The ION’s combined 2018 International Technical Meeting (ITM) and Precise Time and Time Interval (PTTI) meeting drew more than 300 attendees to Reston, Virginia, for a week of tutorials, technical presentations, announcement of The Institute’s annual awards (see accompanying article), and a special workshop of cognizant autonomous systems. Some 28 percent of the participants came from outside the United States to hear 135 technical papers and presentations. It was the first time that the ITM took place on the East Coast, reflecting the PTTI tradition of biennially rotating between the U.S. coasts.

A highlight of the event was a well-received plenary keynote titled “When Navigators Become the Scientists: NASA’s Magnetospheric Multiscale Mission (MMS),” presented by Dr. Barbara Giles, associate chief for the NASA Geospace Physics Laboratory.

MMS is a NASA solar-terrestrial probe mission comprising four identically instrumented spacecraft launched in March 2015 that use Earth’s magnetosphere as a laboratory to study the microphysics of three fundamental plasma processes: magnetic reconnection, energetic particle acceleration, and turbulence. Dr. Giles serves as the lead for the NASA MMS Fast Plasma Investigation, NASA Goddard Space Flight Center.

The MMS mission consists of spin-stabilized, formation-controlled spacecraft in highly elliptic orbits that, to the NASA researchers’ knowledge, achieved the highest-altitude operational use of GPS

KEYNOTE ON HIGHEST-ALTITUDE GPS NAVIGATION

ITM/PTTI Has East Coast Debut

T

MMS Navigator test unit in the thermal chamber is below.

Credits for both: NASA Goddard Space Flight Center photo
This past January the ION hosted a panel of well-recognized experts and leaders from government, industry, and academia in Reston, Virginia, who presented at the first Cognizant Autonomous Systems for Safety Critical Applications (CASSCA) Workshop.

The event, organized by Prof. Zak Kassas from the University of California, Riverside, addressed the opportunities and challenges associated with developing fully autonomous systems that are cognizant and trustworthy for demanding uses in aviation, industrial, and land vehicle environments. More than 100 participants attended the daylong workshop.

I attended and found the program to be extremely interesting and informative, since we were able to hear about autonomy for safety-critical applications from a wide variety of perspectives (commercial, R&D, policy, testing, procurement, legal, and even ethical). The speakers as a group described both the pros and cons of autonomous systems, and I have found myself referring back to things that I heard at CASSCA in many subsequent conversations I’ve had with colleagues about autonomy-related issues.

I would encourage you to read more about the details of the event on pages 6-7. The ION is planning an expanded workshop January 28–29, 2019, again in Reston, Virginia.

ITM/PTTI

The ION’s 2018 co-located International Technical Meeting (ITM) and Precise Time and Time Interval (PTTI) Meeting were held January 29–February 1. More than 320 attendees gathered to exchange academic PNT and timing advances.

Dr. Barbara Giles, associate chief of the Geospace Physics Laboratory and lead for the NASA Magnetospheric Multiscale Mission, presented the plenary keynote. Dr. Giles shared details of NASA’s highest-altitude operational use of GPS navigation to date. These involve the efforts of NASA’s navigation personnel to continuously adjust orbits, formations, and separations for the study of the phenomena of magnetic reconnection—a process that drives virtually all space weather events that can disrupt operations of orbiting spacecraft and lead to interruptions of GPS services, communications, and power systems.

The ION’s Annual Awards were presented and 2018 Fellows were named. See pages 8-9 for details. Congratulations to all our worthy recipients.

Council Meets

The ION Council, which serves as the organization’s board of directors, officially convened in January. Council members completed a number of action items including approving the prior year’s audit and financial statement, approving the budget for the coming fiscal year, adopting updated division and section logos based on the new ION logo approved last September, and approving an ION Ethics Enforcement Process (which members can find in the ION Governance section of our website).

JNC Moves West

The ION Military Division’s Joint Navigation Conference (JNC 2018) will move to the Hyatt Regency Hotel in Long Beach, California, July 9–12. Being located in the heart of the aerospace industry, we are expecting record attendance this year and the exhibit hall has already demonstrated significant growth.

An advance thank-you to The Aerospace Corporation for providing facilities for this year’s classified program and the Joint Navigation Warfare Center for hosting the classified program. (See www.ion.org/jnc for attendance requirements.) The JNC is a “must-attend” event for those who are involved in military PNT technology, and I hope to see many of you there!
The Purpose of the ION®

Founded in 1945, The Institute of Navigation is the world’s premier non-profit organization advancing the art and science of positioning, navigation and timing.

Executive Committee

President: Dr. John Raquet
Executive Vice President: Dr. Yu “Jade” Morton
Treasurer: Dr. Frank van Graas
Eastern Region Vice President: Dr. Anthea Coster
Western Region Vice President: Dr. Gary McGraw
Satellite Division Chair: Dr. Frank van Diggelen
Military Division Chair: Mr. Elliott Kaplan
Immediate Past President: Dr. Dorota Grejner-Brzezinska

How to Reach the ION®

Telephone: 703-366-2723
Facsimile: 703-366-2724
Web site: http://www.ion.org
E-mail: membership@ion.org

The ION® National Office Staff

Executive Director: Lisa Beaty
Program/Author Liaison/Executive Assistant: Miriam Lewis
Director of Information Technology: Rick Buongiovanni
Meeting Planner: Megan Andrews
Director of Membership & Marketing: Kenneth P. Esthus
Graphic Designer: Gwen Rhoads
Newsletter Editor: Glen Gibbons

Fun Facts about NAVIGATION

The NAVIGATION article with the most downloads from our website over the past two years has been, “Hostile Control of Ships via False GPS Signals: Demonstration and Detection.” Authored by Dr. Jahshan Bhatti and Dr. Todd E. Humphreys (University of Texas at Austin Radionavigation Laboratory) and published in the Spring 2017 issue, the article has been downloaded more than 1,500 times.

In the past year, the paper achieving the highest Altmetric Attention Score — which calculates a value for an article based on the quantity and quality of the attention it received via social media, blog posts, and newspaper and magazine citations — was “Absolute Positioning Using the Earth’s Magnetic Anomaly Field.” Authored by Dr. Aaron Canciani and Dr. John Raquet at the Air Force Institute of Technology and published in the Summer 2016 issue of NAVIGATION, media attention for this paper was fueled by a National Public Radio (NPR) news report (https://www.npr.org/sections/thetwo-way/2017/04/13/523450769/eels-may-use-magnetic-maps-as-they-slither-across-the-ocean?utm_medium=RSS&utm_campaign=storiesfromnpr) on eels’ innate sense of magnetic fields and their ability to navigate the ocean. The NPR article suggested this natural navigation as a potential alternative to satellite navigation and linked to the NAVIGATION article via the Wiley Online Library. (Since 2012, The ION has published NAVIGATION in partnership with John Wiley & Sons, Inc.)

yearly average number of citations to recent articles published in a journal. The JIF provides an indication of the relative importance of the journal within its field. Journals with higher impact factors — and citation rates — are generally recognized as more important than those with lower JIFs.

NAVIGATION’s JIF ranks ION’s journal in the top 10 academic journals in its class. We want to keep this high ranking. You can help us by staying aware of the current papers published in NAVIGATION and being generous in citing these manuscripts as you publish and present your original work.

Current articles in NAVIGATION can be found on the ION website at <https://www.ion.org/publications/browse.cfm>. Please share these resources with your colleagues and students.

USE NAVI GRAPHICS

Celebrating NAVIGATION, The Journal of The Institute of Navigation

NAVIGATION, The Institute of Navigation’s quarterly journal, continues to publish original, peer-reviewed articles on all areas related to the art, science and technology positioning, navigation and timing.

An important metric for NAVIGATION is the Journal Impact Factor (JIF), a measurement tool for academic publications used to calculate the
navigation to date. At orbit apogee, about 43,600 miles above Earth, the MMS navigator system determines the position of each spacecraft with uncertainties better than 50 feet.

Navigation personnel continuously adjusted orbits, formations, and separations for the study of the phenomena of magnetic reconnection – a process that drives virtually all space weather events that disrupt orbiting spacecraft and lead to GPS, communications, and power system interruptions. Magnetic reconnection refers to the places where the magnetic field of Earth connects to the magnetic field of the Sun, creating portals or openings where the solar wind can enter Earth's magnetic field. The sudden joining of magnetic fields can propel jets of charged particles from the point of entry.

**Technical Sessions: Multi-Technology, Autonomous**

The ITM side of the agenda reflected industry and academia’s increasing awareness of operational challenges to GNSS positioning, navigation, and timing (PNT) and the quest for alternatives and multiple integrated technologies. Session topics covered autonomous navigation as well as integrity for autonomous systems, GNSS augmentation and resilience, GNSS in Challenging Environments (two sessions), and interference mitigation.

PTTI topics continue to expand beyond institutional metrology and instrumentation advances to include more commercial applications including vehicle-to-vehicle communications, financial networks and power grids, and on board spacecraft.

The timing community also expressed a sensitivity to security issues, with an informational session chaired by NIST consultant Dr. Marc Weiss on the subject, “GNSS Timing Receiver Resilience Working Group - User Needs, Wants and the State of the Market.” The discussion revolved around plans for a one-day workshop sponsored by the ATIS industry forum on April 17 to identify what the telecom, electric power, and financial service industries really want and need for resilience in GNSS timing receiver systems and how
that matches with the state of the market and technology.

One presentation may have set a record for ION meetings, listing 41 co-authors on a paper entitled simply, “Project CLONETS.” Short for CLOck NETwork Services, CLONETS is a new, 30-month European Union funded project launched in January 2017 that is preparing the transition toward a permanent, pan-European, optical fiber-based network providing time and frequency comparisons. The system aims at distributing high-performance data for research infrastructures as well as support to a wide range of services for industry and society. The lengthy authorship reflects the composition of the CLONETS consortium formed by 19 organizations from seven European countries.

So many questions, so little time.

To paraphrase David Byrne, you may find yourself in a world of cognizant autonomous systems, and you may ask yourself, “What does it take to create these things?” And you may ask yourself, “Will cognizant autonomous systems eventually kill off humanity?”

These are just some of the queries addressed by a renowned lineup of speakers and panelists who participated in the inaugural Cognizant Autonomous Systems for Safety Critical Applications (CASSCA) Workshop, sponsored by The Institute of Navigation (ION) and held January 29 in Reston, Virginia.

But there were more questions — many more.

How will these systems transform society, and will society allow them to do so? What role will artificial intelligence (AI) play in cognizant autonomous systems for safety critical applications? Why is now the time to talk about designing these systems?

In Reston, four speakers took the stage in the morning session, followed by a panel discussion. The morning kicked off with opening remarks by the CASSCA 2018 organizer Dr. Zak Kassas, an assistant professor at the University of California, Riverside (UCR) and director of the Autonomous Systems Perception, Intelligence, and Navigation (ASPIN) Laboratory.

Dr. Kassas highlighted the astounding predictions of economic and societal impacts of future autonomous cyber-physical systems (CPS). For example, unmanned aerial vehicles (UAVs) over 10-years could generate 100,000 high-paying technical jobs and contribute $82 billion to the U.S. economy. Self-driving cars could save annually 30,000 lives and $190 billion in healthcare costs associated with accidents in the United States, while conserving seven billion liters of fuel and saving hundreds of billions of dollars in lost productivity.

Despite such optimistic predictions, however, Dr. Kassas pointed out that autonomous CPS could introduce unforeseen problems beyond those imagined thus far, raising such questions as, “How can humans and self-driving cars establish trust and converge on expectations? How fast are we likely to see a large number of autonomous vehicles on the road or in the national airspace? What are policymakers thinking about the actual transition period between no-autonomy and full-autonomy on the roadways?”

He then pivoted to discussing some of the technical and ethical challenges associated with developing fully autonomous, cognizant CPS, particularly GNSS jamming and spoofing and remote UAV and self-driving car hacking over wireless communication links. Dr. Kassas raised the issue of AI limitations and autonomous systems’ recent missteps, Tesla’s autopilot fatal crashes, and surrendering to a self-driving car such a decision as allowing the vehicle to hit a pedestrian in order to save the passenger’s life.

Other Voices

Following Dr. Kassas, the first morning speaker was Dr. Signe Redfield, roboticist and mission manager at the Naval Research Lab (NRL) and the Defense Advanced Research Projects Agency (DARPA), who talked about technical and cultural challenges for fielding autonomous systems. She discussed the hurdles of verifying that an autonomous robot can do the right task, is doing the right task, and contemplated: what is the right task, anyway? She also highlighted human-machine trust hurdles: how to measure trust and gradually increase trustworthiness.

The second speaker was Dr. Joao Hespanha, professor and past department chair of electrical and computer engineering at the University of California, Santa Barbara (UCSB), who focused on the opportunities and challenges in three domains: ubiquitous computation, and communication — devices are becoming extremely fast, cheap, low-power, and
Dr. Steven Rogers, senior scientist for autonomy at the Air Force Research Laboratory (AFRL), argued that AI will experience three evolutionary phases: How to describe? — inquiries first arising in the 1960–70s and focusing on handcrafted knowledge and complex programs with little data, How to classify? — emerging from the mid-’80s through the present time and focusing on lots of data, statistical learning, and machine learning; and How to explain? — which will appear in the future and focus on contextual adaptation and explainable AI. The third wave is where autonomy will be enabled.

Rounding out the morning speakers, Dr. David Corman, program manager of several programs at the National Science Foundation (NSF) including CPS, Smart and Autonomous Systems (S&AS), and Smart and Connected Communities (S&CC); highlighted the challenges associated with developing smart and autonomous CPS that are cognizant, taskable, reflective, ethical, and knowledge-rich. Particular challenges include understanding the decisions that are being made, evaluating and verifying the system behavior, modeling uncertainty in the environment, interacting with humans, and accepting these systems in safety-critical applications.

But That’s Not All
The afternoon session also comprised four speakers, who followed up their presentations with a panel discussion. The first, Dr. Paul DeBitetto, vice president of Top Flight Technologies, discussed how UAVs will revolutionize autonomous air transportation. He focused on the challenges of unmanned electric vertical take-off and landing (eVTOL) and hybrid-powered industrial platforms, particularly energy density, software-enabled safe autonomy, robust navigation, active sense and avoid, unmanned traffic management, and FAA regulations.

Next, Dr. Keith Redmill, research associate professor at The Ohio State University, addressed the new challenges facing the automotive industry relating to diagnosis, functional safety, and fault tolerance. He argued for the need to define automotive safety-integrity levels (ASIL) for automated vehicles and the features needed as we replace the human driver. Of particular importance will be security against hacking attacks and the safety of safety features (e.g., emergency braking, lane control and change, and reliable connectivity to other vehicles and the infrastructure).

Dr. Robert Peterson, professor and director of the center for insurance law and regulation at Santa Clara University, took on liability, insurance, and federal-
Congratulations ION Annual Award Recipients

EARLY ACHIEVEMENT AWARD
In recognition of outstanding contributions made early in one’s career.

Dr. Zheng Yao
For his pioneering contributions in developing new GNSS signals and multiplexing techniques; and advancing the Chinese BeiDou Navigation Satellite System (BDS) signal design.

SUPERIOR ACHIEVEMENT AWARD
For outstanding accomplishments as a practicing navigator.

Captain Gregory DuBose
For sustained performance in combat operations in Afghanistan, Iraq and Syria; and assistance in the recovery of a downed B-1 crew in Montana.

DISTINGUISHED PTTI SERVICE AWARD
To recognize outstanding contributions related to the management of Precise Time and Time Interval systems.

William Bollwerk
For service to the Department of Defense and country in promoting the importance of time, and educating policymakers and mission operators to ensure understanding of time in critical operations.

CAPTAIN P.V.H. WEEMS AWARD
For continuing contributions to the art and science of navigation.

Prof. Allison Kealy
For sustained contributions to advancing the art and science of navigation, and promoting and expanding the use of PNT among worldwide science and engineering communities.

THOMAS L. THURLOW AWARD
In recognition of outstanding contributions to the science of navigation.

Dr. Yang Gao
For significant and sustained contributions and leadership in the development and application of Precise Point Positioning (PPP) and high-precision GNSS technology.

NORMAN P. HAYS AWARD
In recognition of outstanding encouragement, inspiration and support contributing to the advancement of navigation.

David A. Turner
For his role in the formation of the International Committee on GNSS (ICG) and the development of globally recognized principles of GNSS compatibility, interoperability and transparency.
CASSCA 2018 RECAP

Dr. Zak Kassas

ism issues associated with self-driving cars. He described the self-driving car “vehicle threat vectors” and explained how public policy surrounding automobile insurance could evolve to account for new costs, human factors, vehicle-to-vehicle and vehicle-to-infrastructure failure, and state versus federal legislation.

Finally, Mr. Loren Smith, senior advisor to the Under Secretary for Policy at the U.S. Department of Transportation (DoT), discussed the evolution of legislation and infrastructure to support the introduction of self-driving cars. He also touched on how policymakers are thinking about the interplay between safety concerns and the importance of innovation, the transition period between non-autonomy and full-autonomy on the roadways, and public acceptance of fully-autonomous cars.

CASSCA 2018 was well-attended and well-received, infusing autonomy thinking into the ION community and attracting many attendees new to the ION. The International Technical Meeting/Precise Time and Time Interval Meeting took place later that week. (See article beginning on page 1.) Building on the success of CASSCA 2018, an expanded CASSCA 2019 is planned for January 28–29 in Reston, Virginia.

While CASSCA started with a promise to answer some lingering questions, it ended up stimulating many more provocative questions, which only we, cognizant beings, can tackle — at least for the time being.

ION’s 2018 Fellows

The Fellows designation recognizes the distinguished contribution of ION members to the advancement of the technology, management, practice, and teaching of the art and science of navigation, and/or for lifetime contributions to the Institute.

Prof. James Garrison
For contributions in developing and applying GNSS reflectometry methods for space-based and airborne remote sensing of oceanography, agriculture and hydrology; and expanding these methods to other signals-of-opportunity.

Prof. David Last
For distinguished and sustained technical and strategic contributions, leadership, and guidance to fellow practitioners in terrestrial and space-based positioning, navigation, and timing (PNT) solutions.

Dr. Yuanxi Yang
For leadership and technical contributions to the development of the Chinese BeiDou Navigation Satellite System and his effort in promoting international collaboration in satellite navigation.

Dr. Luke B. Winternitz, Dr. William A. Bamford, Samuel R. Price, Dr. J. Russell Carpenter, Anne C. Long & Mitra Farahmand

DR. SAMUEL M. BURKA AWARD
To recognize outstanding achievement in the preparation of a paper contributing to the advancement of the art and science of positioning, navigation and timing.

Ion GNSS+ 2018, the ION Satellite Division’s annual conference and exhibition, will continue the program of short courses, introduced at last year’s event and offered free of charge to all paid ION GNSS+ attendees with the compliments of the Satellite Division and the ION’s Master Instructors. The 90-minute short courses will be presented lectured style on a variety of topics including:

- GNSS 101: An Introduction
- GNSS 102: Measurement from Phones
- Approaches for Resilient and Robust PNT
- Using a Sextant: Celestial Navigation
- Sensor Navigation for Personal Navigation
- Vision Navigation Using Open CV

The goal of the short courses is to help prepare attendees to receive the full benefit of the week’s technical presentations, provide an update and refresher course and for those in the industry, and to hear the viewpoint and expertise of some of the world’s foremost authorities on the topics.

The short courses will be taught by “ION Master Instructors,” all of whom are internationally recognized GNSS experts and educators. The “ION Masters” have generously donated their time and talents to this effort, as a service to the GNSS community, with the ION’s gratitude.

Plenary: LiDAR, Mayan Mapping Project, and Android Emergency Location

The Tuesday night plenary session will feature Dr. Paul LaRocque, vice-president of special projects at Teledyne Optech where he has been involved in the development of Optech’s lidar systems since the late 1980s. In his remarks, Dr. LaRocque will describe the efforts of The Foundation for Maya Cultural and Natural Heritage, or PACUNAM, to map more than 800 square miles in northern Guatemala during an archaeological survey. Dr. LaRocque was instrumental in the design of Optech’s airborne lidar bathymeters, airborne lidar terrain mappers (ALTM), and waveform digitizers, as well as other special lidars used by PACUNAM in the mapping project.

The PACUNAM survey found more than 60,000 houses, places, roads, and other human-made features using LiDAR technology, the largest LiDAR data set ever procured for archaeological research, according to published reports. With the aid of LiDAR, scholars were able to digitally remove the tree canopy from aerial images of the now-unpopulated landscape. In doing so, they revealed the ruins of a sprawling pre-Columbian civilization that was far more complex and interconnected than most Maya specialists had supposed, according to a February 2018 report by National Geographic.

Steve Malkos, a technical program manager at Google, will also address the ION GNSS+ plenary audience, speaking on the subject of emergency location services on mobile devices with Android operating systems. Today, more than 80 percent of calls to emergency services come from mobile phones, but locating these mobile callers can be a major challenge.

With more than 500 abstracts received for this year’s technical program, attendees can also expect another outstanding technical program and dynamic commercial exhibit – all hosted in sunny Miami, Florida. Mark your calendar – September 24-28, 2018. See you there!

Call for Nominations

The Johannes Kepler Award

Nominations Due: June 30

Presentation of the Johannes Kepler award takes place at the Satellite Division’s Annual ION GNSS+ in September. The purpose of the Kepler Award is to honor an individual for sustained and significant contributions to the development of satellite navigation. All members of the ION are eligible for nomination. A special nominating committee determines the winner of the award, which is presented only when deemed appropriate.

ION members are encouraged to submit nominations for deserving individuals. For complete nomination instructions, and to submit a nomination, go to www.ion.org/awards, and click on “Kepler” in the left-hand menu. Nominations must be received by June 30.

For a complete list of previous winners online, visit <www.ion.org/awards/kepler-award.cfm>.
ION GNSS+ 2018

The 31st International Technical Meeting of the Satellite Division of the Institute of Navigation

September 24–28, 2018
Tutorials: September 24 and 25
Exhibit Hall: September 26 and 27

Hyatt Regency Miami
Miami, Florida

Register Now

www.ion.org
Dr. José Ángel Ávila Rodríguez is GNSS Evolutions Signal and Security Principal Engineer in the Directorate of Navigation at the European Space Agency (ESA). (José Ángel is his first name and Ávila Rodríguez, his surname — Spanish surnames include two family names, one for the father and the other for the mother.) He is based in the Netherlands, where ESA’s largest site is located. José Ángel first became involved in the ION right after he finished his Master’s thesis in electrical engineering in 2003.

José Ángel hails from Madrid, Spain where he studied at the Technical University of Madrid and later at the Technical University of Vienna, Austria. After completing his graduate studies, he decided to move to the University of the Federal Armed Forces in Munich, where he received his Ph.D. in aerospace engineering in 2008. He was a research associate with Professor Guenter Hein and Professor Bernd Eissfeller and made contributions to Galileo’s signal plan.

Now that Galileo is operational, José Ángel has been working on Galileo’s next generation satellites and waveforms at ESA since he joined the agency in 2010. His goal is to ensure that Europe maintains its leading role in providing users worldwide with the best satellite navigation system.

When he is not dreaming of future Galileo satellites or stars in the sky, he enjoys his time with his wife and three daughters, who, as he says, make him discover every day the most precious human gift: the wonder of children’s curiosity.

Look to connect with José Ángel at this year’s ION GNSS+ in Miami, Florida. Until then, please read his responses to the Tech Rep Spotlight questionnaire below.

1. **How did you first get involved with ION?**
The very first ION conference that I attended was in 2004 in Long Beach, California. At that time, I was just starting my Ph.D. research on spreading waveforms for satellite navigation, and I submitted a paper to the conference that predicted the performance that Galileo would one day achieve when it became fully operational. I still remember presenting the paper in front of the GPS and Galileo experts in a huge conference room. I was very nervous because it was my first time. But today, many of them are now my colleagues and friends at the European Space Agency.

Professor Guenter Hein and Professor Bernd Eissfeller introduced me to the GNSS community, and I will always be indebted to them for this. As a junior engineer, I was most impressed by how I could meet and talk to all those big names at the ION conference who appeared in the GNSS books. These were the very same books that, years before, I had devoured in my quest to understand the principles of satellite navigation. My experiences at that first ION conference reassured me that satellite navigation was going to be the focus of my career.

2. **What is your favorite aspect of being a member of ION?**
Being a member of the ION means being a member of the satellite navigation family. Compared to other fields such as communications, satellite navigation is a relatively small community. The beauty of this close-knit community is that we all know each other somehow, and the ION conference becomes a kind of a reunion for all of us. We all have different backgrounds, come from different countries, and are specialists in different fields. However, there is one thing that we all have in common — the strong determination to improve the world with our contributions to satellite navigation. And, ION is the catalyst.

3. **What type of GNSS work do you do currently or have you done in the past?**
When I started to work in satellite navigation, my major focus was receiver technology and signal design. I spent my first five years in the Galileo project designing the signals that future operational satellites would later transmit. Obviously this was a team effort with the best signal engineers of the day, and we all learned from each other. Now that Galileo is operational and every new mobile phone receives these signals, it really feels like a dream come true to me.

Now, I live in the Netherlands and work at the European Space Agency where I am paving the way for the next generation of Galileo. I work across the entire Galileo network including the system, space, and ground segment. Being at ESA is the most exciting experience that I have ever had, because it allows me to be in contact with all the disciplines that make up a satellite navigation system. I learn something new every day.

4. **What do you consider some of the most important current research, education, policy, or technical topics in GNSS for the next year?**
During the last few years, the growth of GNSS applications has been impressive, and I expect that this will continue in the
Since GNSS is a key contributor to PNT, the assurance of PNT is becoming an issue of ever-increasing importance, not only for military and government applications but also for civil applications. The success of GNSS over the past years is what has made it so attractive for attackers and what also makes us forget sometimes that this is a technology that needs to evolve at the same pace as the emerging threats.

In addition, the emergence of PNT applications also raises a challenge for GNSS. While for many years GNSS was the fundamental PNT contributor, this role will soon be contested by newcomers, such as telecom networks that are trying to offer similar capabilities from the ground. Whether we will still be talking about Assisted GNSS or if instead we will be talking about “Assisted 5G,” where GNSS is the signal of opportunity rather than the primary signal, will depend on our ability to improve our satellite navigation systems and not rest on the laurels of the great job that the GNSS pioneers did in the past.

5. What areas of ION have you been involved in, and what areas do you hope to see grow in the future?
I currently serve on the ION Council as Technical Representative. I am also the European Technical Advisor in the ION Satellite Division, and I have been session co-chair and track chair at several ION conferences. I hope the ION will grow in the autonomous vehicle field where, I believe, GNSS will strongly contribute. This would reaffirm the role of GNSS in these markets.

6. If you were not in your current field, what would you want to do for a living?
If I were not a satellite navigation engineer and had I not studied electrical engineering or aerospace engineering, I would be an astronomer or an astrophysicist. Since childhood, I have always loved to look at the stars and still remember how I used to devour books on physics and science. In particular, I was fascinated about general relativity and my dream was to one day understand the field equations.

Even though I am extrovert, I still sometimes entertain the idea of living and working at a radio telescope on a remote mountain, sitting and looking for things we have never seen before in space. It is then that my wife and three little girls bring me back to reality and remind me that I already have all I need to be happy on earth without going so far away.

This column is designed to show the depth and breadth of work, research, and interests of ION’s Technical Representatives who guide and advise ION and the positioning, navigation, and timing community during their two-year terms.
SNOWPLOW continued from page 1

the delivery of a few extra truckloads of fresh, uniformly textured snow for each run at the ION’s eighth annual Autonomous Snowplow Competition.

Eleven teams registered to compete in the event, hosted by ION’s North Star Section. Held during four days of the famous Winter Carnival at Rice Park in downtown St. Paul, Minnesota, the goal of the competition is to plow a fixed area and avoid stationary and moving obstacles by autonomously mapping and navigating an environment.

The 2018 winning team, University of Minnesota-Twin Cities, used a compact, track-driven vehicle with a steel base and plow, aluminum frame, and plastic body panels. Their robot, Snow Squirrel, took in data from its surroundings with a LiDAR sensor and a camera, and translated them into an optimal path for plowing. Snow Squirrel successfully avoided two fixed posts and stopped in front of a moving stop sign during its competition runs.

The Institute of Navigation presented the team with the Golden Snow Globe, a cash prize of $7,000 and a $3,000 travel grant to attend ION GNSS+ 2018 in September in Miami, Florida.

Eight of the other registered teams made it through each of the steps required of the competition, which included two design reviews and the final test — getting rid of actual snow on a makeshift sidewalk and driveway.

More Field Challenges for the Robots

As in past competition years, two types of snow paths were built for the teams to clear: the Single-I represented a sidewalk and the Triple-I a driveway. Many teams refined their plowing strategies based on lessons learned from last year’s event. But there were new challenges to come.

This year, the larger and more intricate driveway test added a requirement to place the plowed snow into specific zones. As usual, robots had to avoid two fixed posts, one inside the snow path and one outside, but this year the competition added a point penalty for teams whose robots moved either of the posts.

A moving stop sign with blinking lights around the perimeter was again part of the competition. Teams had to program their vehicles to come to a complete stop — no wheels turning — when...
For the second year, the crowd was entertained with the Collaborative Operational Challenge. Six teams demonstrated how multiple autonomous robotic vehicles could work cooperatively (or not!) to plow snow while simultaneously avoiding collision with each other on a fixed simulated sidewalk.

Lasers, UWB, and More
The navigation systems and vehicle design approaches were unique to each team. Several robots used laser navigation sensors, some used wheel encoders and inertial measurement units, and a couple used image-processing of the local visual field.

One team used a magnetic sensor system, requiring the placement of a magnetic track system on the field. The use of ultrawideband radios in an innovative, and commercially viable concept performed admirably during its third competition year (<10 centimeter accuracies were reported). Several snowplows used stand-alone GPS to support absolute navigation along the snowfield paths.

Snowplow blade designs varied. Most teams used a single blade, set at an angle to the vehicle’s forward direction, similar to a snowplow truck on a highway. A single blade required either multiple passes along the snow path or a blade large enough to cover the one-meter path. Marquette University’s “Arnold,” had a large blade, produced by new sponsor Western Products. It was the only gas-powered engine this year — the rest were powered by batteries.

On Thursday, January 25, each team presented their vehicle design to a panel of judges comprised of professional engineers from event sponsors and contributors, including Honeywell International Inc., Orbital ATK Inc., Optum, ANSYS Inc., The Toro Company, The University of Minnesota, and UTC Aerospace Systems.

On Friday, January 26, teams faced a final qualification review and a safety inspection. Saturday and Sunday, January 27 and 28, were the dynamic competition days where teams were judged on how quickly and accurately their machine cleared the designated snowfield.

The event hosts were the ION Satellite Division and the Minnesota chapter of the ARCS Foundation (Achievement Rewards for College Scientists).
Defense Matters

Uniformity vs. Vulnerability
(Confronting PNT Challenges)

There are numerous benefits in pursuing uniformity when acquiring systems to equip the warfighter.

On one hand, uniformity makes economic sense when viewed from the perspective of purchase quantities, training, equipment operations, configuration management, and sparing of parts and replacement devices. On the other, such benefits are quickly countered by the reality that one-size doesn’t fit all missions. More importantly, the economic advantages completely lose value as soon as an adversary learns how a particular singular approach can be manipulated or eliminated altogether.

Such is the case when it comes to the very precise, accurate, and globally available positioning, navigation and timing (PNT) information provided by the Global Positioning System (GPS). Over the past few decades, warfighters and warfighting systems have grown critically dependent on very precise and always available positioning and timing information delivered through this single source.

Navigation operations require accurate and robust PNT information, but reliance on cheap and easily integrated GPS receivers as the only source of such information makes them attractive targets to adversaries. Reports on jamming and spoofing of GPS are now becoming commonplace. Examples range from the relatively innocuous (delivery service employees trying to avoid surveillance by management) to the potentially catastrophic (cargo ships deriving erroneous positioning information in the Black Sea).

Not by GPS Alone

Even though these well-publicized examples involved applications using civil GPS signals, and not hardened military signals, the takeaway is obvious — reliance on single-source PNT information represents a clear and ever present danger to be avoided.

So, the question is, what must the Department of Defense (DoD) do to ensure access to precise and reliable PNT services when our adversaries are well aware that GPS represents a cornerstone source of that information? The answer is clear — the DoD must pursue alternative and complementary sources of PNT services for the Joint Force.

Today, GPS is the most obvious and lucrative PNT-related target for adversaries because it is well understood that satellite-based U.S. system comprises such a significant percentage of the warfighter’s PNT dependencies. To diminish this situation, the DoD must strive to introduce new sources of PNT information to support the variety of modern, integrated, and networked warfighting systems.

By diversifying the sources of PNT, GPS as a source will become a less interesting target for an adversary. Today the current counter-PNT problem set is fairly simple for the adversary — focus the attack on GPS to disrupt the execution of military missions. DoD’s challenge for the future is to defend against such disruptive strategies through the development and integration of a comprehensive PNT enterprise comprised of layers of distributed and persistent PNT sources fulfilling the end-state need for assured PNT.

A Work in Progress

The DoD has already started down the path of viewing PNT as an enterprise comprised of multiple and diverse PNT capabilities that can be combined to meet the specific platform and mission needs. The Army’s Assured PNT initiative is leading the charge and is focused on providing secure, authenticated access to PNT information from a collection of multiple sources and technologies.

This initiative is driven by the Army’s recognition that it must develop a means to assure reliable PNT information (to achieve “PNT overmatch”) while dealing with the challenges of outfitting the Army’s large, diverse force structure on a pace that stays ahead of the threat. This is an ambitious challenge confronted with the necessity to balance the cost and schedule of outfitting the force structure against the multiple years it takes to cycle the Army’s large inventory of platforms through the various depots.

This initiative is also founded on the recognition that one size does not meet all needs. The Army’s approach is distinctly non-GPS-centric, since modernized GPS capabilities (such as M-code) are to be incorporated only as they become available.

Until such time that high-precision time and position can be determined and maintained autono-
mously (theoretically, and maybe even unrealistically, suggesting 100 percent independence of external inputs or corrections), a layered collection of multiple PNT information sources will be necessary.

While GPS is and will remain a cornerstone of the DoD PNT Enterprise for the foreseeable future, DoD dependencies and signal vulnerabilities to evolving threats must be addressed even as GPS on-orbit, control system, and receiver modernization projects proceed.

GPS was the source and the catalyst for a realization of the value PNT represents to modern military operations, but its success has also made it a target for adversaries.

The uniformity GPS brought to solving the problems of timing and navigation has now resulted in unintended consequences that need to be corrected. Going forward to achieve this goal there is wisdom in a quote attributed to Albert Einstein, “We cannot solve our problems with the same thinking we used when we created them.”
The era known as the Age of Discovery, sometimes called the Age of Exploration, began in the early 15th century and lasted through the 17th century. Europeans began exploring the world by sea in search of new trading routes, spices, and wealth. Their maps, shipbuilding, discoveries and conflicts hastened the development of modern geography and navigation.

The Portuguese made the first journeys away from the familiar Mediterranean. They were the lone European power with no easterly sea route access to the Middle East and Asia. For centuries, most sailors had stayed well within sight of land or traveled known routes between ports, but Portugal’s Prince Henry the Navigator changed that.

Europe Sails Away

Henry encouraged his mariners to sail beyond the mapped routes and discover new trade routes to West Africa. Portuguese explorers discovered the Madeira Islands in 1419 and the Azores in 1427.

Over the coming decades, they would push farther south along the African coast, reaching the coast of present day Senegal by the 1440s and the Cape of Good Hope by 1490. Less than a decade later, in 1498, Vasco da Gama would follow this route all the way to India.

Spain, Portugal’s competition on the Iberian Peninsula, also invested heavily in a number of perilous and unprofitable ventures towards finding a westward sea route to India and China.

Christopher Columbus, an Italian from Genoa, convinced Spain’s King Ferdinand and Queen Isabella to finance his first westward journey in 1492. Legend has it that, as a result of an infamous misestimation of the radius of the earth, Columbus, instead of reaching India, found the island of San Salvador in what is known today as the Bahamas.

He also explored the island of Hispaniola, home of modern-day Haiti and the Dominican Republic. Columbus would lead three more voyages to the Caribbean, exploring parts of Cuba and the Central American coast.

The Portuguese reached the New World as well, when explorer Pedro Alvares Cabral explored Brazil, setting off a conflict between Spain and Portugal. As a result, the Treaty of Tordesillas officially divided the rest of the world in half in 1494, ceding discoveries to one Iberian power or the other.
Columbus’ journeys opened the door for the Spanish conquest of the Americas. During the next century, military leaders like Hernán Cortés and Francisco Pizarro, ruthless and hungry for gold, would decimate the Aztecs of Mexico, the Incas of Peru, and other indigenous peoples of the Americas.

By the end of the Age of Exploration, Spain would rule the American continents from the southwestern United States to the southernmost reaches of Chile and Argentina.

Meanwhile, England, Italy, the Netherlands, and France had also begun seeking new trade routes and lands across the ocean. In 1497, John Cabot, an Italian explorer working for the English, reached what is believed to be the coast of Newfoundland.

But the most ambitious expedition that took place during the Age of Exploration was that of Ferdinand Magellan, a Portuguese sea captain sailing under the Spanish flag from 1519 to 1521, whose depleted fleet finally had one ship survive in its circumnavigation of the globe, completed under the direction Juan Sebastián Elcano following Magellan’s death in the Philippines.

A number of French and English explorers crossed the North Atlantic shortly thereafter, including Giovanni da Verrazano, who discovered the entrance to the Hudson River in 1524, and Henry Hudson, who mapped the island of Manhattan first in 1609.

Over the next decades, the French, Dutch, and British would vie for dominance. England established the first permanent colony in North America at Jamestown, Virginia, in 1607. Samuel du Champlain founded Quebec City in 1608, and Holland established a trading outpost in present-day New York City in 1624.

The Age of Exploration was capped off in 1768 by Captain James Cook, a brilliant British explorer, navigator, cartographer, and captain in the Royal Navy, who completed the “discovery” of the southern hemisphere including New Zealand, Australia, and Antarctica.

**Why Not Go by Land?**

But what triggered this intense, costly European competition to find Westward sea routes across the vast Atlantic Ocean and beyond, when the conventional, well-known, and well-traveled overland routes were, at least geographically, more advantageous?

Historians mark the conquest of Constantinople in 1453 by the Ottoman Empire as the principle motivation for the emergence of the Age of Exploration. Constantinople was renamed Istanbul, “the city of Islam,” and became a dominant international center of trade and culture as the capital of the empire.

The Ottoman, or Turkish, empire, was one of the most robust and long-lasting dynasties in world history. This Islamic-run superpower was treacherous, with the Ottomans having made their deepest foray into Europe and hostility escalating on both sides. Europeans had two unpleasant choices: face the unknowns of the Western sea crossings of the Atlantic, or the known hazards of the Eastern land route through the powerful Turkish Empire.

While Western Europeans generally viewed them as a threat, many historians regard the Ottoman Empire as a source of regional stability and security, as well as important achievements in the arts, sciences including cartography and navigation, religion and culture.

Ottoman society nurtured and sustained major cartographic/navigation traditions for 400 years from the early decades of the 15th century when the distinctive institutions and culture of this world empire began to take shape to the final quarter of the 18th century when increasingly rapid assimilation of contemporary Western European cartographic practices into Ottoman culture almost completely squeezed out older “traditional” Ottoman patterns of mapmaking.

**Majorca and Cartography**

Most scholars agree that the Ottoman Turk rulers were tolerant of other religions. Christians and Jews fell under the millet system of personal law that gave minority groups limited power to control their own affairs while still under Ottoman rule. Some millet communities paid taxes, while others were exempt. Meanwhile, even before the expulsion by the Inquisition of 1492, Jews were severely discriminated against in Spain and most portions of Western Europe.

Ottoman expertise in mapmaking and navigation was attributed in large part to its acceptance of the Majorcan school of cartography, whose major contributors were Jews from Spain, Morocco, and the Balearic islands.

Majorca, one of those islands south of Spain in the western Mediterranean, had been a maritime focal point during the 12th to 16th centuries and had been intermittently under Muslim control. The Majorcans were great navigators and cartographers. Their geographical knowledge was earned from their own experi-
ence and developed in a multicultural atmosphere.

Muslim and Jewish merchants participated in extensive trade with Egypt and Tunisia, and in the 14th century they started doing business with England and the Netherlands. These groups were not limited by the rules imposed by the Christian framework, and their maps were way ahead of their time.

The Majorcans developed their own distinctive style or “school” of portolan cartography, which created navigational maps based on compass directions and estimated distances observed by the pilots at sea, and is distinguished from the “Italian school.” Both Italian and Majorcan portolan charts focus on the same geographic area familiar to mariners of that era that is sometimes called the “Normal Portolan”: the Mediterranean Sea, the Black Sea, and the Atlantic Ocean coast up to the shores of Flanders.

As time and knowledge progressed, some cartographers would extend the boundaries of the normal portolan further into the Atlantic Ocean, including many Atlantic islands (real and imagined) as well as a longer stretch of the West African coast to the south, the Baltic Sea in the north and the Caspian Sea in the east.

The distinction between the Majorcan and Italian school is one of style rather than range. Italian portolan charts were sparsely illustrated and limited in coverage, focused primarily on coastal detail, with the inland areas left largely or completely empty.

The Majorcan style found its epitome in the Catalan Atlas of 1375, attributed to the Jewish Majorcan cartographer Abraham Cresques. It contained a lot more inland detail and included colorful illustrations depicting cities, mountain ranges, rivers, and miniature travelers.

The next historian article will expand on the navigation/cartographic achievements of the Ottoman Empire, whose influence motivated the European Age of Discovery.

If you’re interested in the Age of Discovery, you might read these articles by the ION Historian in previous ION Newsletters:

- Magellan’s Circumnavigation of the Globe Spring, Summer and Fall 2013
- Henry the Navigator and 15th Century European Navigation Winter 2009-10 and Spring 2010

References
- https://en.wikipedia.org/wiki/Majorcan_cartographic_school
- https://www.thoughtco.com/age-of-exploration

Marvin B. May is Chief Navigation Technologist for Mayven Engineering and the Applied Research Laboratory of the Pennsylvania State University. His email is mbm16@arl.psu.edu.
Situation Awareness
How to party in spite of automatic weapons

After the horrific gun massacre at a Las Vegas country music festival last year, large celebratory crowds are of heightened concern to law enforcement and entertainment impresarios.

Case in point: The huge Coachella Music Festival, held on two weekends each spring in the southern California desert.

Sounds like quite a target. Enter the drones.

An Indio, California police spokesperson told the Los Angeles Times, “Drones will be flying over watching the perimeters. It takes us a few minutes to get an officer to a perimeter breach, but a drone takes 45 seconds. The drones will also allow us to monitor traffic better than before.” UAVs, however, can’t fly over crowds or cars.

Festival security planning is complex and thorough, one might even say to the level of wartime conditions. And precise positioning, location and navigation technology is a big part of it — including wristbands for every attendee that tracks location and time of entry and exit.

https://commons.wikimedia.org/w/index.php?curid=39361711

Enough Already!
When the navigation app sends cars down your cul de sac

Los Angeles city councilor Paul Krekorian says, “The use of (navigation) apps to save 90 seconds of travel time is not only destroying quality of life in neighborhoods all over, but also endangering public safety.”

He’s talking about WAZE and its fellows, and he’s asking the megacity’s transportation department to figure out ways to reduce negative consequences of GPS apps. He also wants to see if the creators and marketers of these apps can be liable if their product causes an accident or other damages.

The problem in L.A. is too much of a good thing. Apps give commuters highly creative solutions to gridlock on the morning commute — such as routes through small streets and alleys and cul de sacs and rights of way that keep the actual residents from getting out of their own driveways.

Here’s an Idea. . . .
Peer-Reviewed Publications and Poetry

In 2001, a presenter at the Lunar and Planetary Science Conference was working on the one-sentence summary of his paper and was struck by the muse. Why not a Haiku? A possibly dull sentence on using the ALTA II spectrometer as a tool for teaching about light and remote sensing became:

Bright leaves on dark sky
Beyond the brilliant rainbow
Vision fades away.

And so tradition was born. This year, 200 presenters at the conference in Houston, Texas summarized their work in Haiku form.

**EDUCATIONAL OPPORTUNITY**

**ESA/JRC International Summer School on GNSS 2018**

This year’s European Space Agency/European Commission Joint Research Center (ESA/JRC) International Summer School on GNSS will take place from July 16 to 27 in Loipersdorf, Austria. The event is held in cooperation with Stanford University in the United States, the Institut Supérieur de l’Aeronautique et de l’Espace (ISAE-SUPAERO) in Toulouse, France; Graz University of Technology in Austria, and the University FAF Munich in Germany.

The 10-day course will cover all aspects of satellite navigation, up to and including the creation of a satnav-based business.

Supported by Graz University of Technology and the Austrian Institute of Navigation, the Summer School is open to graduate students, PhDs, and postdoctoral researchers, as well as young engineers and academics, aged 35 or younger, working within industry or agencies.

Participants must register before May 15 to benefit from an early registration discount. The number of participants is limited to 50, on a first-come, first-served basis.

Internationally renowned scientists and specialists will give lectures as well as oversee practical exercises and lab work.

Participants will receive a full-spectrum overview of satellite navigation, starting from the theoretical basis of the Global Navigation Satellite System, its signals, the processing performed by signal receivers, and how the position-navigation-time solution is worked out.

Discussion will also cover threats to satnav systems, such as spoofing or jamming, and the countermeasures available against them, along with back-up navigation solutions for use in a GNSS-denied environment.

Practical exercises will include tracking signals from the various satnav constellations now in orbit — including Europe’s Galileo — to give course members direct, hands-on experience. In addition, lectures will cover business aspects, including patents and intellectual property rights.

The main emphasis of the course will be the development of a group business project, building on an innovative idea to take in the planning of the product or service, its technical realization, and finally its marketing to customers. For more information see <www.esa-jrc-summerschool.org>.

---

**Dayton Section News**

The Dayton Section met on November 9, 2017, at the Northrop Grumman facility in Beavercreek, Ohio, for a box lunch followed by a presentation by Mr. Ryan Watson, a Ph.D. student at West Virginia University. His topic was the application of advanced graph-theoretic-based sensor fusion methods to GNSS. Watson showed that several recently developed methods to make graph optimization more robust to erroneous data can also be applied to GNSS data processing in degraded environments, such as urban canyons.

The Section assembled again on January 11 at the same venue to hear 2Lt Seeley Pentecost, a student at the Air Force Institute of Technology, describe his research into advanced signal concepts and flexible payload architectures for next-generation GPS satellites.

---

For more information on corporate membership in the Institute of Navigation, please contact Kenneth P. Esthus at 703-366-2723 extension 1004.
Calendar of Upcoming Events

MAY 2018
14-17: The European Navigation Conference (ENC), Gothenburg, Sweden
   Contact: ENC 2018 Conference Office
   Tel: +46 31 708 86 90
   Web: www.enc2018.eu

23-25: The 9th China Satellite Navigation Conference (CSNC), Harbin, China
   Contact: The Academic Exchange Center (AOE) of the China Satellite Navigation Office
   Web: www.beidou.org

JULY 2018
9-12: ION Joint Navigation Conference (JNC) 2018, Hyatt Regency Long Beach, Long Beach, California
   Contact: The ION
   Tel: +1 703-366-2723
   Web: www.ion.org

SEPTEMBER 2018
24-28: ION GNSS+ 2018, Hyatt Regency Miami, Miami, Florida
   Contact: The ION
   Tel: +1 703-366-2723
   Web: www.ion.org

NOVEMBER 2018
Nov. 12-15: International Navigation Conference, Mercure Bristol Grande Hotel, Bristol, UK
   Contact: Royal Institute of Navigation (RIN)
   Web: www.rin.org.uk

Nov. 28-Dec. 1: International Association of Institutes of Navigation (IAIN) 16TH World Congress, Makuhari Messe International Convention Complex, Chiba, Japan
   Contact: IAIN
   Web: www.iain2018.org

JANUARY 2019
   Contact: ION
   Tel: +1 703-366-2723
   Web: www.ion.org

APRIL 2019
8-11: ION Pacific PNT 2019, Hilton Waikiki Beach, Honolulu, Hawaii
   Contact: ION
   Tel: +1 703-366-2723
   Web: www.ion.org