figure. As a UAV designed for long-endurance flight, it has collected data for Earth science projects, demonstrated technologies for wildfire response, served as a testbed for aeronautical systems, and supported tests of air traffic management systems. Visit NASA's research in UAV technologies and applications.

▲NASA's research UAV, named Ikhana, in 2007. Courtesy of NASA / Photo by Lori Losey

Finally, the magazine continues to represent IEEE-HKN with quality content and presentation. THE BRIDGE received a 2017 APEX Award of Excellence in the "Most Improved" category. The magazine was recognized in prior years 2016, 2015 and 2014, and most recently with a 2017 APEX Award of Excellence in the "Writing Series" category. Congratulations to the Editorial Board, IEEE-HKN staff, and our authors for their contributions to the magazine. Visit archive of recent issues.

Regards,

Steve E. Watkins

2017 IEEE-HKN President-Elect

WINNER
2017
APEX®
AWARDS FOR
PUBLICATION EXCELLENCE

Nancy M. Ostin

Gamma Theta Chapter

n.ostin@ieee.org

What did I do this summer?

1. Special Panel on IEEE-HKN at COMPSAC 2017 in Turin, Italy (July)
2. Visit to Mu Nu Chapter at Polytechnic of Torino, Italy (July)
3. IEEE Sections - Sydney Australia (August)
    a. Section Leaders Guide to IEEE-HKN
    b. IEEE-HKN Ignite Session

Thank you to the Mu Nu Chapter for the very warm reception, for all of your support at our special panel session at COMPSAC, and the Chapter dinner enjoyed by all! Meeting with one of our newest chapters, experiencing the enthuasism, and learning about the successful programs that this chapter was able to put together in such a short time was a highlight of this trip. Congratulations Mu Nu! If you would like to learn more about this Chapter, please email me; I am happy to share their chapter report.

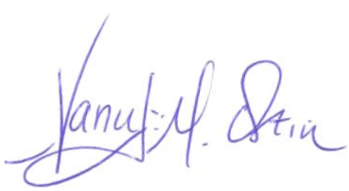
COMPSAC 2017 – The IEEE Computer Society extended an invitation to hold a special panel session during their conference to promote HKN throughout the Computer Society and IEEE, and to discuss professional development. HKN and IEEE are invaluable in developing a professional network, volunteering as a way to build your reputation as a professional and providing access to engineering and engineering technology leaders through your involvement.

IEEE Sections Congress is a triennial gathering of Section leadership from all Regions around the world to collaborate, share ideas, concerns and solutions. IEEE-HKN's presence was to inform and engage IEEE Sections and Regions to work with and support HKN chapters and members; raise visibility for our chapters; and create new opportunities for our members.

All this, plus our new website, Board of Governors meetings, committee work and developing new collateral and other materials to promote HKN...we have been busy!

As HKN prepares to celebrate FOUNDERS DAY, thank you for your creativity in building HK's reputation on your campus, with your alumni, in the engineering profession, and within yourselves. Let us all celebrate IEEE-HKN; THANK YOU for being a part of our HKN team!

Yours in HKN,



Director, IEEE-HKN

It's hard to believe that 2017 is nearing its end. The past 10 months have flown by and our chapters and alumni have accomplished a great deal in terms of welcoming new members, hosting activates on campus and in the community, and much more. This month, we're asking all our chapters and alumni to help us celebrate HKN's 113th birthday through our *Founders Day* program which includes social gatherings and community service opportunities. As we celebrate our founding, I ask every inductee to think about what HKN has meant to you and what you can do to give back to the next generation of HKN members.

One way to rededicate ourselves is to connect with other inductees. For alumni and students alike, I implore you to reach out to one another; for alumni, re-engage with your chapter of induction. No matter how far removed you might be from your days as a student, you have wisdom, experience, and expertise to share with our new members. I encourage you to contact our staff to get in touch with your chapter's current leadership team.

Finally, I would be remise if I didn't comment on the advances that we've made over the past 10 months relating to the student experience. I'm pleased to report that our chapter leaders have gathered monthly for the first time and have shared their successes and failures with one-another. Additionally, as a result of these candid conversations, new resources have been developed and are in the process of being distributed through our new website. Further, to help our chapter leaders continue their conversations on a more regular basis, we've created a Slack to facilitate instantaneous group conversations away from the monthly meetings. These discussions are ongoing and I'm hopeful that this new communication platform will enable our current and future leaders to tackle challenges both big and small. In addition to hosting these monthly meetings, I'm privileged to serve on several of our Society's committees, including the Ritual Committee which I chair. This Committee is hard at work responding to the requests of our chapters to help them better prepare for transitions and changes. Specifically, the committee is working to develop new resources to help chapters effectively transition new members into leadership roles as well as an optional officer installation ceremony, which can be used to add formality and purpose to a transition. Similarly, the Committee is working on a way to properly recognize graduating students for their contributions to their chapter and its community. These resources will be made available on hkn.org shortly.

Michael Benson

Beta Epsilon Chapter, University of Michigan

mbenson@ieee.org

In closing, happy Founders' Day; have a fantastic holiday season, and please remember that a strong character and positive attitude coupled with high scholastic achievement can mean only one thing: excellence. Be excellent and enjoy the season!

-Michael

New Technology Group

Intel®: Breaking New Ground in the Drone Industry

Drones are driving the next frontier of flight and are being applied to existing problems to provide new solutions across myriad industries, from construction to aircraft inspection. Intel is in the forefront of helping companies do amazing things, thanks to innovative drone technology. With Intel's sensors, computing, and communication technologies, drones are becoming much more versatile and ubiquitous, providing both entertainment and value where previously not considered.

One of the most exciting ways Intel has led innovation in the drone market is by developing an entirely new form of entertainment with drone-powered light shows. The Intel Shooting Star™ Drone was custom-built specifically for entertainment purposes (Figure 1). It features built-in LED lights that can create over 4 billion color combinations and is easily programmed for any animation. As shown on the cover and in the logo display in Figure 2, these drone light shows paint captivating and dynamic pictures in the night sky and have dazzled audiences from the Pepsi Zero Sugar Super Bowl LI halftime show to the Coachella Music Festival.

When we're not busy entertaining audiences around the globe, the drone team and I have been pursuing commercial applications for unmanned aircraft systems (UAS). Several industries such as construction, agriculture, utility inspection, and oil& gas are realizing the benefits of incorporating drones into the work. Using drones as a

Fig. 1: Intel's Shooting Star Drone

Fig. 2: Intel's Logo during Light Show

tool to collect data not previously available or difficult to get leads to better insights and better business decisions.

Intel's commercial UAS products include both fixed wing and multi-rotor systems to address a multitude of commercial applications. The Intel Falcon™ 8+ drone is an advanced commercial drone, designed with safety, performance, and precision in mind, enabling companies to generate valuable aerial data. The Intel Falcon 8+ System will be an indispensable business tool for the growing markets in inspection, close mapping, and surveying applications. For high precision, large area surveying and mapping use cases, Intel offers the MAVinci Sirius Pro fixed wing drone.

In addition, Intel offers a developer drone product line targeted to university and commercial developers called the Intel® Aero Ready to Fly Drone. The Intel® Aero Ready to Fly system is an open-source Linux-based platform, purpose-built for developing and testing UAV solutions that can assist with exploring advanced use cases, such autonomous flying features (object recognition, environment sensing, and collision avoidance).

As an alumnus of GEM, I am proud to say my education and background has prepared me for many diverse and challenging experiences at Intel, including my current adventure in drones. It is our team's mission to evolve and broaden the use of drone technology in everything from record-setting light show performances to commercial applications. Intel is leading the way to demonstrate how drones can be used in productive and exciting ways – making the most amazing experiences of the future possible.

For more information on GEM, visit the Gem Fellowship website. For more information on Intel in drones, visit Intel's drone website. If you are interested in joining our team, we invite you to explore our career at Intel page.

Joan Tafoya
Director and Senior Principal Engineer
New Technology Group, UAV Segment

About our cover

Our cover image is supplied by the New Technology Group, UAV Segment of Intel. It is part of a light-show display that was created by a single pilot using 500 LED-equipped drones. This light show set the Guinness World Record in October 2016 for the "Most unmanned aerial vehicles (UAVs) airborne simultaneously." See the Guiness World Record youtube video https://www.youtube.com/watch?v=u-vxo_yMQwk and other videos at Intel's youtube channel https://www.youtube.com/user/channelintel

Safety and Privacy Policy Regarding Unmanned Aerial Vehicles (UAVs)

by: Logan T. DiTullio

Abstract

Unmanned Aerial Vehicles (UAVs), or drones, are a revolutionary technology that has emboldened the creative power of entrepreneurs and the general public. However, they are a fast-moving technology that has outpaced regulatory activity. The Federal Aviation Administration (FAA) minimally regulates UAVs to protect people from physical harm and to ensure that privacy rights are not violated, but growing safety and privacy concerns have spurred calls for the FAA to update current regulations. This work reviews the current regulations, discusses policy concerns, and identifies areas for potential regulatory change. Areas for change could address the maximum weight, maximum speed, and the flight locations of recreational and commercial UAVs. Also, the implementation of anti-collision technology and geo-fencing should be explored.

I. Introduction

Unmanned aerial vehicles (UAVs) have military, commercial, and recreational applications. As UAV technology advances, additional uses for UAVs are continuously appearing. UAVs can significantly impact many disciplines such as warfare, transportation, real estate, agriculture, and even education. However, as with any powerful technological device, UAVs can cause harm either intentionally or unintentionally. The Federal Aviation Administration (FAA) regulates UAVs, but the regulations are minimal and uncertainty impedes commercial use. Additionally, safety and privacy concerns have spurred calls for the FAA to update current regulations.

The exponential growth of UAVs entering the air space has created an obvious need for policymakers to address the potential for harm, accidents, misuse, etc. UAVs vary in size and shape, and they have very few physical limitations on where and how they can fly. They are not limited by physical barriers, e.g. walls and fences, that traditionally maintained a degree of security and privacy. UAVs pose obvious dangers to aviation safety due to crashes and collisions. They can be unpredictable in the hands of inexperienced or careless users. UAVs easily invade personal space because of their ability to record anything and everything in view. Consequently, UAVs have the potential to infringe upon our privacy rights due to their capacity to invade personal space.

Safety and privacy issues related to recreational and commercial use of UAVs are the focus of this work. Given the rate of rapid advancement in UAV technology in the United States, it is becoming abundantly clear that new public policies and regulations must be created to protect public safety and personal privacy. The current regulations for UAVs are reviewed and the inadequacies of these policies are discussed. The paper concludes with several recommendations to begin addressing safety and privacy issues.

II. Current UAV Regulations

UAVs come in many different shapes and sizes and differ substantially in weight depending on the appointed task. For example, the MQ-9 Reaper is a military UAV that weighs 2,223 kg and is used for surveillance and weapons deployment. The DJI Phantom 3 is a commercial UAV that weighs 1280 g and is primarily used for recreational applications such as photography. The commercial uses of UAVs cut across various disciplines and include:

- Crop monitoring/inspection,
- Educational/academic uses,
- Power-line/pipeline inspection in hilly or mountainous terrain,
- Antenna inspections,
- Aiding certain rescue operations,
- Bridge inspections,
- Aerial photography, and
- Biological applications such as wildlife nesting area evaluations.

FAA regulations must manage the proliferation of UAVs as well as their varied types and applications. The number of UAVs for commercial and recreational use has grown enormously. The FAA estimates that 430,000 UAVs were sold in 2014. By contrast, approximately 1.6 million UAVs were sold in 2015 [1]. This change in use translates to about a 272% increase in UAVs sales in just one year.

Regulation of UAVs is an ongoing debate. Current regulations differ depending on whether the UAV is used for military, commercial, or recreational purposes. Considering the recreational and commercial uses of UAVs, it is difficult to determine the exact dividing line separating the two. Recreational use is a hobby with the main purposes being pleasure and enjoyment, while commercial uses relate to business support. "For example, using a UAV to take photos for your personal use is recreational; using the same device to take photographs or videos for compensation or sale to another individual would be considered a non-recreational operation" [2]. Hence, the same UAV could be used for photography by a hobbyist and by a commercial real estate broker.

In June 2016, the Federal Aviation Administration (FAA) set stricter regulations for commercial UAV flights to help ensure safety. Individuals flying UAVs within the scope of these set parameters do not require permission to operate their UAV, however any flight outside these parameters requires FAA authorization [2]. These new regulations set limits on various parameters including weight, the distance the UAVs can travel vertically and horizontally, and hours of operation. The operation limitations are summarized below.

- Unmanned Aircraft must weigh less than 55 lbs. (~25 kg) (all inclusive).
- The unmanned aircraft must stay in Visual Line of Sight (VLOS) of the remote pilot.
- Small unmanned aircraft may not operate over any persons not directly participating in the operation.

- Operations are only allowed during daylight or civil twilight with appropriate anti-collision lighting.
- UAVS must always yield right of way to other aircraft.
- Use of a first-person-view camera cannot satisfy "see and avoid."
- Maximum groundspeed of 100 mph.
- Maximum altitude of 400 feet above ground.
- No operations may be performed from a moving vehicle or aircraft unless the operation is over a sparsely populated area.
- No carriage of hazardous materials.
- Preflight inspection must be performed by the remote pilot in command.

Further regulations were added regarding pilot certification and responsibility. The original regulations had a registration requirement with the FAA for either commercial or recreational use through a multi-step process. These registration requirements were modified in 2017 by a court decision that gave recreational users two options for flying UAVs. The first option requires users to abide by the Special Rule for Model Aircraft. This rule is summarized below. The second option requires that operators fly under the Small UAS Rule. This rule requires that operators register their UAS (Unmanned Aircraft System) with the FAA as a “non-modeler,” obtain an FAA Remote Pilot Certificate (RPC), and follow the operational requirements listed above.

III. Safety and Privacy Concerns

A. Safety Issues

A major concern regarding UAVs is safety. Reports highlight the problem of accidents from collisions, loss of pilot control, malfunctions, debris, etc. “The current accident rate for UAVs is 100 times that of a manned aircraft” [4]. As more and more UAVs enter the airspace and their altitude and speed capabilities grow, potential threats and hazards increase to both aircraft and land vehicles. The consequences of a 20-kg UAV crashing into a person, car, or even a house are non-trivial and the danger to existing airplane traffic is significance.

Special Rule for Model Aircraft [3]
a. Fly for hobby or recreational purposes only
b. Follow a community-based set of safety guidelines
c. Fly the UAS within VLOS
d. Give way to manned aircraft
e. Fly UAV that weighs less than 55 lbs

Definitions

Geo-fencing – The creation of virtual fences around areas or points of interest using a global positioning system (GPS). [5]

Frangible – A structure that disintegrates upon impact.

See and Avoid – The process in which a pilot sees a potential hazard and avoids the collision.

Current regulations address safety with limits for altitude, location, and line-of-sight control. UAVs must not be flown over 400 feet; they must not be flown near an airport, a wildfire, stadiums, or other restricted airspace; and they cannot be flown beyond line of sight (BLOS). However, violations and accidents will happen, and these safety restrictions will not prevent UAV collisions with other UAVs. Strict enforcement of existing FAA regulations are impractical or unfeasible. Also, the liability rules related to damage caused by and misuse of UAVs are not clear. Payloads are not restricted, and UAVs could be used to transport questionable items such as weapons or drugs.

Features to improve safety are being proposed by users and are being developed by UAV manufacturers. These safety features include “sonar, LIDAR, and even geo-fencing for short-range collision avoidance” and autopilot modes for “return to home,” “auto land,” and “hover in orbit” in case of unforeseen emergencies [4]. Also, frangible UAV structures are proposed in which the UAV is designed to disintegrate upon impact as a means to limit collateral damage. Such improvements come at a greater UAV cost and cannot handle all situations, e.g. weather. For instance, UAVs that have the anti-collision sensors are significantly more expensive than those without anti-collision capabilities. The DJI Phantom 3 (without anti-collision sensors) is estimated to be about $499 while the DJI Phantom 4 (with anti-collision sensors) is estimated to be about $1,399. With both of these UAVs on the market, the DJI Phantom 3 is the more economical choice.

B. Privacy Issues

Another concern regarding UAVs is privacy. The expectation of privacy regarding activities on one’s property (e.g. house and yard) is commonly held and supported through legal protections such as the U.S. Fourth Amendment. The use of UAVs in combination with high-performance cameras can be hard to detect and have made physical barriers virtually useless when it comes to protecting privacy. "The development of identification technology and detailed tracking is also being supported by political, legal, and market forces which are moving us toward a surveillance-based society. These technological and societal developments pose a serious threat to an individual's anonymity and personal privacy." [6]

Current FAA regulations do prohibit consumers from using a UAV to stalk others. "Flying a UAV over or near any house, occupied vehicle or other place where one may reasonably expect to be safe from uninvited intrusion or surveillance is a form of harassment that could be considered stalking" [7]. However, the protections of this policy are unclear when a camera-equipped UAV may be at high altitudes or at a large stand-off distance. Damaging images or videos from inadvertent use or intentional misuse of technology are common in the news. If UAV technology makes collection of such images and video easier, then new forms of security may be needed to protect personal privacy rights.

IV. Summary and Policy Recommendations

UAVs are very powerful technological devices with varied commercial and recreational applications. The capabilities and use of UAVs are expected to continue growing. The temporal disconnect between these technological developments and regulatory policy has resulted in significant concerns regarding safety and privacy. The potential for harm from accidents, misuse, etc. should be a priority. Commercial versus recreational use must be part of the considerations.

There are a few major concerns that should be addressed before allowing the public to fly recreational and commercial UAVs. Commercial operators need to obtain an RPC and follow the same rules that apply to recreational users. However, the rules are not that restrictive. The first, and main, problem is the capability of attaching dangerous payloads to UAVs (e.g. guns and explosives). Fifty-five-pound UAVs are capable of carrying larger and heavier weapons. The second major concern is the maximum speed that UAVs can operate. As vehicles operate at higher speeds, the severity of collisions increases. Reduced maximum speeds would limit the damage inflicted in a collision.

Regulatory changes in several areas could begin to address safety and privacy concerns.

- No-drone zones could be more clearly defined. Restrictions within heavily populated areas are reasonable.
- Guidelines for appropriate operational weight and speed could be defined.
- Insurance requirements could be mandated for specific situations.
- Anti-collision technology could be mandated for specific situations.
- Geo-fencing capabilities could be mandated for specific situations.

Regulatory change must balance the need to facilitate positive use of UAVs with the need to provide adequate safety and privacy safeguards.

References

1. Sara Bongiorni, *Recreational Drones: Out of Control*. (2016). Available http://www.consumersdigest.com/special-reports/recreational-drones-out-of-control
2. *Operation and Certification of Small Unmanned Aircraft Systems. Final Rule* Federal Aviation Administration, Office of the Secretary of Transportation, and Department of Transportation. (2016). Available https://www.faa.gov/uas/media/Sec_331_336_UAS.pdf
3. *Unmanned Aircraft Systems (UAS) Frequently Asked Questions. Federal Aviation Administration* (2017). Available <https://www.faa.gov/uas/faqs/#ffr>.
4. Rachel L. Finn and David Wright. *Unmanned Aircraft Systems: Surveillance, Ethics and Privacy in Civil Applications.* (2012).
5. Phil Harris, *DJI Geofencing System for Drone Safety*. DJI Innovations News (2016). Available https://www.rcgeeks.co.uk/blog/dji-geofencing-system-drone-safety
6. Shawn C. Helms, *Translating Privacy Values With Technology.* (2001). Available http://www.bu.edu/law/journals-archive/scitech/volume72/helms.pdf
7. Jen Fifield, *Data, Drones and Apps: States Debate Privacy Protections as Technology Speeds Ahead.* (2016). Available http://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2016/07/01/data-drones-and-apps-states-debate-privacy-protections-as-technology-speeds-ahead

Author Biography

Logan T. DiTullio is a senior at Clemson University in South Carolina. He is pursuing a B.S. in Electrical engineering and will graduate in the spring of 2018. He participated in the Washington Internships for Students of Engineering (WISE) program during the summer of

2016. This summary is based on his public policy research during that experience. The original paper can be found at http://www.wise-intern.org/journal/2016/documents/Logan_DiTullio_Paper.pdf.

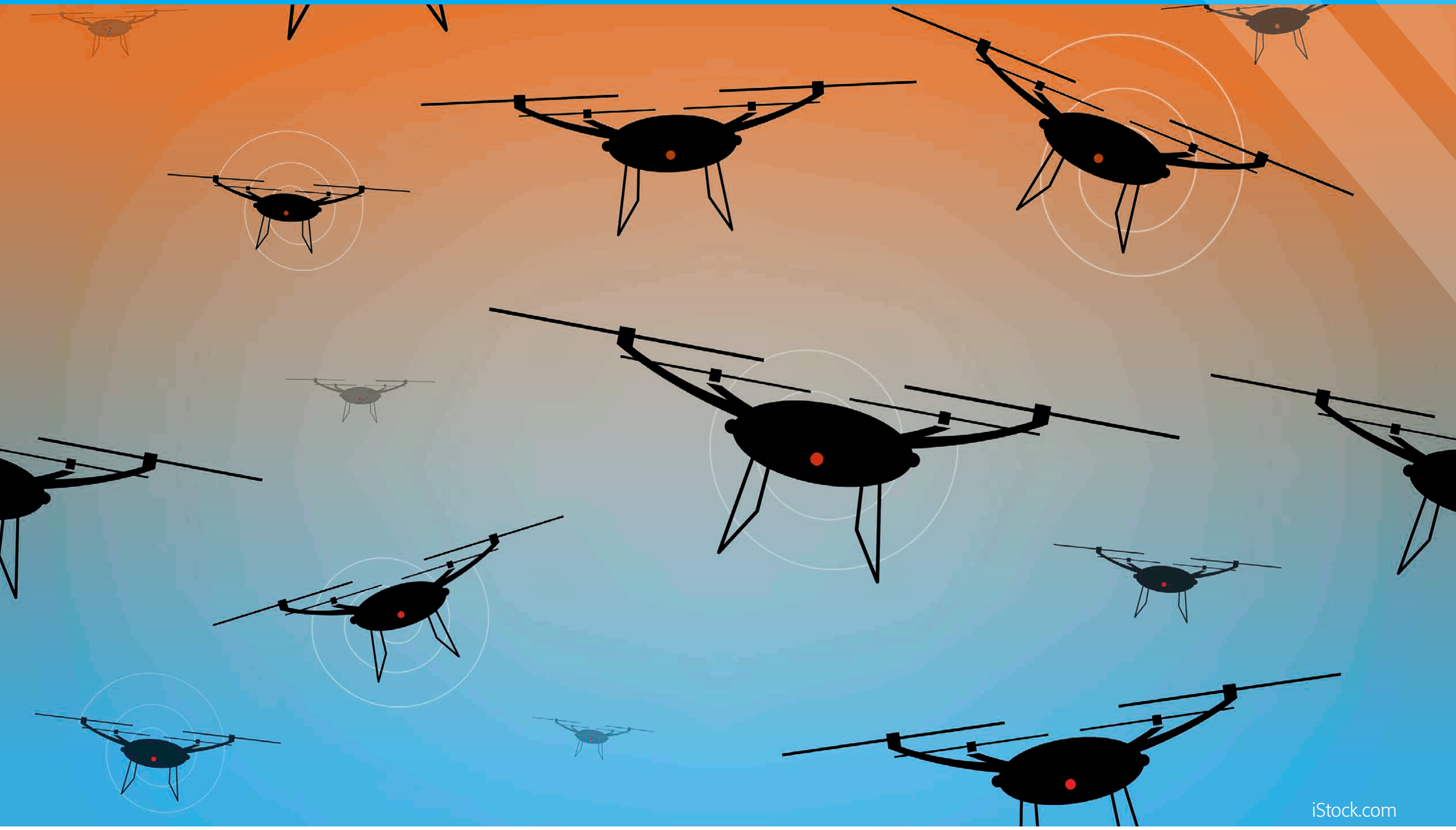
Engineering Internships in Public Policy

The Washington Internships for Students of Engineering (WISE) Program is an educational opportunity for engineering undergraduates to learn about and explore the issues related to science and technology public (S&T) policymaking. Third-year or fourth-year students and new graduates are selected through a national competitive process for a paid summer in Washington, D.C. The program includes mentoring activities on issues of engineering and public policy, interactive meetings with leaders in federal government and public policy organizations, and student research on an engineering-related public policy issue. A collaborative effort among several sponsoring engineering societies, WISE has operated since 1980. Students participate each year with sponsorships from the Institute of Electrical and Electronics Engineers- USA (IEEE-USA), SAE International, ASHRAE, ASTM International, American Nuclear Society, American Institute of Chemical Engineers, and American Ceramic Society.

The objectives of the WISE program are to teach students how S&T public policy decisions are made, to show students how engineers can contribute to legislative and regulatory decisions, and to guide students on an independent research project related to their sponsoring society. The 9-week schedule includes private visits with staff from congressional committees, administrators in executive agencies, reporters of the Washington press, members of lobbying organizations (including engineering groups), and other public policy leaders. Each student produces an independent public policy paper on an issue of their own choosing, which is published in the online *Journal of Engineering and Public Policy* and orally presented to the sponsoring societies at the end of the program. Information on the program and copies of past student papers are available at http://www.wise-intern.org. Student applications are due December 31, 2017 for the 2018 summer.

IEEE Sponsored WISE Interns for 2016
(L-R) Logan DiTullio, Jen Madary and Michael Crenshaw

WISE
Washington Internships for Students of Engineering


iStock.com

Connectivity in Networked Unmanned Aerial Vehicles

by: Rajdeep Dutta, Zachary Ruble, and Daniel Pack

Abstract

The versatility of Unmanned Aerial Vehicles (UAVs) has given rise to a rich area of research that spans an increasing number of technical disciplines. In many cases, the use of multiple UAVs for a given task not only provides robustness to individual UAV failure, but improves efficiency and operational capability through the sharing of information over wireless communications. Wireless communications between cooperative UAVs, however, can be negatively impacted by environmental obstacles and large distances between individual UAVs. In this paper, we present our recent developments in cooperative control of UAVs flying with desired communication 'connectivity'. The particular cooperative task pertains to a class of target tracking problems, where the goal is to drive UAVs to a symmetric formation surrounding a hostile mobile target while maintaining and preserving network connectivity.

R. Dutta is with the Computational Mechanics Laboratory, Department of Civil Engineering, Indian Institute of Science, Bangalore, KA-560012, India (e-mail: rajdeepdutta.iisc@gmail.com).

Z. Ruble and D. Pack are with the Unmanned Systems Laboratory, College of Engineering and Computer Science at the University of Tennessee, Chattanooga, USA 37403, (e-mail: daniel-pack@utc.edu)

I. INTRODUCTION

With the steady arrival of smaller more powerful embedded computers at reduced costs, Unmanned Aerial Vehicles (UAVs) have recently emerged as an inexpensive way to perform a wide variety of tasks, ranging from power line inspection in commercial applications [1], [2], [3], to intelligence, surveillance and reconnaissance (ISR) missions in military operations [4], [5], [6]. Many of these tasks are well suited for a network of UAVs, which provides greater flexibility, redundancy, efficiency, and overall operational capability over a single UAV. For example, a network of UAVs can share information on previously explored areas in a surveillance mission, reducing the overlap of areas already searched and further expanding the search area. If some of the UAVs in the network fail due to a battery shortage or unforeseen breakdown of software or hardware systems, the networked UAVs can be reconfigured to compensate for the loss or system failure.

In a team of cooperating UAVs, wireless communication plays a pivotal role in the efficiency and successful completion of distributed tasks, where shared information is necessary for the cooperation and coordination of UAVs. However, due to environmental obstacles and mission needs for UAVs to move beyond the wireless communication range of other units, consistent and stable communications often fail. For this reason, cooperative control techniques that strongly rely on multi-hop communication for distributed consensus must take into consideration the communication network topology for reliable performance and convergence. In these circumstances, the radio signal strength can be used for the guidance and control of UAV positioning to ensure network connectivity.

A common approach to topology control of networked UAVs uses a graph, where vertices represent individual UAVs and edges the communication capability between UAVs, i.e. there is an edge between two UAVs, if they are within a communication range of each other characterized by a pre-specified communication model. In this context, network connectivity is defined as the ability to successfully transmit information between any pair of nodes in the graph. A primary research area for cooperative control focuses on exploiting local information received from neighboring UAVs for rendezvous, flocking or formation. The goal of rendezvous is for UAVs to reach consensus on a single location and the time, while the goal of flocking is for UAVs to match velocities with their neighbors. Maintaining connectivity through formation control, which is the subject matter of this article, focuses on keeping a fixed relative distance between UAVs in the network.

Formation control of networked UAVs generally fall into two categories: leader-based and leaderless. Leader-based techniques either designate some UAVs as leaders or define virtual leaders that neighboring UAVs use as a reference. In leader-based formation, maintaining network connectivity is reduced to ensuring all existing communication connections are preserved throughout a mission. Leaderless approaches, on the other hand, are typically based on the algebraic connectivity of the graph [7] corresponding to the network topology. The algebraic connectivity, or sometimes called Fiedler value [7], is a connectivity metric based on the second smallest eigenvalue of a matrix that describes the connectivity of networked entities, called the Laplacian matrix [8]. The Laplacian matrix of a graph captures the network structure while the corresponding Fiedler value provides a measure of information exchange capability of the networked UAVs.

In general, there are three main existing approaches to control network connectivity: (1) optimization, (2) feedback and (3) hybrid. Optimization based approaches maximize the Fiedler value by applying non-increasing weights to the edges of the graph [9], [10], [11], [12]. Optimization techniques are well suited for UAV rendezvous missions, but are not appropriate for formation as maximizing the Fiedler value will continuously bring the team of UAVs together which may violate the desired spatial separation. The common approach in network feedback connectivity control is to design a closed loop system, where the input to the system is defined as the gradient of some potential field that treats connectivity violation as an obstacle. The network feedback connectivity approach ensures all edges present in an initially connected network are preserved for all time [13], [14], [15], [16]. Many of the recent methods that focus on maintaining communication connectivity utilize a variation of this idea. In the hybrid feedback approach, UAVs decide if edges may be deleted based on the network topology which give UAVs more freedom in control objectives such as exploration or coverage. A review of these approaches can be found in [17].

While there has been a considerable amount of research regarding the connectivity maintenance of cooperative robots, few have addressed achieving a desired time-varying connectivity profile. Introducing a controller that adjusts the relative position of UAVs to track a communication connectivity profile provides greater flexibility in cooperative tasks, where the environment may require UAVs to have differing levels of connectivity for a successful mission. For example, the required connectivity for shared information during a search and rescue mission may be lower for an open field compared to that of an urban environment where much more information is captured by sensors.

This article describes a leaderless, distributed approach for a network of cooperative UAVs to track a single ground target while maintaining desired network connectivity. In our approach, a UAV autonomously adjusts its position to establish a formation around a mobile ground target while simultaneously tracking a desired algebraic connectivity profile.

II. Representation of Swarm

A swarm of UAVs can be considered as a multi-agent graph with point-mass agents as graph nodes and inter-agent communication links as graph edges. In our previous work [18], [19], we assumed an undirected multi-agent graph where agents communicate through bidirectional links. The communication exchange topology among agents is considered as time-varying. In a two-dimensional (2D) realization, each agent has a circular communication range of equal radius, and an agent is connected to its neighboring agents situated in its circular neighborhood. The inter-agent connection strength decreases as the corresponding relative distance increases and the connection is lost when the relative distance exceeds a threshold value.

The inter-agent connections in a graph can be captured mathematically using the Laplacian matrix [8]. The matrix describes the connections among UAVs including weights that show the strengths of those connections. To model actual inter-agent communication limits, time varying weights are added to the graph edges to simulate decreasing signal strength relative to increasing inter-agent distances. We use an exponential decay model, where the communication capability reduces at an exponential rate with increasing distance between agents. As the Fiedler value of the Laplacian matrix gives a global connectivity measure of the network, a high value of connectivity is typically desired when there is a need for a large amount of inter-agent information sharing capability.

III. UAV Control

In the cooperative target tracking mission, UAVs aim to fly in a symmetric formation surrounding a moving target. Figure 1 shows a visualization of a group of UAVs flying in a target-centric formation. Starting from an initially connected, but arbitrary, topology, all UAVs move toward desired formations by utilizing appropriate control commands. A necessary condition for the success in a cooperative mission is to maintain the global connectivity throughout the formation process.

A. Target Tracking

The target tracking goal is to keep the mobile target at the center of the UAV formation, thus the target tracking goal is coupled with the formation controller. This is accomplished by ensuring there is a distance δ and angle ψ between each UAV and the target as shown in Figure 1. The majority of target tracking algorithms use a camera for visual detection and extraction of the target location. This requires the use of image processing algorithms, and filtering techniques to estimate the 3D position of the target using 2D information provided by the camera. As the focus of this article is formation control, we assume the target location can be obtained by at least one UAV. In our experiments, the target moves in a predefined pattern while the UAVs continually adjust their relative

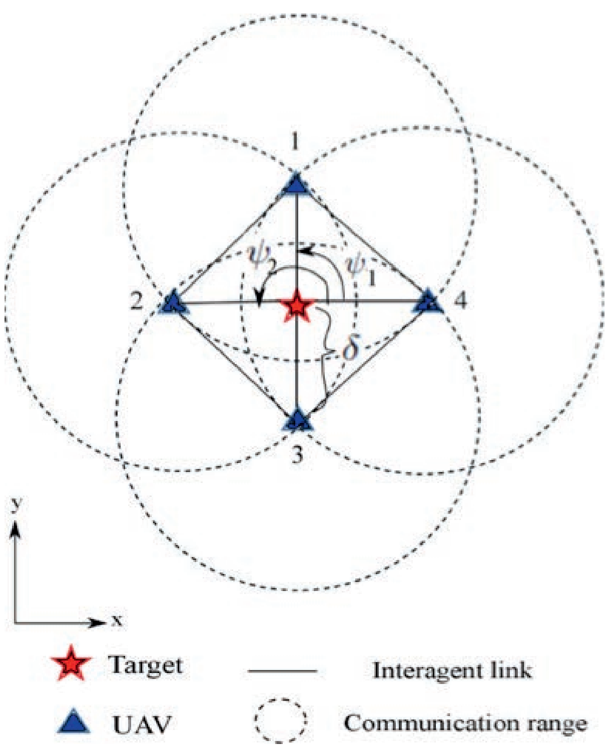
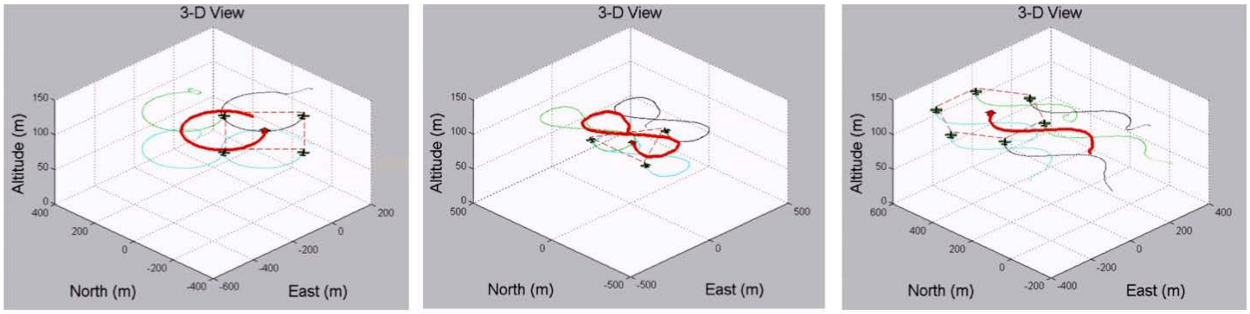


Fig. 1: A desired formation of four UAVs around a target.



(a) 3 UAVs tracking a target moving in a figure eight.

(b) 4 UAVs tracking a target moving in a circle.

Fig. 2: Target tracking for 3-6 UAVs with different target trajectories.

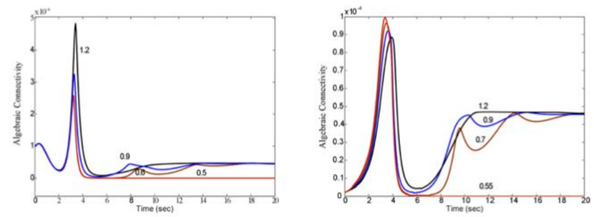
position and orientation to keep the target centered in the UAVs formation. All UAV dynamics are governed by a simple point-mass dynamic model for two degrees of freedom systems [19], and assumed to fly at a constant altitude on a 2D plane. The developed controller, formally defined in Subsection III-B, successfully tracks a target with different trajectories with a varying number of UAVs, as shown in Figure 2. The thick red line shows the target trajectory, the dashed line between UAVs is the polygon created for the desired connectivity, and the thin multi-colored lines represent the UAV trajectories.

B. Formation Control

The formation controller on each UAV makes decisions on position and orientation of the UAV based on the states of its own UAV and the neighboring UAVs. The controller is designed using the second order system $\ddot{\boldsymbol{p}}_i = M_i u_i$, where $\ddot{\boldsymbol{p}}_i$ is the acceleration of UAV *i*, *Mi* captures the UAV dynamics, and *ui* is the control input. The input to the system is then described by a proportional and derivative controller given as [4]

$$\boldsymbol{u}_i = \frac{M_i^{-1}}{\sum_{j \in N_i} w_{ij}} \sum_{j \in N_i} w_{ij} \left[\ddot{\boldsymbol{p}}_i - \alpha_1 \left(\hat{\boldsymbol{p}}_i - \hat{\boldsymbol{p}}_j \right) - \alpha_2 \left(\dot{\boldsymbol{p}}_i - \dot{\boldsymbol{p}}_j \right) \right], \quad (1)$$

where input, *ui*, is a vector containing the *ith* UAVs control inputs: acceleration and yaw rate. Vector $\hat{\boldsymbol{p}}_i$ represents the estimated position of UAV *i*, while $\alpha 1$ and $\alpha 2$ are controller gains. Each UAV determines its control inputs by comparing its position error and velocity, ($\hat{\boldsymbol{p}}, \dot{\boldsymbol{p}}$), with the position and velocity of other UAVs within its communication range. Controller weights, *wij*, are determined by the graph edge weights and are carefully chosen so that more control effort is applied to UAVs that are further away, providing support in improving the time-varying connectivity. When the relative position error, ($\hat{\boldsymbol{p}}_i - \hat{\boldsymbol{p}}_j$), and relative velocity, ($\dot{\boldsymbol{p}}_i - \dot{\boldsymbol{p}}_j$), converge to zero, then the multi-UAV network reaches the desired formation or position consensus.



(a) Good initial condition

(b) Poor initial condition

Fig. 3: Change in Fiedler value with varying damping coefficient.

Necessary theories with supported simulations [19], show the proportional gains, $\alpha 1$, have influence in the rate of formation convergence. Interestingly, the derivative control gains, $\alpha 2$, have influence in the slope of the achieved connectivity profile, which is exploited in our work for regulating connectivity covered in Subsection III-C. Bounds are determined for the controller gains to ensure a positive connectivity measure for all time during the formation process, and can be found in [19]. Figure 3 shows how connectivity profiles are smoother with an increase in the derivative control gain values while keeping the proportional gain fixed. Consequently, the total number of rises and valleys on UAV paths diminish, and UAVs attain a fluid path toward the desired positions for surrounding a mobile target.

C. Desired Connectivity

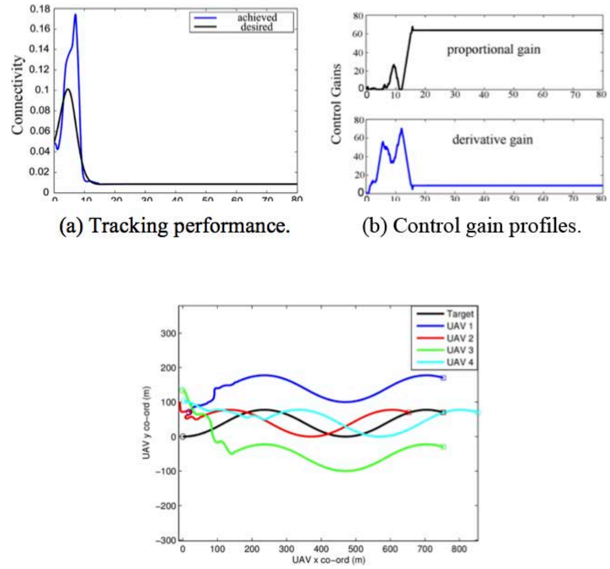
The problem of achieving a desired connectivity while making formation can be treated as an optimal control problem, where optimal control gains $\alpha_1^*(t)$ and $\alpha_2^*(t)$ are iteratively selected in time by minimizing a connectivity tracking error function, given by

$$E^*(t) = \min_{\alpha_{1ij}, \alpha_{2ij} \in S(t)} E(t) = \left[\lambda_2(t + \Delta t) - \lambda_2^d(t + \Delta t) \right]^2, \quad (2)$$

where $\lambda 2(t)$ and $\lambda_2^d(t)$ are the achieved and desired Fiedler values determined from the graph Laplacian, L_{n+1}, respectively. $E(t)$ represents the connectivity tracking error calculated one time step forward, and $E^*(t)$ is the minimum error. At each time instant, future desired and achievable Fiedler values are determined from a range of controller gains $\alpha 1$ and $\alpha 2$. The gains used to find $E^*(t)$ are chosen as the optimal gains $\alpha_1^*(t)$ and $\alpha_2^*(t)$.

To follow a desired connectivity profile, we apply identical time-varying gain values for all UAVs [18]. Constraints for the optimal gain search are posed carefully in concern with the feasibility of the proposed algorithm. At every time instant t, our proposed algorithm finds the current optimal gain values in a 2D search space in the neighborhood of the gain values determined at the previous time instant. This gain selection scheme avoids jumps in the time-varying gain profiles, and saves in invested control effort.

In simulations, we considered a specific desired connectivity profile where the Fiedler value increases exponentially at the initial stage, and then decreases at the same rate to finally settle on a specific Fiedler value. Such a connectivity profile is chosen to mimic a typical scenario where the multi-UAV group attains adequate information exchange capability at the early stage of a cooperative mission, and then gradually converges to a desired formation. Figure 4 shows a sample run of connectivity tracking using the controller in Equation (1) [18].



(a) Tracking performance. (b) Control gain profiles.

Fig. 4: Results of the network connectivity tracking over time.

IV. Future Work

When the task of multiple cooperative robots is formation, exploration, or area coverage, it is required that some level of communication in the network must be maintained. There exists, however, multiple formations that result in the same connectivity. Finding alternate formations that provide the same connectivity profile gives a group of UAVs flexibility in adding or breaking communication links, thus increasing its operational capabilities. Such capabilities could be useful in avoiding certain areas or obstacles by readjusting the formation accordingly and still maintain a specific level of connectivity.

V. Conclusion

Distributed controllers for driving multiple UAVs to a formation surrounding a mobile target while also preserving the time-varying network connectivity are becoming essential for multiple cooperative UAVs. We show one such controller that maintains the connectivity and enables UAVs to fly in varying formations using optimal gain tuning techniques. We expect that much efforts by researchers in the UAV community will further advance our knowledge of connectivity and formation in the near future.

VI. References

[1] D. Jones, "Power line inspection-a UAV concept," in *Autonomous Systems, 2005. The IEE Forum on (Ref. No. 2005/11271)*, 2005.

[2] J. Katrasnik, F. Pernus and B. Likar, "A survey of mobile robots for distribution power line inspection," *IEEE Transactions on Power Delivery,* vol. 25, no. 1, pp. 485-493, 2010.

[3] Z. Li, Y. Liu, R. Hayward, J. Zhang and J. Cai, "Knowledge-based power line detection for UAV surveillance and inspection systems," in *Image and Vision Computing New Zealand, 2008. IVCNZ 2008. 23rd International Conference*, 2008.

[4] M. E. Campbell and W. W. Whitacre, "Cooperative tracking using vision measurements on seascan UAVs," *IEEE Transactions on Control Systems Technology,* vol. 15, no. 4, pp. 613-626, 2007.

[5] M. Flint, M. Polycarpou and E. Fernandez-Gaucherand, "Cooperative control for multiple autonomous UAV's searching for targets," in *Decision and Control, 2002, Proceedings of the 41st IEEE Conference on*, 2002.

[6] J. Tisdale, A. Ryan, Z. Kim, D. Tornqvist and J. K. Hedrick, "A multiple UAV system for vision-based search and

localization," in *American Control Conference, 2008*, 2008.

[7] M. Fiedler, "Algebraic connectivity of graphs," *Czechoslovak Mathematical Journal,* vol. 23, pp. 298-305, 1973.

[8] C. Godsil and G. F. Royle, Algebraic graph theory, vol. 207, Springer Science \& Business Media, 2013.

[9] M. C. D. Gennaro and A. Jadbabaie, "Decentralized Control of Connectivity for Multi-Agent Systems," in *Proc. 45th IEEE Conf. Decision and Control*, 2006.

[10] Y. Kim and M. Mesbahi, "On maximizing the second smallest eigenvalue of a state-dependent graph Laplacian," *IEEE Transactions on Automatic Control,* vol. 51, no. 1, pp. 116-120, #jan# 2006.

[11] A. C. Satici, H. Poonawala, H. Eckert and M. W. Spong, "Connectivity preserving formation control with collision avoidance for nonholonomic wheeled mobile robots," in *2013 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2013.

[12] M. M. Zavlanos and G. J. Pappas, "Potential Fields for Maintaining Connectivity of Mobile Networks," *IEEE Transactions on Robotics,* vol. 23, no. 4, pp. 812-816, #aug# 2007.

[13] J. Cortes and S. Martinez, Distributed Control of Robotic Networks, Princeton University Press, 2009.

[14] Z. Kan, A. P. Dani, J. M. Shea and W. E. Dixon, "Network Connectivity Preserving Formation Stabilization and Obstacle Avoidance via a Decentralized Controller," *IEEE Transactions on Automatic Control,* vol. 57, no. 7, pp. 1827-1832, #jul# 2012.

[15] H. Yu and P. J. Antsaklis, "Formation control of multi-agent systems with connectivity preservation by using both event-driven and time-driven communication," in *Proc. IEEE 51st IEEE Conf. Decision and Control (CDC)*, 2012.

[16] M. M. Zavlanos and G. J. Pappas, "Distributed Connectivity Control of Mobile Networks," *IEEE Transactions on Robotics,* vol. 24, no. 6, pp. 1416-1428, #dec# 2008.

[17] M. M. Zavlanos, M. B. Egerstedt and G. J. Pappas, "Graph-theoretic connectivity control of mobile robot networks," *Proceedings of the IEEE,* vol. 99, no. 9, pp. 1525-1540, 2011.

[18] R. Dutta, L. Sun and D. Pack, "Multi-agent formation control with maintaining and controlling network connectivity," in *Proc. American Control Conf. (ACC)*, 2016.

[19] R. Dutta, L. Sun, M. Kothari, R. Sharma and D. Pack, "A cooperative formation control strategy maintaining connectivity of a multi-agent system," in *Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on*, 2014.

Biographies

Rajdeep Dutta received his PhD in Electrical Engineering from the University of Texas at San Antonio in 2016. He is currently a Research Associate at Indian Institute of Science, Bangalore.

His research interests include: Dynamics and Control, Cooperative Control, Game Theory, Localization and Mapping, and Inverse Problems.

Zachary Ruble received the B.S. degree in computer engineering from the University of Wyoming, Laramie, WY USA in 2007 and the M.S. and Ph.D. degrees in electrical engineering also at the University of Wyoming in 2009 and 2015 respectively. He is currently a postdoctoral fellow in the Unmanned Systems Laboratory at the University of Tennessee at Chattanooga, Chattanooga, TN, USA.

From 2010 to 2015, he was a Research Assistant with the Electrical and Computer Engineering Dept. at the University of Wyoming. Since 2015, he has been with the Unmanned Systems Laboratory at the University of Tennessee Chattanooga. His research interest includes cooperative unmanned systems, robotics, embedded systems, and distributed control systems.

Daniel J. Pack is the Dean of the College of Engineering and Computer Science at the University of Tennessee, Chattanooga. Prior to joining UTC, he was Professor and Mary Lou Clarke Endowed Department Chair of the Electrical and Computer Engineering Department at the University of Texas, San Antonio and Professor (now Professor Emeritus) of Electrical and Computer Engineering at the United States Air Force Academy (USAFA), CO, where he served as founding Director of the Academy Center for Unmanned Aircraft Systems Research.

He received the Bachelor of Science degree in Electrical Engineering, the Master of Science degree in Engineering Sciences, and the Ph.D. degree in Electrical Engineering from Arizona State University, Harvard University, and Purdue University, respectively. His research interests include unmanned aerial vehicles, intelligent control, automatic target recognition, robotics, and engineering education.

A Student-Built Fixed-Wing UAS for Simulated Search-and-Rescue Missions

by: Chase R. Yasunaga, Kalani R. Danas Rivera, Joseph D. Harris III, Marte A. Martinez Jr., Stephen L. J. Mau, Reyn H. Mukai, Kevin Y. Sonoda, Wayne A. Shiroma, and A Zachary Trimble
College of Engineering, University of Hawaii at Manoa

Abstract
Unmanned aerial systems (UAS) have become increasingly popular, especially as multidisciplinary projects in the engineering curriculum. This paper describes a student-built UAS that was entered in the 2017 Association for Unmanned Vehicle Systems International (AUVSI) Seafarer Student Unmanned Aerial System (SUAS) Competition, which simulates a search-and-rescue mission. A fixed-wing UAS was selected for its aerial endurance and long-range capabilities, and was equipped with autonomous capabilities, aerial data transfer, and aerial image capture with onboard image processing. The UAS is capable of autonomously navigating to a designated area and conducting a search for alphanumeric targets over the competition's 370,000-m^2 search area. The onboard image processing and computer-vision algorithms can correctly detect and define the alphanumeric targets with 75% accuracy. The UAS is capable of a 30-minute mission, which also includes dropping a water bottle to a simulated lost hiker.

I. Introduction

In today's world, the word *drone* means a variety of things to different people. To the general public, a drone is simply a nifty gadget or toy that is the perfect gift for any hobbyist or middle-school student for Christmas. To some, it is viewed as a necessary tool for capturing breathtaking views of landscapes, city skylines, and events for great video productions. However, we at University of Hawaii Drone Technologies (UHDT) view drones, or unmanned aerial systems (UAS) as they are more appropriately labeled, as effective tools for solving real-world problems [1]. The real-world problem that UHDT is specifically addressing is search and rescue (SAR).

Current solutions for SAR missions require costly manned aerial vehicles be deployed to the area of interest. A SAR vehicle deployed to rescue an individual costs the US National Park Service up to $220,000 [2]. Not only is the high operating cost a factor, but risks involving SAR crew safety is a concern as well. High risks to safety of both crew and target could compromise the SAR mission. Reducing operational costs and safety risks for SAR missions will lead to a more effective solution, motivating the need for a SAR-specific UAS [3]–[5]. Due to the unmanned aspect of a UAS, the safety and operational costs for a rescue crew are no longer ethical or financial concerns in SAR. Removing the onboard human operator reduces the required lift; therefore, less fuel is consumed and less powerful, and less expensive propulsion methods can be considered.

For SAR, the risks and consequences are real. Using real SAR missions as a testing method would be inappropriate. Finding an appropriate means of testing a SAR UAS during development is a must [6]–[8]. The Association for Unmanned Vehicle Systems International (AUVSI) Student Unmanned Aerial System (SUAS) competition simulates a SAR mission complete with waypoint navigation, target search and identification, and air delivery of a payload to a stranded individual [9]. The annual competition provides a comprehensive simulated SAR mission without the risks involved with an actual SAR mission.

This project was carried out as part of the University of Hawaii's Vertically Integrated Projects (VIP) Program [10]. The goal of the VIP Program is for students to work on a project over several years, so that a student rises in experience to the senior level and passes down the knowledge to new students joining the project. The team was comprised of approximately 20 undergraduate students in computer, electrical, and mechanical engineering of various academic standings ranging from freshmen to seniors.

II. System Overview

The system can identify specific targets of interests, such as alphanumeric targets of various shapes and colors in a specified area, and safely deploy a package to a specified target. To perform these tasks, the system is comprised of the following subsystems: air frame, air delivery, flight controller, image capturing and processing, communications, and ground control station (GCS). Figure 1 depicts the system-level diagram of the UAS. There are two major components: the aircraft and the GCS. The UAS must be able to have the appropriate usable flight weight and internal volume to accommodate all of the electronic components needed to complete the tasks of autonomous flight, target classification and localization, and air delivery.

For the simulated SAR mission, the UAS first navigates a set of waypoints provided by the competition. The UAS then searches a predefined 370,000-m^2 area for targets by capturing images every four seconds while flying a linear, cross-grain search pattern at an altitude of 70 m. While taking pictures, the UAS processes the images in real time on the onboard Raspberry Pi computer. The images are also sent to and processed on the GCS during post processing for redundancy. The processing algorithm filters images with possible targets and further analyzes them for color and shape of the detected target. The algorithm identifies at least two of the following characteristics: shape, background color, alphanumeric symbol, alphanumeric color, and GPS coordinates. Next, the UAS leaves the search area to fly to the specified air-delivery location where it deploys an 8-oz water bottle payload. Lastly, the UAS completes

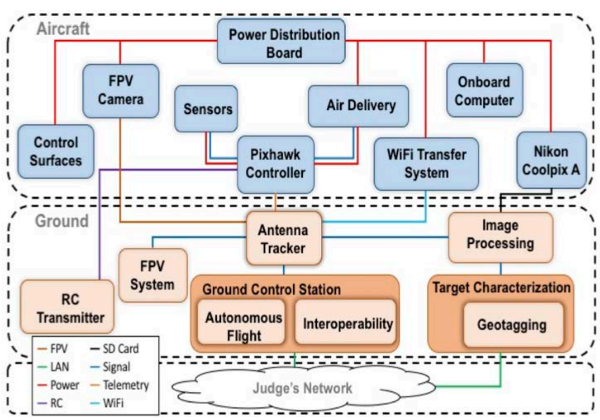


Fig. 1. System-level diagram of UAS

the simulated mission by returning home to the launch point and lands for recovery.

III. Onboard Electronics and Flight-Control System

The onboard electronics and flight-control system is responsible for the autonomous functionality and image-capture capabilities of the UAS. These two main electronic systems are illustrated in Figure 2.

The flight-control subsystem encompasses the flight electronics and autonomous functions. The core of this subsystem is the Pixhawk flight controller which integrates several external sensors for navigation and stable autonomous flight. The motors and control surfaces are also part of this subsystem and consumes most of the power. Power is supplied by two 14.8-V batteries with 16-Ah capacities. This yields an overall flight time of 30 minutes to an hour.

The image-capture subsystem's primary purpose is to handle the capturing, processing, and transferring of images to the GCS. The subsystem is comprised of a camera, an onboard computer, and a WiFi radio. The onboard computer is connected to the camera which sends the camera capture commands. The images are then offloaded to the onboard computer in real time. The radio is connected to the GCS over WiFi and forms a wireless bridge between the GCS and aircraft. The GCS then downloads the images from the onboard computer and stores the images for further use.

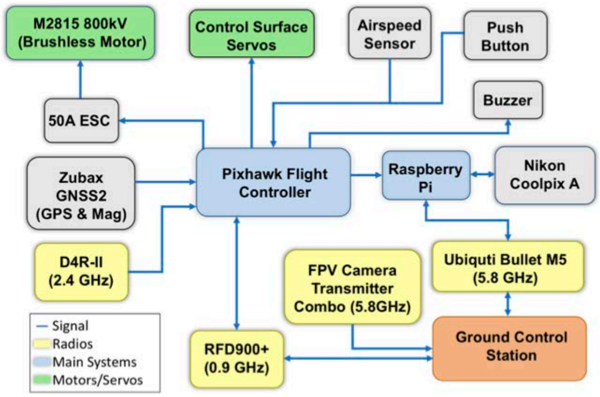


Fig. 2. Onboard electronics and flight-control system diagram

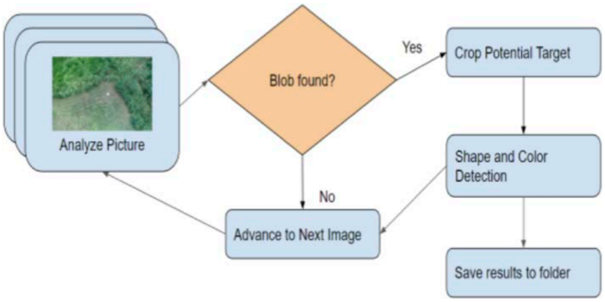


Fig. 3. Image processing workflow

IV. Imaging System

The image-processing system is responsible for analyzing target characteristics and estimating the geolocation of targets. During the simulated SAR mission, targets have five characteristics: background color, shape, letter color, letter, and letter orientation. It must be sufficiently lightweight to be included onboard the aircraft yet powerful enough to perform [11].

Images are first captured by a ground-facing Nikon Coolpix A camera controlled by a Raspberry Pi through the gPhoto2 interface library. A script on the Raspberry Pi triggers the camera to take pictures every four seconds to ensure proper search-area coverage. Each image is processed on the Raspberry Pi for targets and sent to the GCS for further analysis.

A custom C++ program using the OpenCV library is used to analyze captured images [12]. The program detects targets in an image, crops the target, and identfies the shape, background color, and letter color. It saves this cropped target to a folder of targets. After the program is finished, the GCS crew manually checks the folder to confirm the target and its characteristics. Figure 3 depicts the workflow used by the image-processing system.

For the geotagging task, the GPS coordinates of the image center are estimated using the aircraft's GPS coordinates, altitude, pitch, roll, and yaw. These values are fetched from the telemetry log file. An excel spreadsheet calculates the estimated GPS coordinates of the image center.

The C++ program was designed to filter out any image that has no targets detected, thus reducing the total number of raw images. This method is completed by using the OpenCV SimpleBlobDetector class [13], a basic algorithm that creates clusters of pixels based on color difference and thresholds. Images identified to contain possible targets are cropped to focus on the target. The next step involves applying Canny edge detection [14] to each cropped target. The algorithm takes the edges of each target and approximates the closest polygon matches. These approximated polygons are compared with a feature database of possible target shapes. If the target matches a valid shape, it is put through OpenCV kMeans clustering [15], a mathematical

Fig. 4. Target identified and extracted

model that elects k colors that represent the pixel space with the least error. The result of the kMeans clustering is identification of the two colors with the highest pixel spaces, the color of the target's background, and symbol color. Figure 4 depicts a target, a blue "H" on a red star", that has been identified and extracted by the computer-vision algorithms.

V. Communications

Communications on the UAS is handled by four transmitters/receivers. Telemetry data is handled by an RFDesign 900+ radio operating at 915 MHz. Featuring high output power and high receiver sensitivity, these radios were paired with low-gain antennas allowing for a high degree of freedom in radio orientation. Manual override for the flight controls operate on the 2.4-GHz band and features a one-way communication link from the remote control to the UAS. First-person view (FPV) video and image transfer are handled by two separate radios operating on the 5.8-GHz band. Both radios are configured to operate at different frequencies within the 5.8-GHz band. Due to the limitations of the WiFi-based radios for image transfer, directional antennas are used, requiring the implementation of an antenna tracker on the GCS. Due to the long ranges, Ubiquiti Network's AirMax technology is used which modifies the existing 802.11 standard to allow for higher losses and higher latencies. Average in-flight data rates are ~2.5 MB/s which allows for real-time image transfers.

Link budgets for the radio systems are used to tune the radios and ensure an operational range of 1 km. Figure 5 shows a diagram of the communication links utilized by the UAS.

VI. GCS

The GCS is a portable control center that provisions the facilities needed to interact with the aircraft. Architecturally, it consists of at least two computers, a router, and the radio components needed to communicate with the aircraft.

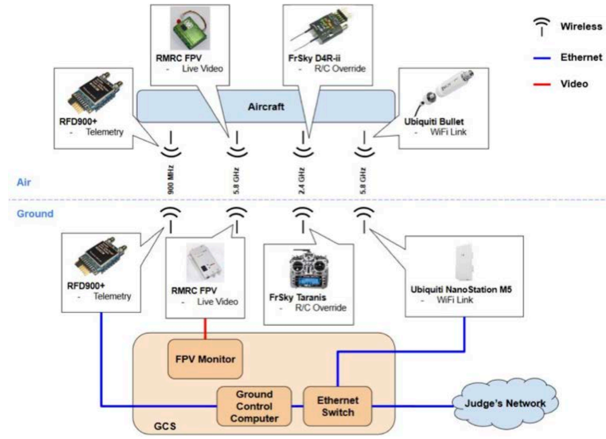


Fig. 5. Communications diagram

One of the computers is dedicated toward operating a ground station application, Mission Planner [16]. This open-source software is used to plan flights and monitor the health (location, airspeed, battery voltage, etc.) of the aircraft. Figure 6 shows the user interface of Mission Planner.

Another computer is utilized to interface the onboard computer. Interfacing the onboard computer is facilitated by the router which forms an 802.11N wireless point-to-point link between the aircraft and the GCS. A secure shell is established over this communication link for remotely interacting with an imaging camera. Images captured by the camera are synchronized on the GCS computers over a combination of Windows Network Sharing (Samba) and File Transfer Protocol SSL (FTPS). IP addresses of all systems on the router's network are statically assigned beforehand.

VII. Aircraft

When determining the type of airframe that would best suit the needs and functions of UHDT, both the multi-rotor and fixed-wing airframe designs were taken into consideration. Upon analysis, a fixed-wing airframe offered a longer flight time compared to a multi-rotor airframe, and for that primary reason, the commercial-off-the-shelf My Twin Dream (MTD) fixed-wing air frame was selected. The MTD airframe is made of high-quality EPO foam and equipped with fiberglass rods that run through the wings for support. The internal volume of the stock MTD is large enough to house all of the components necessary for both the electronics and image-processing subsystems with modifications to the airframe to properly house each component in their respective positions. The proper position for each component was determined by minimizing the overall moment produced by all components while maintaining an overall center


Fig. 6. Mission Planner user interface

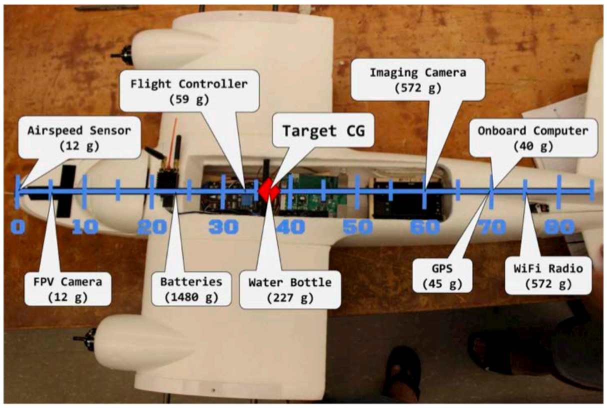


Fig. 7. Component placement

of gravity (CG) with good flight stability characteristics. Figure 7 shows a diagram of the component placement regarding the manufacturer's suggested CG point.

The MTD has full control over all three rotation axes (roll, pitch, and yaw) via ailerons, one on each wing, and an elevator and rudder, both located on the tail, for flight control. Propulsion for the MTD is generated by two brushless motors installed with 30.5-cm propellers that create a total combined static thrust of 4400 g at maximum throttle. The total weight of the system is 4.8 kg and has an experimentally verified maximum takeoff weight of 5.5 kg. The MTD airframe is illustrated as a three-dimensional SolidWorks model in Figure 8.

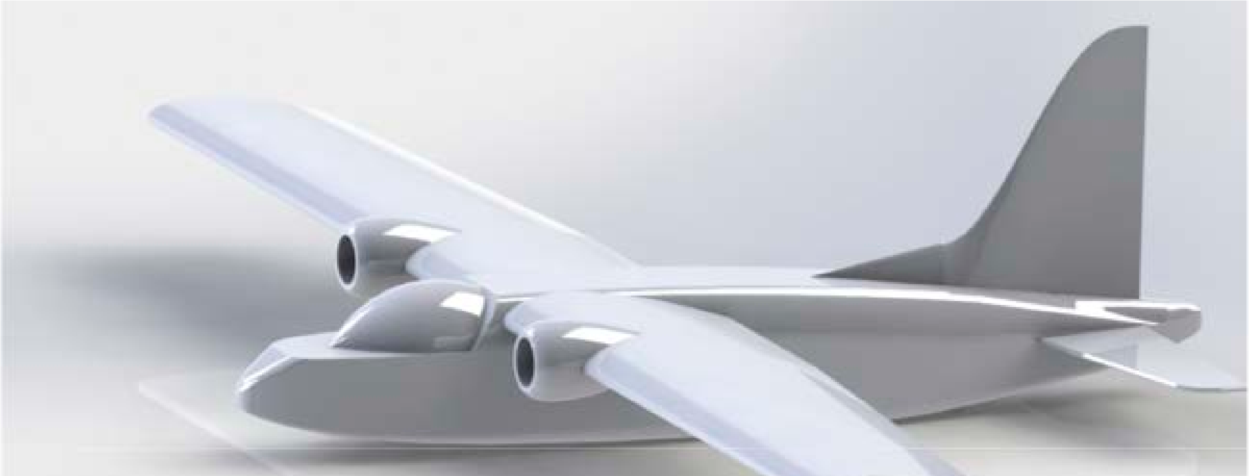


Fig. 8. 3D model of MTD in SolidWorks

Fig. 9. Air-delivery box installed in the aircraft

VIII. Air delivery

Air delivery is responsible for ensuring that an airdrop package, an 8-oz water bottle, can be deployed from the aircraft and arrive within 46 m of its intended drop location.

The air-delivery subsystem is divided into three major components: air-delivery box, air-delivery mechanism, and air-delivery capsule. The air-delivery box houses the air-delivery capsule and maintains the capsule at the aircraft's CG so that upon deployment, as the capsule leaves the aircraft, the CG of the aircraft is unchanged and flight stability is maintained. The air-delivery mechanism is composed of a servo motor-actuated latch whose activation opens a 3.2-mm-thick plywood bottom panel of the air-delivery box and deploys the air-delivery capsule from the aircraft. Figure 9 depicts the air-delivery box and its installment on the aircraft.

The air-delivery capsule is comprised of fiberglass-reinforced cardboard tubing and polyethylene foam cushioning, and is designed to fall with the foam cushioning contacting the ground and compressing upon impact, thus absorbing a substantial amount of energy. The energy that remains is then uniformly distributed to the sides of the 8-oz water bottle in the form of friction from tight-fitting fiberglass-reinforced cardboard tubing, ensuring its survival.

For successful air delivery, the air-delivery capsule must contact the ground with the foam cushioning first. The orientation of the air-delivery capsule in free-fall is stabilized with a 25-cm-diameter drogue chute containing a 3.8-cm-diameter spill hole. Figure 10 depicts the air-delivery capsule with the attached drogue chute.

IX. Conclusion

UHDT has successfully designed and developed an autonomous UAS that is capable of autonomous

Fig. 10. Air-delivery capsule with attached drogue chute

waypoint navigation, aerial image capture, target detection and identification, and communication to a GCS. UHDT placed sixth out of 54 teams in the 2017 AUVSI SUAS competition. The UAS has proven itself capable of executing a simulated 30-minute SAR mission within a maximum tested range of 1 km. The UAS is capable of autonomously navigating to a specific area of interest, searching a 370,000-m^2 area and identifying alphanumeric target with 75% accuracy, and delivering an 8-oz water bottle to a specific location (a simulated person in distress). This student-built UAS was developed with commercial-off-the-shelf components, resulting in a low-cost solution that addresses the high-cost issues faced by manned SAR operations.

A systems engineering approach was used in completing this project. A mission statement was defined to address the problem at a high level. Mission requirements were developed based on the mission statement. The mission requirements are further broken down into system requirements to define more details of the system. By creating a written set of requirements that follow the given constraints of the problem, the completion of the project can be confirmed once all requirements have been met.

To ensure the successful completion of this project, three main subsystems were created to fully address every aspect of the UAS. The three subsystems are aircraft, electronics and communications, and image processing. Each subsystem had a subsystem lead who would manage the members of their respective subsystem and report to the chief engineer. The Chief Engineer reports to the Program Manager, Team Captain, and Financial Officer to address programmatic aspects such as work hours, system performance and funding.

The VIP aspect of this project ensures that the knowledge and experience gained stays within the project for future use. This process creates stepping stones for the students to work from and continue to advance the project. Senior members of the project mentor newer members and pass on their knowledge. As the newer members evolve into senior members, it becomes their turn to mentor the new members. The cycle continues as each individual student progresses during their time working on the project and as the project matures. Both the project and the individual mature and progress resulting in a rich learning environment that is passed down to new students for their own experience with this VIP project.

Acknowledgment

The authors acknowledge the contributions made by past and present members of VIP UHDT. This work was supported by the Boeing Company, VIP Consortium, and the University of Hawaii College of Engineering. The authors wish to acknowledge the assistance and support of Mr. Ted Ralston and Mr. Iam Bouret for their knowledge and expertise in drone technologies.

References

[1] M. Ilarslan, M. K. Bayrakceken, and A. Arisoy, "Avionics system design of a mini VTOL UAV," *IEEE Aerospace and Electronic Systems Magazine*, vol. 26, no. 10, pp. 35–40, Oct. 2011.

[2] W. Ward, L. Park, and E. Coulson. *Park Operations: Economic Impacts of Search-and-rescue Operations on Wilderness Management in the National Parks* (n.d.): n. pag. *National Park Service*. Web.

[3] D. Erdos, A. Erdos, and S. E. Watkins, "An experimental UAV system for search and rescue challenge," *IEEE Aerospace and Electronic Systems Magazine*, vol. 28, no. 5, pp. 32–37, May 2013.

[4] H. Qin *et al.*, "Design and implementation of an unmanned aerial vehicle for autonomous firefighting missions," *2016 12th IEEE International Conference on Control and Automation (ICCA)*, Kathmandu, Nepal, 2016, pp. 62–67.

[5] Y. Naidoo, R. Stopforth, and G. Bright, "Development of an UAV for search & rescue applications," *AFRICON*, Livingstone, 2011, pp. 1–6.

[6] J. Roberts, D. Frousheger, B. Williams, D. Campbell, and R. Walker, "How the outback challenge was won: the motivation for the UAV challenge outback rescue, the competition mission, and a summary of the six events," in *IEEE Robotics & Automation Magazine*, vol. 23, no. 4, pp. 54–62, Dec. 2016.

[7] F. E. Schneider, D. Wildermuth, and H. L. Wolf, "ELROB and EURATHLON: Improving search & rescue robotics through real-world robot competitions," *2015 10th International Workshop on Robot Motion and Control (RoMoCo)*, Poznan, Poland, 2015, pp. 118–123.

[8] S. Kang, W. Lee, M. Kim, and K. Shin, "ROBHAZ-rescue: rough-terrain negotiable teleoperated mobile robot for rescue mission," *IEEE International Safety, Security and Rescue Robotics, Workshop,* Kobe, Japan, 2005, pp. 105–110.

[9] "Competition Rules | SUAS 2017." *AUVSI SUAS*. N.p., n.d. Web.

[10] A Z. Trimble, W. A. Shiroma, D. Garmire, and A. T. Ohta "Multidisciplinary vertically integrated project (VIP) teams at the University of Hawaii: challenges and synergy," *in 2016 ASEE Annual Conference & Exposition,* New Orleans, LA, June 2016.

[11] J. F. da Silva, A. V. Brito, J. A. G. de Lima, and H. N. de Moura, "An embedded system for aerial image processing from unmanned aerial vehicles," *2015 Brazilian Symposium on Computing Systems Engineering*, Foz do Iguacu, Brazil, 2015, pp. 154–157.

[12] "OpenCV Library." *OpenCV Library.* N.p., n.d. Web.

[13] OpenCV: CV::SimpleBlobDetector Class Reference. N.p., n.d. Web.

[14] "Canny Edge Detector." *Canny Edge Detector — OpenCV 2.4.13.2 Documentation*. N.p., n.d. Web.

[15] "Clustering." *Clustering — OpenCV 2.4.13.2 Documentation*. N.p., n.d.

[16] "Mission Planner." *Mission Planner Documentation*. N.p., n.d.

Biographies

Chase R. Yasunaga is a University of Hawaii at Manoa graduate with a BS degree in electrical engineering. He was the Program Manager for VIP UHDT from 2015 to 2017. During his time at the university, he was also involved in projects with the Hawaii Space Flight Laboratory.

Kalani R. Danas Rivera is a mechanical engineering undergraduate at the University of Hawaii at Manoa with an expected graduation date in Spring 2018. He has been a member of VIP UHDT since 2015. During the 2015-2016 academic year, he served as a member of the image-processing subsystem. Throughout the 2016-2017 academic year he was the subsystem leader for both the aircraft and air-delivery subsystems. His research interests include fluid mechanics, guidance and navigation controls.

Joseph D. Harris III is a computer engineering undergraduate at the University of Hawaii at Manoa. He has been a member of VIP UHDT since 2015 and has served as the Mission Operations Lead and Chief

Engineer. He has a passion for drone technologies which includes piloting racing drones as a hobby.

Marte A. Martinez is a University of Hawaii at Manoa graduate with a BS degree in mechanical engineering. He was the Team Captain for the 2016-2017 VIP UHDT. In his time at the university, he was involved in research for Instantaneous Screw Axis of a UAV and a member of the Pi Tau Sigma Mechanical Engineering Honor Society. He plans to work for an engineering firm and later continue his studies in engineering.

Stephen L. J. Mau is a senior computer engineering student at the University of Hawaii at Manoa. He first joined VIP UHDT in 2014. Since 2015, he has been the leader of the image-processing subsystem. His research interests include signal processing and big data analytics.

Reyn H. Mukai is currently pursuing a BS degree in computer engineering at the University of Hawaii at Manoa. He is involved in the Electrical Engineering Student Advisory Board, UH Drone Technologies, UH Smart Campus Energy Lab, and the 2017 IEEE MTT-S International Microwave Symposium STEM Program. His current research interests include software and smart device development.

Kevin Y. Sonoda is an electrical engineering undergraduate at the University of Hawaii at Manoa. He has been a member of VIP UHDT since 2015. He has had the responsibilities of GCS development and air-to-ground communications.

Wayne A. Shiroma is a Professor and Department Chair of Electrical Engineering at the University of Hawaii at Manoa, and also serves as the faculty advisor for the Delta Omega Chapter of IEEE-HKN. Since 2001, four of his students have won the Alton B. Zerby and Carl T. Koerner Outstanding Student Award.

A Zachary Trimble is an Assistant Professor of Mechanical Engineering at the University of Hawai'i at Manoa. Zac's research focuses on precision machine design, industrial automation and autonomous systems, and renewable energy. See rip.eng.hawaii.edu for more details.

▲ The University team and their entry into the 2017 AUVSI Seafarer Student Unmanned Aerial System (SUAS) Competition

Emerging Technologies Expert Nathalie Gosset Shares Career Highs & Lows in New WIE E-book

By Helen Horwitz

If you were to ask Nathalie Gosset what is on her career dashboard, the first word she would use is "volunteer."

That's because this Southern Californian believes being an IEEE volunteer has been as valuable to her career trajectory as the jobs she has had. "The time I've spent volunteering for technical professional societies after my work day has ended has been the number one booster for my professional advancement," she says.

After joining IEEE in 1989, Gosset quickly discovered that raising her hand brought many volunteer opportunities--with both the IEEE Buenaventura Section and several technical societies, especially the IEEE Engineering in Medicine and Biology Society and the IEEE Communications Society.

Gosset's 30-year career as an engineer has centered on emerging technologies, and her achievements built her reputation as a highly respected technology innovator. Most recently, she was Senior Director of Marketing and Technology Innovation at the Alfred E. Mann Institute for Biomedical Engineering at the University of Southern California, for the past 12 years.

How she developed her impressive career, as well as her encounter with workplace sexual harassment, is the subject of the newest volume in the award-winning IEEE Women in Engineering (WIE) e-book series. *Vignettes of Discovery and Growth: The Journey of a 21st Century Female Engineer*, by Nathalie Gosset, is the 16th work in the series.

In her e-book, Gosset recalls how, at a very early age, she processed and learned the math lessons her engineer father was teaching her. She writes that she actually saw shapes driven by arrangements that mirror the logic of mathematical principles.

"At an early age, I could solve problems in these imaginary worlds much faster than the traditional way," she writes. "As a result, I was acknowledged as a solid student in math."

The author is from the village of Danjoutin, in the Alsace Lorraine region of France. After five years of study in Paris, and receiving her BSEE engineering degree, she wanted to study further--in the United States. But obtaining the needed $15,000 for tuition and expenses at the University of Colorado, where she had been accepted to work toward a Master's in telecommunications, was an enormous problem. Gosset visited five banks in the Danjoutin area for a loan, but without her skeptical parents' signatures, she was turned down. Then, during a second round of bank visits, one officer agreed to the loan, with no collateral. "Instead," she says, "he wanted me to write to him once a month about my progress."

The author faithfully complied, and as soon as she graduated and started working, she regularly wired funds until the loan was repaid. "The banker's faith in me was a life lesson in trust, and inspired me to pay it forward," she says.

Her career took off with her first supervisory position at Alcatel and eventually included Sabeus, where she was vice president of engineering. Along the way, she acquired critical leadership lessons, such as not being afraid to have individuals on her technical teams who had more experience and expertise, and thus earned more, than she did. "If you do not work with the best, you will clip your own ability to learn and to help your team to succeed," she quotes her own manager at the time.

In a chapter titled, with some irony, "The Best Job I Ever Had," Natalie Gosset relates how she joined the Alfred Mann Institute (AMI) for Biomedical Engineering at the University of Southern California. Leveraging her technical and business knowledge, she advanced to Senior Director of Marketing and Technology Innovation Evaluation. In this role, she introduced many hundreds of physicians and researchers who wanted to share their product ideas, to AMI, then organized the studies to determine whether a new concept was suitable for the marketplace.

In this chapter, Gosset describes how the sexual discrimination and harassment she experienced on the job affected her, and the high price that she ultimately paid when she spoke up. The author lost both her job and her daughter's free tuition at USC. Because the case is currently in litigation, Gosset is limited by what she can write about it. However, she offers solid advice about what a person should do when confronted with what she describes as "a societal problem." She remains convinced about the value of engineering as a career for women. "With the right support from colleagues and supervisors," she concludes, "the engineering journey can be a remarkable ride!"

Except for the first book, an overview of STEM occupations, each volume is a personally written account of how a noteworthy woman technologist became interested in technology; obtained her education; and developed a productive, satisfying career.

This year marks the fourth year of the landmark e-book series. Educators and women's organizations have praised the series, for providing girls and young women with real-world role models of successful female engineers. In 2017, the publishing industry honored the series with 10 publishing industry awards.

Georgia Stelluto, IEEE-USA Publishing Manager; and Manager & Editor, IEEE-USA E-books, notes that the group offers a diverse cross-section of backgrounds, and each author has a distinctive story to tell.

Vignettes of Discovery and Growth: The Journey of a 21st Century Female Engineer, by Nathalie Gosset is available at http://shop.ieeeusa.org at the IEEE member price of $7.99; non-members can purchase the volume for $9.99 each.

Four more volumes in the IEEE-USA Women in Engineering series will be published in 2018. Recent e-books are:

- *Women in Engineering – Book 15: From Physics to Wall Street: My Accidental, Unplanned and Eclectic Life and Career,* by Rowena Track, Global Vice President of Digital, Channel and Partner Strategy and Marketing at Cigna Corporation.
- *Women in Engineering – Book 14: Becoming an Engineer Accidentally,* by Monique Morrow, CT – Evangelist for Cisco Systems' New Frontiers Development and Engineering.
- *Women in Engineering – Book 13: An Engineer in the Making*, by Susan Delafuente, a Silicon Valley technologist.
- *Women in Engineering – Book 12: It's Not a Career Path – It's an Obstacle Course! by Lisa Schoedel, a Chicago attorney.*
- *Women in Engineering – Book 11: Quietly, Clearly and Authoritatively* by Amy K. Jones, a senior systems engineer at John Deere.
- *Women in Engineering – Book 10: My Three Journeys: Finding Professional and Personal Fulfillment as an Engineer* by Oracle principal hardware engineer Jeewicka Ranaweera.
- *Women in Engineering – Book 9: Recognizing & Taking Advantage of Opportunities* by consultant Jill S. Tietjen, P.E.

All the above volumes, as well as the first eight in the series are also available at http://shop.ieeeusa.org/, and also are priced at $7.99 for members and $9.99 for non-IEEE members.

Helen Horwitz is an award-winning freelance writer who lives in Albuquerque, N.M. She was with IEEE from 1991 through 2011, the first nine as Staff Director, IEEE Corporate Communications.

Leaving a Legacy

By Stan Retif, IEEE Foundation, s.retif@ieee.org

People care.

They care about the needy and the underprivileged. They care about providing education to children and health care to the sick. They care about preserving history and celebrating culture. It truly is a remarkable phenomenon.

Every year millions of people make charitable gifts to organizations in whose mission they believe. Most gifts are made in cash, securities or some other liquid vehicle. Unfortunately those in a position to give don't always consider the variety of options available to them.

In previous issues of *The Bridge*, we have discussed the importance of estate planning. Time and effort spent planning today can ensure that your wishes are followed tomorrow. They can give you confidence that your estate will be directed as appropriate, and provide peace of mind to those you love.

Many donors in these situations have an asset that they don't normally consider when they think philanthropically – life insurance. In today's society life insurance has become increasingly prevalent. As such, donors who own policies would be wise to consider life insurance as an effective way of providing support to people and causes that they hold dear.

Making a gift of a life insurance policy can often significantly reduce a prospective donor's taxable estate, which can result in substantial tax savings depending upon the donor's income and potential tax liability. Gifting a policy can provide an immediate tax deduction of the fair market value of the donor's policy. As you can imagine, this can result in quite significant deductions, depending on the circumstances.

Some important points to remember when considering a gift to a charitable organization, such as IEEE-Eta Kappa Nu (HKN) include:

- IEEE-HKN receives the entire amount of the policy upon the death of the insured;
- There is no cap on the size of the policy that may be donated to IEEE-HKN, since charitable donations have no ceiling for estate tax purposes;
- In most cases such a gift does not alter a donor's current investment strategy;
- Such an arrangement may provide a creative way to dispose of a policy that was originally meant to cover a need that may no longer exist.

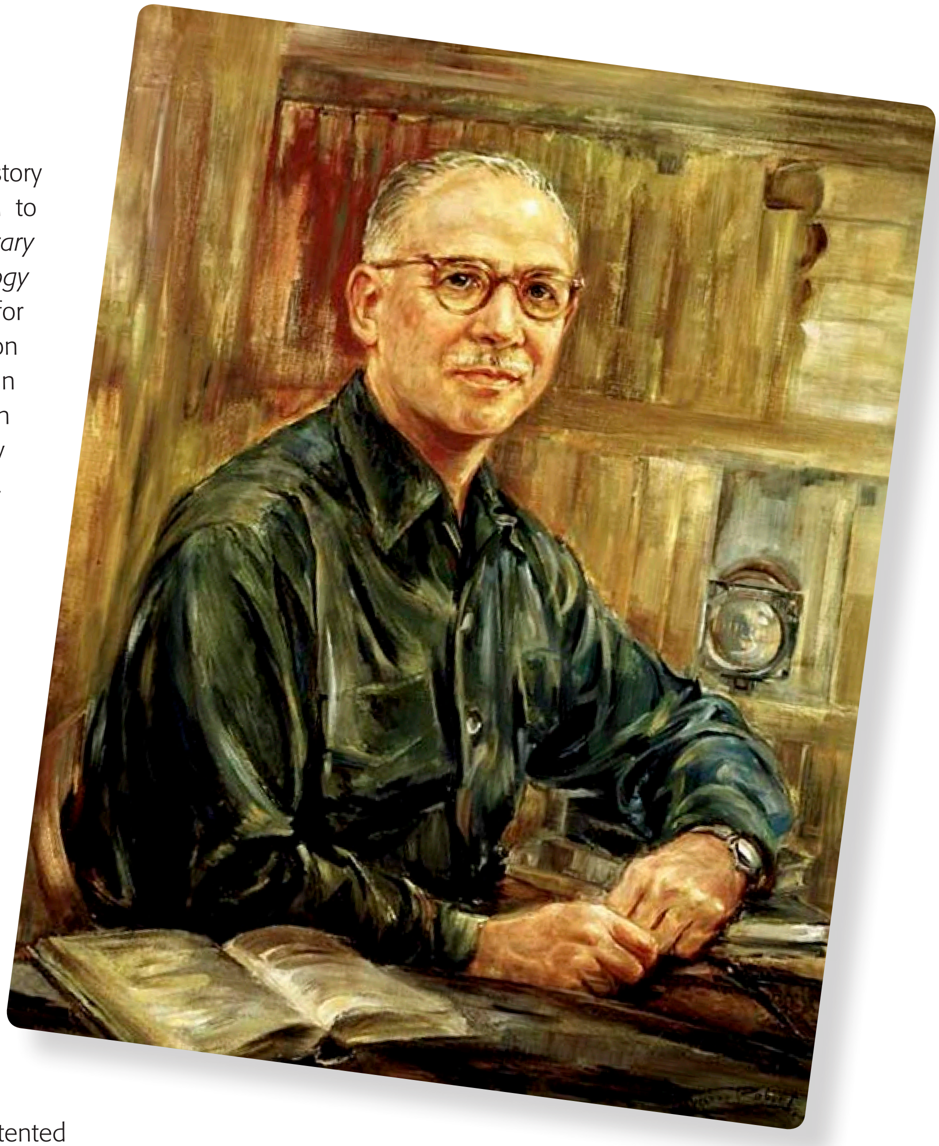
Naming IEEE-HKN as the beneficiary of your life insurance may be the simplest way to enact this transaction. It is a win-win for both IEEE-HKN and the donor. IEEE-HKN receives the proceeds from the policy, and by virtue of the gift, the donor's taxable estate is reduced by the amount of the death benefit.

To recap, by either gifting a policy or naming IEEE-HKN as beneficiary, donors can provide their beloved honor society with significant major support, thus providing a lasting legacy for a cause they hold dear. While the IEEE Foundation stands ready to assist donors considering such a transaction, it is always wise to first consult your own insurance agent or estate planner.

Bern Dibner

by: Steve E. Watkins

Two major library collections on the history of science and technology are attributed to an electrical engineer. The *Dibner Library of the History of Science and Technology* at the Smithsonian Institution is named for Bern Dibner, who made the initial donation of rare books, manuscripts, and portraits in 1976. This special collection is located in the National Museum of American History and includes works spanning mathematics, astronomy, chemistry, physics, technology, and engineering. The Huntington Library in San Marino, CA is the current holder of additional items related to the history of science and technology that were collected by Dibner. This later collection includes both written source material and many examples of antique scientific instruments.



▲ Bern Dibner, Electrical Engineer, Businessman, and Historian

Bern Dibner (1897-1988) was a successful electrical engineer and businessman before he became a noted historian and collector. He immigrated to the United States from the Ukraine as a child and graduated with an electrical engineering degree from Polytechnic Institute of Brooklyn in 1921. He invented and patented a solderless electrical connector, founded a related company, and continued innovating with a series of patents involving connection technology. He was a fellow of the AIEE.

Dibner's Ten Founding Fathers of Electrical Science:

William Gilbert
Benjamin Franklin
Andre Marie Ampere
Karl Friedrich Gauss
Joseph Henry
Otto Von Guericke
Alessandro Volta
Georg Simon Ohm
Michael Faraday
James Clerk Maxwell

He authored the well-known book, *Heralds of Science* (original edition 1955) in which he highlights two hundred of the most important works from his collection. As an electrical engineer, he had a special interest in electricity and magnetism. He also authored *Ten Founding Fathers of the Electrical Science* (1954), which was also published as a series by AIEE in *Electrical Engineering* (the predecessor to *IEEE Spectrum* magazine). IEEE Xplore archives this series (as shown in the table) as well as his series on *Early Electrical Machines* and other historical papers.

Welcome Back!

IEEE-HKN is proud to welcome back two chapters:

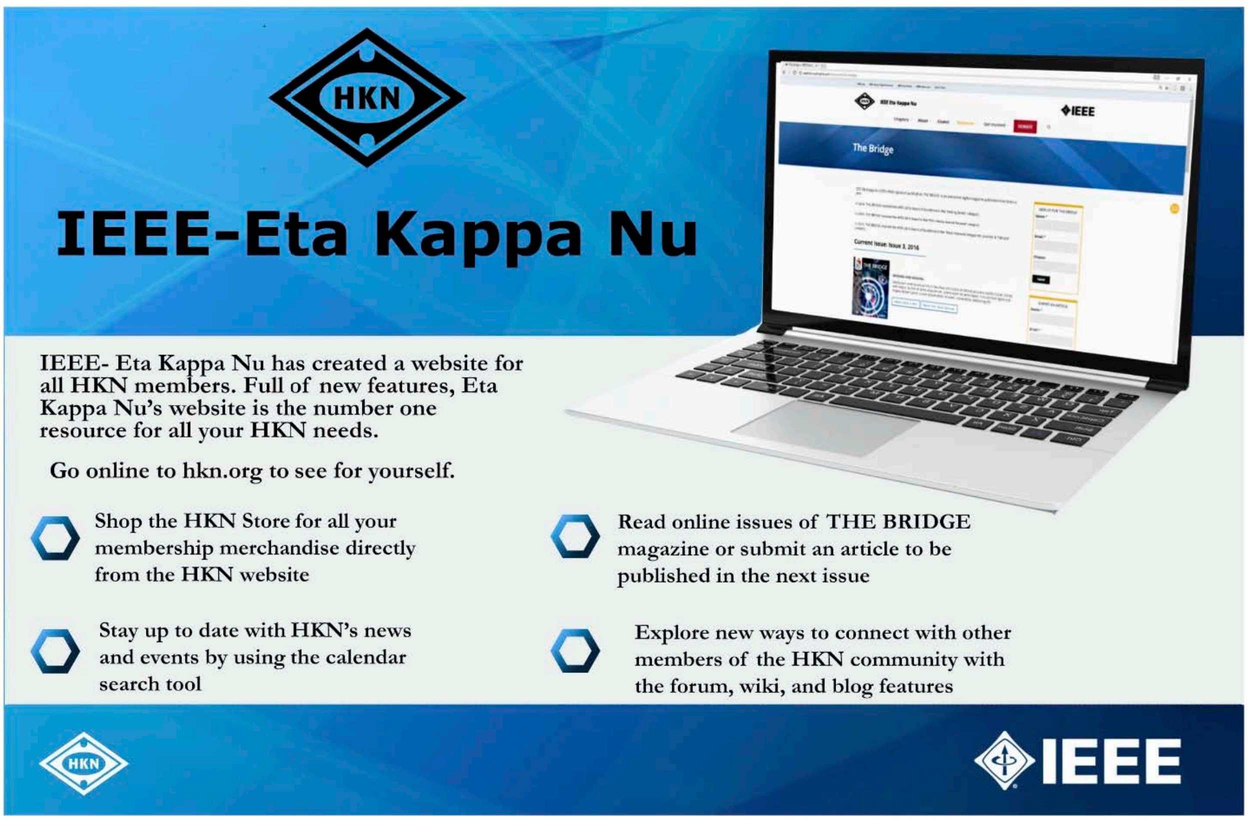
- Kappa Alpha Chapter at Northern Illinois University
- Zeta Pi Chapter at the University of Buffalo

Congratulations to both chapters! And we hope to welcome you at all upcoming events and gatherings!

Student Leadership Conference 2018

The IEEE-HKN Board of Governors is happy to announce that the next Student Leadership Conference will be hosted by Epsilon Sigma Chapter at the University of Florida between the 4/13-4/15. Further details will be announced shortly, including accommodation, schedule and registration.

Congratulations to Epsilon Sigma and we look forward to an amazing Conference!



What have our chapters been up to this year?

Here are some highlights of events from across our global community, displaying all of the core attributes required to be an outstanding member of IEEE-HKN!

Nu Chapter: Iowa State University

- **Code Camp**: The female members of the Nu Chapter volunteered to coach/ mentor all girl teams who had little or no programming experience during a 24 event similar to a hackathon. Each team was a group of 4 and each team had one mentor assigned to them. One of the teams with a member of our chapter as their mentor won the overall prize (pictured above). There were approximately 12 teams total competing, therefore, about 50 student participants were present at the code camp.
- **Nerd and Technology Trivia Night**: By collaborating with the ISU After Dark committee, we were able to host an event during the last ISU After Dark event for the Spring of 2017. We hosted a trivia night where approximately 50 students (throughout the night) competed for prizes in teams by answering trivia questions related to technology and pop culture.

Mu Eta Chapter: University of Kwa-Zulu Natal

- Community Uplifting by running laboratory sessions and other supplemental instructional lessons.
- Individual chapter members were granted awards for engineering innovations and scholarships.

Mu Nu Chapter: Politecnico di Torino

- Attended a closed workshop about Cyber security on the Automotive AizoOn Company headquarters. Shows how cyber security is important for today, especially in the automotive sector.
- Organized two seminars to educate students about the technical concepts behind ChatBot software integrated in many messaging services.

Gamma Mu Chapter: Texas A&M University

- **Howdy Farm:** Howdy Farm is a student-run organic sustainable farm on the campus of Texas A&M University. Volunteers would go to the farm and do basic farming duties such as removing weeds or cultivating ripe vegetation. Through this event we were able to promote sustainable living and provide healthy alternatives.
- **Tech Talk with Exxon Mobil:** Exxon Mobil expressed interest in establishing a recruitment team dedicated to Texas A&M University. The Gamma Mu chapter played a key role in helping to host a tech talk for electrical and computer engineering students. Both events were a huge success and Exxon has expressed interest in have special events with the Gamma Mu Chapter of HKN in future semesters.
- **HKN Officer's Soccer with SWE:** The officer team participated in the Student Engineering Council's Soccer Tournament. We competed against teams from other Engineering Organizations at Texas A&M. The officer team bonded in a fun but competitive match of soccer.

Delta Pi: Colorado State University

- Ms. Veronica Foster, the president (AY2016-17) of the CSU IEEE-HKN chapter participated as an invited panelist at an IEEE Student Professional Awareness Experience (SPAX) event organized by the CSU IEEE chapter in April 2017.
- CSU IEEE-HKN also organized professional seminars for students including *Keysight - Opportunities Within Companies, Working in Aerospace, and Revolutionizing Engineering Departments (RED).*

Beta Epsilon: University of Michigan

- **Club Scouts Day:** We partnered with our university's branch of Tau Betta Pi to host a Cub Scouts Day. Members of local Cub Scouts troops came to campus to earn their Engineering pins. Volunteers from HKN hosted the scouts and their parents and managed activities such as EECS Tutoring Program The EECS Tutoring Program (ETP) is one of the many ways that HKN gives back to the EECS community. The ETP facilitates tutoring between EECS students and is administrated by the EECS department. Tutors are required to undergo two hours of training to prepare them for the challenges of tutoring. Then, each week during the semester, the tutor will spend 2–3 hours helping other students in a particular EECS class. Currently, the ETP supports tutoring in circuits, programming, discrete math, signals, and systems. This is an efficient way for HKN to give back to the community, doing what it does best: EECS homework!

- **The dB Café:** The dB Café, formerly the HKN Donut Stand, is one of the most visible features of the EECS building. At the Café, we sell bagels, donuts, pizza, fruit, and much more. The dB Café is one of biggest ways in which we raise funds to subsidize our activities throughout the semester. We also offer corporate sponsorship opportunities, where sponsors pay for pizza, bagels, or donuts in exchange for the publicity and good will this fosters in the student body.

Kappa Upsilon: University of Texas at San Antonio

- Hosted a soldering workshop for high school students and has launched a peer mentoring program for lower division students.
- HKN has also been influential in the department-pushed online learning modules. Currently, six videos are available to students across two courses.

Epsilon Kappa: University of Miami

- **Raspberry Pi Competition:** A competition in which chapter members created and showed projects made with a raspberry pi (a computer the size of a credit card originally designed for education) to be judged by Nielsen representatives.

Beta Omega: University of Connecticut

- Beta Omega taped and published 10 tutoring videos to our HKN YouTube page, exploring a wide range of topics; from introductory circuits' courses, to digital communications, analog circuits, and even robotics. They plan on increasing their correspondence with their subscriber base by managing a secondary email to answer any questions from subscribers.
- **Reverse Career Fair:** We created a poster displaying the activities that we currently do as well as what we would like to do in the future. We had a booth set up at the Reverse Career Fair with this poster and business cards for each officer. During this fair multiple companies approached us and discussed holding a tech talk for our chapter or supplying us with funding of their own. This would be extremely beneficial to our chapter in helping with networking and internship and job opportunities.

IEEE-HKN currently has 254 chapters. These chapters reported over 91.000 hours of service to their communities. A directory of chapters is available on the new IEEE-HKN website

List of Candidates for the 2017 IEEE-HKN Board of Governors Elections:

Election Information:

- Each IEEE-HKN active chapter receives one vote in the election. To achieve "active" status, a chapter must have submitted inductee documentation and payment, or an annual report, to IEEE-HKN Headquarters at least once since 1 January 2014.
- The election will run during the period 1 October through 1 November. Each active chapter will receive an email link to the ballot. Each active chapter is asked to hold an IEEE-HKN meeting during this timeframe to explain the ballot and election process, distribute/review information on the candidates, and take a vote on each item as indicated on the ballot. If no regular meetings of the chapter are scheduled during this timeframe, a special meeting should be called.
- Each chapter will have one vote for each position, dependent on their region.
- It is critical that all active chapters participate in the election process. Every active chapter should make every effort to participate in this activity.
- If more than one ballot is sent from a chapter, the first one received will be the ballot that is counted and considered valid.

Election information and candidate bios can be found on our website. If you have any questions about this process, please contact info@hkn.org

2018 President-Elect:

- Mo El-Hawary, Lambda Theta Chapter
- Karen Panetta, Epsilon Delta Chapter

2018-2020 Region 5-6:

- John DeGraw, Upsilon Chapter
- Rakesh Kumar, Eta Chapter

2018-2020 Governor at-Large:

- James Conrad, Beta Eta Chapter
- Norliza Mohd Noor, Gamma Nu Chapter

2018 Student Governor:

- Michael Benson, Beta Epsilon Chapter
- Kathleen Lewis, Kappa Sigma Chapter

Tribute to Tom Rothwell: Mr. Eta Kappa Nu

Tom Rothwell, beloved member and a leader of Eta Kappa Nu passed away on July 14 2017. Tom was a dedicated volunteer and member since his induction at the University of Southern California, Upsilon Chapter in 1953, he served as Treasurer, Secretary, Vice President, and President of the Upsilon Chapter and the L.A. Alumni Chapter, and nationally as Director (1962), Vice President (2001-2002), President (2002-2003), and Past President (2003-2004). Tom served in every elected capacity that IEEE/HKN offers. Tom served as Chair of two national IEEE/HKN committees and as the Past Chair of The Outstanding Electrical and Computer Engineering Student of the Year Award. Tom was presented with the HKN Distinguished Service Award in 1999.

Tom's life-long passion of amateur radio ultimately resulted in Tom becoming an Electrical Engineer.

▲ S.K Ramesh, 2016 HKN President, presents a special plaque to Tom Rothwell in recognition of his contributions

Tom was veteran of both World War II and the Korean War, when he returned home from active duty he earned a Bachelor of Engineering degree with honors from the University of Southern California (USC), and a Master of Science in Electrical Engineering.

He joined the Hughes Aircraft Company his work included the design and implementation of computer-controlled test systems for the inertial guidance systems for the Minuteman and Titan Intercontinental Ballistic Systems. He retired from Hughes in December 1992.

Tom served his community and was appointed to the City of Los Alamitos, California Personnel Appeals Commission (1984), and served until 2004--the last six years as Chairman. In 1990, he was named the Radio Amateur Civil Emergency Service (RACES) Assistant Radio Officer for Los Alamitos. This RACES organization is nationwide and provides communications in support of municipalities and communities during emergencies. Tom was the Los Alamitos Citizen of the Year in 2005.

▲ John DeGraw, Tom Rothwell, and Eric Herz

Tom's dedication, concern, and contributions have played a significant role to distinguish Eta Kappa Nu as the premier Honor Society for our profession, and as a result, the Society continues its important role of promoting and recognizing excellence in electrical and computer engineering, from the college level through the professional level.

The IEEE-Eta Kappa Nu Board of Governors has recognized Tom for a lifetime of service and dedication to IEEE-Eta Kappa Nu.

Tom is survived by his daughter Laura and her husband Larry Fisher.

Saturday Engineering for Everyone

IEEE-HKN Alpha Chapter, University of Illinois at Urbana-Champaign

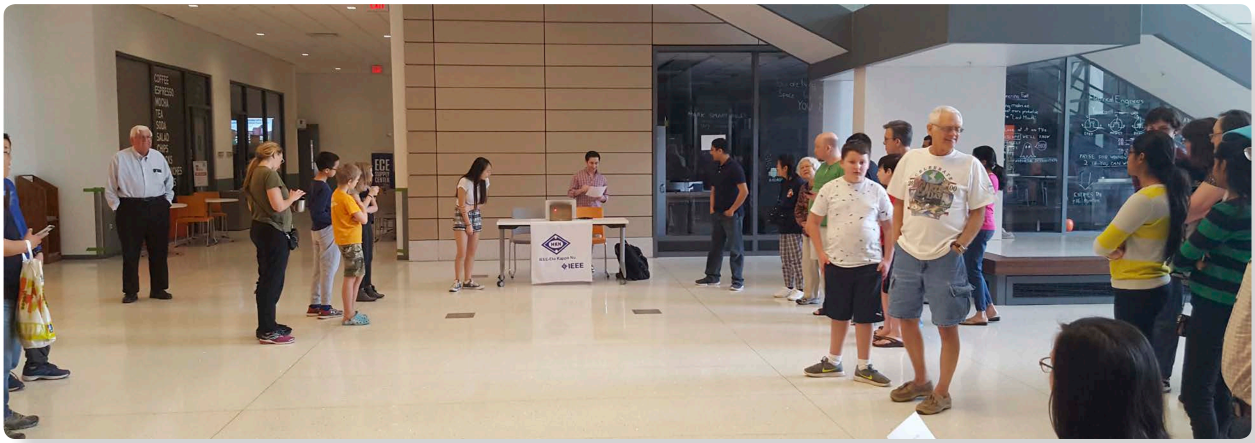
In an effort to actively educate and support fellow ECE undergraduates in their studies each year, the HKN Alpha holds dozens of exam review sessions, provides open office hours for any student, and schedules hundreds of one-on-one tutoring hours. However, in order to accomplish HKN's mission of encouraging and recognizing excellence in ECE, we expanded our outreach by educating anyone in the community about the immeasurable relevance of our field in society today.

Every spring, the ECE Department from the University of Illinois at Urbana-Champaign holds a technical lecture series titled 'Saturday Engineering for Everyone' for the Urbana-Champaign community at-large. The program serves to educate non-engineers on significant technological advancements and the physical world around them. The listener does not need to have any STEM background or relevant prior knowledge. This year, the two featured topics were drones and photonics.

The Alpha Chapter took it upon themselves to enhance these talks by constructing and staging related demos for the audience. Our demos provided a tangible and hands-on means to fully comprehend the topic on which a professor lectured. Following the talk on drones, we presented a facial recognition demo that showcased open-source libraries like OpenCV. We explained to listeners how drones could use the same technology to identify people or other points of interest. Further, we discussed how their favorite mobile applications, like Snapchat, could use the same concepts to apply novel filters to their photos and much more.

After the presentation on photonics, we set up an optical Morse Code generator using an Arduino, a couple photo resistors, a speaker and a laser pointer. Participants would stand on one end of the ECE Building Atrium (~50 feet apart) and use the laser pointer to illuminate each photo resistor. One sensor provided a short tone, while the other gave a long tone, just as is employed in Morse code. Thus, while one attendee was shining a laser at photo resistors, another one would stand next to the speakers and attempt to decode the sent message. Necessary precautions were taken to ensure the safety of those nearby. This demo provided a powerful example about how information can be sent using light. As one young participant exclaimed, "you mean I can say 'Hi' to my mom using lasers?" Cool, right?

As engineers, we know that not everything can be wrapped in a simple, insightful demo. It takes years to accumulate the knowledge and experience to be comfortable with these topics. Still, programs like these can have a significant impact by sparking an interest in a future engineer or educating an adult. We want to make the foreign a bit more familiar. Technology should not be mysterious or inaccessible, it should be intriguing and inspiring. We believe these talks give relevant examples that can motivate people to learn more or attend similar events. By using low-cost and easily-assembled demos, we further highlighted the accessibility of this learning to a wide audience. Here at the Alpha Chapter, we look forward to educating people inside and outside our department because knowledge becomes most rewarding when shared with others.



MEMBER PROFILE

Epsilon Eta Chapter

Doug Tougaw

Doug Tougaw received his B.S.E.E. from Rose-Hulman Institute of Technology in 1991, his M.S.E.E. from Notre Dame in 1994, and his Ph.D. in Electrical Engineering from Notre Dame in 1996. At that time, he joined the Department of Electrical and Computer Engineering at Valparaiso University, where he has taught for 21 years; he currently serves as Richardson Professor of Engineering and Department Chair.

Dr. Tougaw received his MBA from Valparaiso University in 2005, and his Master of Higher Education degree from North Park University in 2013. His scientific research interests focus on Quantum-dot Cellular Automata, a novel nanoscale computing architecture. He is also very active in IEEE and in ASEE, where he is serving as the Vice-President of Finance.

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

Engineering allows me to apply my love of math and science to solve problems and help make the world a better place. Having an opportunity to tackle interesting and challenging problems is great, but knowing that the solutions to those problems will help improve the lives of other people makes it all worthwhile. My favorite part about being an engineer is facing a problem that I know no one has ever solved before, and working to solve it. In that moment when I first solve the problem, I know that I am the only person in the history of the world to understand the solution. That is a very powerful feeling.

What do you love about the industry?

I love how rapidly it changes. Seeing how technology improves every year, I am able to update my courses and teach students new things that literally didn't exist the last time I taught the course. I love seeing emerging technologies and looking forward to what a great impact they will have on society once they are adopted.

What don't you like about the industry?

Since it is so rapidly changing, much of what I have learned is now obsolete. That's a shame, because those tools were really interesting, however, they have now been replaced by something newer and better. As I progress into the second half of my career, I also realize how hard I have to work to continue to keep my knowledge current.

Whom do you admire (professionally and/or personally) and why?

I admire anyone who dedicates their life to serving others. Whether as a high school teacher, a nurse, a fire fighter, or a stay-at-home parent, I have the greatest admiration for people who put the interests of others ahead of their own. The world gives us all an opportunity to be of service, and I admire those who answer that call with their whole heart.

How has the engineering field changed since you entered it?

In one word, computers. When I was a student in the 1980s, computers were tools that were sometimes helpful in solving very intensive problems. Today, computers are the essential tool for

It is essential to be able to effectively communicate your solution to others and to advocate for its adoption

solving all problems. The rapid cycle time in simulation and visualization allows us to solve problems that would have been completely impossible just 10 years ago. I look forward to seeing how we manage the transition to a world where computers directly solve problems with only limited intervention from humans.

In what direction do you think engineering and other IEEE fields of interest are headed in the next 10 years?

The role of data in our daily lives will become much more prominent than it is today. The rise of machine learning, wireless communications, and the Internet of Things will lead to transformations in all aspects of engineering. As with the rise of computing power over the past several decades, we will use these capabilities to find new ways to solve problems and new tools to address challenges that face us today.

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

I believe that when I was a student, I underestimated the importance of communication for an engineer. Being smart is not enough, nor is being good at solving problems. It is essential to be able to effectively communicate your solution to others and to advocate for its adoption. Those steps require highly effective writing and speaking skills. Increasingly, effective on-line communication skills are also becoming essential. I have just begun to learn how to create on-line videos, and they are changing the way I teach my classes. It is important to effectively use all of the communication channels available to you and to select the communication method that is most likely to reach your desired audience.

What advice can you offer recent graduates entering the field?

Work hard, learn everything you can, and be respectful to everyone. Remember that your first job very likely won't be your last job, and most of your promotions will be based on your interpersonal skills, at least as much as your technical skills. Study your leaders carefully to see what makes them effective or ineffective. Sooner than you think, you will be in a leadership position, and you will want to have developed a toolbox of effective leadership techniques before that day arrives.

If you weren't in your current field, what would you be doing?

I honestly struggle to imagine doing anything other than being an engineering professor. I'm called so strongly to this profession that even thinking about doing something else seems like a shame. But, if I had to do something else, I might become a solar energy engineer. I think that the next decade will see a tremendous increase in the prevalence of solar energy; and that seems like a job where the results of your work at the end of each day would be very tangible.

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

If I had more time, I would read more books. There is so much to learn and so little time to learn it all. That can be frustrating, but it is also inspiring. I am in awe at how much humanity has discovered and created, and I look forward to spending my life absorbing as much of it as possible.

MEMBER PROFILE

Iota Phi Chapter

Jonathan Dencker

Jonathan Dencker Originally from Brentwood, Tennessee, Jonathan attended the United States Military Academy in West Point, NY. He was President of the IEEE-HKN Iota Phi Chapter at West Point where he received his B.S. in Electrical Engineering with Honors, and Mathematical Sciences with Honors. He is currently commissioned in the U.S. Army as an Infantry Officer.

Jonathan's accomplishments include: Distinguished Cadet Award, Dean's List, and Superintendent's Award for Achievement (Top 10% of graduating class when Academic GPA, Physical GPA, and Military GPA are weighted equally); research sponsored by the Army Research Laboratory on vertical cavity surface emitting lasers resulting conference appearances at Photonics West 2016; ARL Technical Symposium 2016; and NCUR 2016…as well as publications in the SPIE and NCUR 2016 proceedings; and Internship at MIT Lincoln Laboratory's Division 7 focusing on Micro-Satellite Design.

Why did you choose to study the engineering field (or the particular field you are studying)?

I have always been genuinely interested in how things work, so I went to college knowing that I wanted to study engineering. I ultimately chose to study electrical engineering because it is one of the hardest majors offered at my school and I wanted to challenge myself.

What do you love about engineering?

What I love the most about engineering is understanding what's going on inside the black box. There are so many systems, particularly electrical systems that people use on a daily basis and have no idea how they work. Growing up right outside Nashville gave me a passion for music that exposed me to many of these black boxes. Playing guitar as a kid, I became familiar with effect pedals and amplifiers, but I had little understanding of how they produced their effects. Little did I know, as an electrical engineer I would be building my own audio amplifier and karaoke machine based on these very same principles. Electrical engineering allowed me to expand my horizons and dive deeper into the black boxes that control what I am passionate about and, that is what I love most about engineering.

What don't you like about engineering?

Engineering is very time consuming, as it should be. Unlike most engineering students, when I graduate I will immediately serve as an officer in the U.S. Army. The only thing I don't appreciate about engineering at my school is that it takes away from the time I could be using to prepare myself physically and mentally for my future job.

What is your dream job?

My dream job is to serve as a light infantry platoon leader in the U.S. Army. I have always wanted to be in the Army, and to me there isn't a greater job in the Army than a platoon leader in the Infantry. I'm extremely blessed to have the opportunity to commission into the Infantry in May and I can't wait to get to work. If I were to pick a dream job outside of the military, it would be as an engineer at a defense research laboratory or at an engineering firm that specialized in defense contracts. I believe when I'm done with my time in

> The most important thing I've learned in my four years at West Point is the importance of doing things that are hard. The only way to grow is to push your limits.

the military, working at a place like this would be a good transition back into the civilian sector where I can apply my first-hand knowledge and re-ignite my passion for engineering, all while continuing to serve my country.

Whom do you admire (professionally and/or personally) and why?

Professionally I admire Elon Musk because he started his companies solely to further technology for the benefit of mankind and has been extremely successful thus far. I also admire CPT Ryan Wilson, a mentor of mine for the past couple years, for the passion he brings to work every day and can't help but inspire in others. Personally, I admire my parents, who are two of the most resilient, dedicated, and hardest working people I know. I wouldn't be where I am today without their love and support.

In what direction do you think that engineering and other IEEE fields of interest are headed in the next 10 years?

I think that there is going to be a lot of growth in control systems, particularly in vehicles and biomechanical applications such as prosthetics. I believe that computers will undergo many changes in the near future, incorporating advances in quantum computing and integrated optics. I also believe that solar energy will become increasingly popular as its ability to be seamlessly and aesthetically integrated into systems continues to improve.

What is the most important thing you've learned in school?

The most important thing I've learned in my four years at West Point is the importance of doing things that are hard. The only way to grow is to push your limits.

What advice would you give to other students entering college and considering studying your major?

I would say a few things. First, make sure you are passionate about what you are doing. Second, get as much out of the experience as you can. Never just check the box and settle for passing by. The more you challenge yourself, the more you will get out of your experience. Take pride in the fact that what you are doing isn't easy, if it were anyone could do it, and ultimately it your willingness and dedication to working hard that will separate you from others, not only in school, but in everything you do. Finally, stay balanced. Make sure you are learning more than just engineering in college. Take time to experience the world around you and meet as many people as you can.

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

Get into mountain climbing. I've always wondered what it feels like sitting on the top of a mountain. If I had the time, I would definitely train up and try to climb Mt. Everest. That would be the experience of a lifetime.

IEEE Humanitarian & Philanthropic Opportunities

You can help advance technology for humanity by contributing your time, talent, and/or treasure to the diverse menu of IEEE humanitarian and philanthropic opportunities. Leverage the strength and reach of the IEEE network to make a difference worldwide.

#MyIEEEPledge
I will continue supporting and promoting EPICS in IEEE.

#MyIEEEPledge
To work with students and young professionals to seek out new humanitarian and philanthropic opportunities.

#MyIEEEPledge
To volunteer my time and talent to develop an IEEE SIGHT program in my country.

#MyIEEEPledge
I pledge a monthly donation to the IEEE History Center.

#MyIEEEPledge
I plan to start a Life Member group in my section.

#MyIEEEPledge
I pledge my support by donating to IEEE Smart Village.

#MyIEEEPledge
Help my section's Eta Kappa Nu chapters and develop a pathway program with STEM activities.

#MyIEEEPledge
I pledge to support internet inclusion for ALL and to get involved with HAC.

Doing good brings GREAT returns.

FIND OUT MORE AND MAKE YOUR PLEDGE

IEEE
Advancing Technology for Humanity

www.ieee.org/doing-good