AUTONOMOUS SYSTEMS & LOCATION

Putting Humans Back in the Loop

Fans of classic Walt Disney films may well remember the Sorcerer’s Apprentice episode in the 1940 movie “Fantasia.”

In it, a plucky apprentice — with Micky Mouse in the title role — uses a spell to animate a broom to save him from the tedious task of filling a cauldron with water. All goes well until, the apprentice awakens from a nap to find the cauldron overflowing and flooding the chamber. He attempts to stop the diligent broom, only to realize that while he knew how to launch the spell, he had not learned how to end it.

In a moment of desperation, the apprentice chops the broom into pieces, only to see all the splinters come to life and begin toting water. Pandemonium ensues.

The episode comes to mind when continued on page 6

So, Election 2020. Ready or not.

While we’re following the ups and downs of the candidates through rallies, media reports, Twitter, and polls, they may well be following us. Yes, personally, specifically, individually.

In past articles of the ION Newsletter, we have reported the rise of mobile location-based advertising as well as the related issue of location privacy (Winter 2019). Now recent news reports have begun identifying positioning, navigation, and time (PNT) technologies as key enablers of more customized political campaign communications with existing and potential supporters.

Along with that capability, of course, comes the practice of some of the darker political arts, such as those deployed by Cambridge Analytica during elections including the 2016 U.S. presidential campaign.

“Using location data to reach possible voters has quickly become the new normal for organizations on both sides of the political spectrum,” concluded a December 17 article in the online magazine Slate. A Vox Media article, also published in December, described personal location data weaponized on behalf of partisan campaigns as “the next frontier in political advertising . . .”

Last October, the Wall Street Journal (WSJ) published a front-page article headlined “Campaigns Track Voters’ Phone Data,” noting “Political groups use location data to target people based on where they've been.”

The article led off with President Donald Trump’s visit to North Carolina at a rally in support a Republican congressional candidate the previous month. “Unknown to the crowd, the Committee continued on page 4
The Institute of Navigation (ION) was founded in 1945 by a group of practical navigators, originating from both military and civilian air navigators. A large part of the Institute's energy during the early years was devoted to building an effective organization that would advance the art and science of navigation, by coordinating the knowledge and achievements of practitioners, scientists and developers of navigation equipment.

In the 1990s, ION really began to flourish, as we garnered support from anyone interested in position-determining systems. Advancements in navigation technology enabled performance of the navigation function to become a subset of other activities, thus eliminating the need for specialized navigators for most applications. Navigation became automated through the replacement of humans and electromechanical devices with microcomputers, integrated circuits, and sensors.

Accuracy and coverage performance for all phases of navigation were rapidly enhanced through the evolution of the various GNSS's of today. The manner in which the ION adapted to, and in some cases, played a key leadership role in these changes has accounted for our success.

This year, the ION will celebrate its 75th anniversary. I am honored to be president during this historic year and invite you to join me in celebrating this anniversary throughout the year as you read special historical articles in this newsletter, see celebratory memories and testimonials posted on the ION website, and join with others in our ION community as we celebrate at each of the ION’s meetings held throughout 2020.

Please also be on the lookout for our invitation to upload any special memories or images of ION memorabilia you may have that you might want to share with the ION community as part of our 75th year.

IEEE/ION PLANS Around the Corner
The ION is committed to representing a full range of navigation disciplines through its plentiful and varied programs. We have worked cooperatively with the IEEE’s Aerospace and Elec-
The Purpose of the ION®
Founded in 1945, The Institute of Navigation is the world's premier non-profit professional society advancing the art and science of positioning, navigation and timing.

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to Defend the President . . . had hired a company to collect unique identification numbers from attendees’ smartphones that evening, based on location data those phones were sending to third parties,” the Journal wrote. “The goal was to target ads at people it could drive to the polls the next day.”

Left Joins Right
Politically, of course, location is an equal opportunity technology that has been deployed on both Democratic and Republican election campaigns.

In December, Hawkfish, the digital advertising startup former New York Mayor Michael Bloomberg launched to support political candidates and his own presidential campaign, hired Jeff Glueck, former CEO of location-tracking firm Foursquare Labs, Inc., as head of Digital. Among Foursquare’s products is the Foursquare City Guide, which promulgated the concept of real-time location sharing and “checking in” by its customers. Later, the company began creating products that leverage the location data collected from the billions of customer check-ins.

“[T]he marriage of the online and offline data about the individual — that’s the biggest force multiplier,” Justin Miller, a political data consultant who has worked on campaigns for Barack Obama and Hillary Clinton, told the WSJ.

In September 2018, a company working on behalf of then-Senate candidate Beto O’Rourke collected mobile device ID numbers of attendees at a rally with musician Willie Nelson, according to the WSJ article. Working with an O’Rourke campaign consulting firm, then company paired the phone IDs with contact information, such as email addresses enabling the campaign to follow up with those contacts later.

Following publication of the Wall Street Journal article, CatholicVote President Brian Burch acknowledged its efforts in this area. “Starting last year, we created ad campaigns targeted to mobile devices that have been inside of Catholic churches,” he wrote in an article on the group’s website, going on to describe his organization’s efforts urging Missouri Catholics to defeat then-Senator Claire McCaskill.

Mobile location data is provided separately or in blended solutions by GNSS, WiFi hotspots, mobile phone cell IDs, Bluetooth beacons, and other positioning technologies residing on a mobile device.

Location is an equal opportunity technology that has been deployed on both Democratic and Republican election campaigns

Geofencing enables campaign technology companies to draw a virtual boundary around sites or areas of interest, such as event appearances, polling centers, sporting events — even an opponent’s campaign rally.

Business Is Booming
One of the early entrants into the field
is Phunware, an Austin, Texas–based provider of a software platform for mobile services that has won a slew of high-profile business honors since its founding 10 years ago.

In a November 2017 blog post on its website, Phunware touted the benefits of tracking voters using location data from their smartphones or other mobile devices.

“[S]ome campaign managers are beginning to realize that each voter’s smartphone is the ultimate voter file,” wrote Emily Reynolds, at the time the company’s senior director of marketing. “Mobile data can tell them everything from the device operating system (iOS or Android) to what other apps are on the device, what Wi-Fi networks the device joins and much more. And that doesn’t even cover the information it’s possible to infer, such as gender, age, lifestyle preferences and so on.”

Indeed, location-derived information can be paired with other online or offline databases to identify home addresses, email addresses, and names. This often comes from data brokers that exploit permission granted by unwitting users when they download third-party apps — such as mobile games, weather forecasts, photos, and online banking — that also log user locations. By placing a cookie into the mobile device of someone who enters a specific location, these apps turn users into targets for political messaging wherever the device-owner goes.

“Because mobile devices go everywhere with voters and have location-aware technology embedded in them, political campaign managers have an unprecedented ability to target voters based on where they are (or have been),” Reynolds added.

Election campaigns represent a rapidly growing market for business development. In addition to Phunware, the WSJ article mentioned other technology companies — including Los Angeles-based Factual Inc., San Francisco–based NinthDecimal Inc., and Louisville, Kentucky–based El Toro — that supply location-based services to commercial and political clients.

“Upgrading to Premium Professional Membership has given me additional support for my research. With downloads of up to 25 papers per month from the ION database, I have direct access to highly-specialized technical papers from ION’s conferences and peer-reviewed articles related to PNT.”

Allison Kealy, ION Member

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Autonomous Systems  continued from page 1

considering the recent history of autonomous aircraft and vehicles, the development and implementation of which have taken giant leaps forward in recent years, largely as the result of adopting advanced positioning, navigation, and time (PNT) technologies.

Smaller, ever-more-affordable, and available PNT options have accelerated the adoption of unmanned systems, particularly the airborne versions that the Federal Aviation Authority (FAA) calls unmanned aircraft systems (UAS) and known elsewhere as unmanned aerial vehicles (UAVs) or, even more commonly, drones. Lidar, inertial, camera-based, and, above all, GNSS technologies have enabled aircraft to operate remotely beyond visual line of sight (BVLOS) with increasing facility, even as the FAA races to take back control of the burgeoning sector.

By the end of 2019, nearly 1.5 million drones and 160,000 remote pilots were registered with the FAA, including 428,245 UASs registered for commercial use. At the end of 2018, registered commercial and recreational drones numbered 900,000. FAA officials acknowledge that many more autonomous aircraft, especially smaller models, go unregistered.

Meanwhile, every major auto manufacturer and companies such as Google and Amazon are throwing immense amounts of resources, human and financial, at bringing autonomous systems to market and into commercial use.

Manifold benefits of autonomous systems are driving these efforts: reduced highway traffic and accidents, faster and more cost-effective delivery of goods, improved surveillance of infrastructure and search and rescue, and many, many applications.

According to news reports, farmers in North Canterbury, New Zealand are now herding sheep with a drone outfitted with a speaker that barks like a dog, accomplishing in 45 minutes what once took two hours for two people and two teams of dogs. In France the postal service can now deliver packages up to two kilograms by UAV to the remote alpine village of Fontanil-Cornillon, a trip that takes hours by land vehicle.

In Africa, a company named Zipline says it uses drones to make around 500 deliveries each day of critical medical products, such as blood and vaccines, to healthcare facilities in Ghana and Rwanda.

The experience of a PNT/sensor/IT-driven revolution in farming has demonstrated the power and profitability of such innovations. Several different studies released in 2019 estimated the global precision agriculture market size at $4 to $5 billion in 2018 and projected its growth to between $14 and $15 billion within five years.

Not So Fast

Like the sorcerer’s apprentice’s brooms, however, autonomous modes of transport bring risks along with their blessings. Safety and security are growing issues surrounding autonomous systems.

“The FAA recognizes the increasing availability and potential use of UAS for illegal activities such as the carrying and smuggling of controlled substances, illicit drugs, and other dangerous or hazardous payloads; the unlawful invasion of privacy; illegal surveillance and reconnaissance; the weaponization of UAS; sabotage of critical infrastructure; property theft; disruption; and harassment,” the agency said in announcing a proposed UAS rule earlier this year.

On average, the FAA receives six reports each day of UAS allegedly conduct-

UK’s Gatwick Airport
Chris Sampson, on Wikimedia Commons
ing unauthorized operations. Additionally, based on information provided by other U.S. government agencies, there may be many additional UAS sightings involving unauthorized or illegal operations not reported to the FAA.

In 2018, drones flying near London’s Gatwick airport during the peak of holiday travel affected 110,000 passengers and 760 flights, according to UK officials. More recently, protestors have attempted to close Heathrow Airport using illegal drone flights, leading to proposals for legislation for a five-kilometer no-fly zone around the runways in which UAV would be banned.

Since mid-December, citizens in Colorado, Kansas, and western Nebraska have reported dozens of nighttime drone sightings, sometimes in large swarms. Representatives of the FBI, Federal Aviation Administration (FAA), U.S. Air Force, and local law enforcement met in Denver on January 6 and established a federal/state task force to investigate the incidents.

Last October, the U.S. Department of the Interior grounded nearly its entire fleet of UAVs due to concerns that the aircraft, mostly made in China, might pose a threat to U.S. national security. Ninety-five countries now own military drones, according to The Drone Databook issued last September by the Center for the Study of the Drone, a research institution at New York’s Bard College. In one recent incident illustrating their use, two Saudi oil facilities were struck by drones and missiles last September, destroying half of that nation’s oil production.

Motivated in part by well-publicized accidents involving vehicles operating in autonomous mode on public highways, industry and government initiatives have targeted safety, security, and privacy issues in the automotive sector.

Last year, a consortium including Aptive, Audi, Baidu, BMW, Continental, Daimler, Fiat Chrysler Automobiles, Here Technologies, Infineon, Intel, and Volkswagen published a primer entitled “Safety First for Automated Driving” that lays out 12 guiding principles of automated driving. In January, the U.S. Department of Transportation issued a publication, “Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0,” that focuses first on protecting users and communities by prioritizing safety, emphasizing security and cybersecurity, and ensuring privacy and data security.

The ION is doing its part to address the engineering side of the issue, sponsoring its new Cognizant Autonomous Systems for Safety Critical Applications (CASSCA) Conference, the second gathering of which took place last September as reported in the Fall 2019 ION Newsletter. The goal of CASSCA is to bring together individuals with varied backgrounds and disciplines from across academia, government, and industry to explore the larger issues and questions concerning autonomous systems, focusing on systems that are safety-critical.

**A New FAA Rule**

In the wake of the Midwest drone reports, the FAA proposed a major new rule that would require manufacturers and operators of UAS aircraft to make them remotely identifiable and locatable.

On December 26, the Federal Register published a Notice of Proposed Rulemaking (NPRM) for Remote Identification (Remote ID) of UAS. The rule would facilitate the collection and storage of certain data such as identity, location, and altitude regarding an unmanned aircraft and its control station. The Defense Matters column in this issue of the ION Newsletter discusses some of the implications and historical context of the proposed rule.

In it, the FAA proposes to mandate that all UAS produced for operation in the airspace of the United States would have to comply with a standard set of design and production requirements. Amateur-built UAVs, U.S. government UAS, and unmanned aircraft that weigh...
less than 0.55 pounds would be excluded from the requirements. Unmanned aircraft would have to be able to broadcast remote identification information, including location, via radio frequency and connect via the Internet (when service was available) to a UAS Service Supplier (USS).

When the document was posted online for comments, the FAA website online document logged more than 100,000 views and 1,000 comments within three days of its publication. Public comments on the measure will be accepted until March 2, 2020.

The proposed rule envisions that “within three years of the effective date of this rule, all UAS operating in the airspace of the United States will be compliant with the remote identification requirements. No UAS could be produced for operation in the United States after two years and no UAS could be operated after three years except in accordance with the requirements of this proposal.”

The measure represents a sine qua non before the FAA would allow advanced operations to be undertaken without the need for operators to obtain permission, including routine drone flights at night, over people, and beyond the remote pilot’s line of sight.

These efforts lay the foundation for more complex operations, such as those beyond visual line of sight at low altitudes, as the FAA and industry move toward a traffic management ecosystem for UAS flights separate from, but complementary to, the air traffic management system.

In addition to improving air safety, the FAA rule notes that certain public activities “have been hampered by the inability to identify UAS and their locations.” It cited the cases of a drone interfered with a police helicopter assisting with a cliff rescue and another assisting a fire response. “In 2017, a helicopter performing security for the United Nations General Assembly struck an unmanned aircraft, causing more than $100,000 worth of damage to the helicopter.”

“Such risks are multiplied with the increasing sophistication of technology, the availability of UAS equipment, and the proliferation of UAS operations across the airspace of the United States,” the FAA said. Although Federal, state, and local law enforcement agencies are responsible for the investigation and prosecution of illegal UAS-related activities, the FAA retains the regulatory and civil enforcement authority and oversight over aviation activities that create hazards and pose threats to the safety of flight in air commerce.

“Remote ID technologies will enhance safety and security by allowing the FAA, law enforcement, and Federal security agencies to identify drones flying in their jurisdiction,” said U.S. Transportation Secretary Elaine Chao in comments about the proposed rule.

The proposed rule emerged from the deliberations of the Unmanned Aircraft Systems (UAS) Identification (ID) and Tracking Aviation Rulemaking Committee (ARC) (UAS–ID ARC) chartered in May 2017 to inform the FAA on technologies available for remote identification and tracking of UAS and to make recommendations on how to implement these.

Meanwhile, some agencies are taking action on their own to deal with potentially intrusions of UAVs. In December Bard College’s Center for the Study of the Drone released the second edition of Counter-Drone Systems, authored by Arthur Holland Michel. The study found 537 systems for sale, of which 350 purported to be able to intercept and disable drones while the others could only detect the UAVs. Radio jamming was the most popular method for countering potentially hostile UAVs, with other approaches involving lasers, nets, or a “sacrificial collision drone.”

London’s Heathrow Airport has installed a system to detect and identify unauthorized UAVs. Called “Counter Drone,” the technology uses a holographic radar system to detect and track unauthorized drones as well as locate the drone pilots, who can face up to five years in prison for flying in a UK Flight Restriction Zone without permission.

According to the Financial Times, within two weeks after the Gatwick drone incident, the airport announced that it had already spent more than $6 million installing counter-drone systems to prevent future incidents.
A PNT: It started out as alternative or alternate positioning, navigation, and timing and evolved in some sectors — influenced by a military take on the acronym — toward assured PNT.

Both takes on the terminology referred to GNSS systems and, implicitly, their vulnerabilities. And both terms continue to be employed, nuanced by whether the user is lifting up and advocating for another PNT technology or assuming GNSS as the cornerstone that may need a little help from time to time.

In many ways, GNSS has become a victim of its own success, making it a target of adversaries at that same time that widespread consumer and commercial adoption of the technology complicates military leaders’ control and manipulation of it.

In 2016 the European Union (EU) Horizon2020 project launched a three-year research effort called STRIKE3 (for Standardization of GNSS Threat Reporting and Receiver Testing through International Knowledge Exchange, Experimentation and Exploitation). Over the course of the project, results from more than 50 monitoring stations installed in 23 nations recorded more than 450,000 incidents of GNSS-L1/E1 interference signals, including 59,000 identified as jammer signals.

The DoD’s public release last August of a version of its “Strategy for the Department of Defense Positioning, Navigation, and Timing (PNT) Enterprise” underlines GPS’s “foundational” role for military users at the same time acknowledging GPS “will not always be available in contested military operating areas, or perhaps globally.” The DoD’s solution is to create a layered PNT architecture with modular, open-systems integration.

In December, Michael Griffin, DoD Undersecretary for Research and Engineering, established a PNT task force under the Defense Science Board (DSB) that would address the current performance and resilience limits of current GPS systems and how these are expected to change over the next decade. The task force would undertake its mission over the course of six to nine months.

In a memo to DSB Chairman Dr. Craig Fields, Griffin directed the task force to explore the benefits and risks associated with other PNT technologies, including commercial space communications systems, RF array technology, and “incorporating alternative means to acquire and update PNT information to accomplish military missions,” including portable atomic clocks, image-based navigation, quantum sensors or terrestrial-base navigation and timing distribution.

Dana Goward, president of the Resilient Navigation and Timing Foundation and a leading advocate for enhanced Lo-

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**APNT & GNSS VULNERABILITY**

**Looking for Other Ways to Do the PNT Job**
ran (eLoran) as a backup system to GPS, has identified the following characteristics for an effective alternative PNT system:

- Have physical properties different from those of GNSS to the greatest extent possible.
- Have physical properties different from clocks, inertial systems, and other sources of PNT now used in their countries.
- Be easy to access anywhere in the service area (i.e. wireless) and at no cost.
- Be a mature technology that can be implemented without delay.
- Be interoperable with existing and future APNT systems elsewhere around the globe.
- Have government support, but be implemented and operated by a non-government entity.

A Congressional Mandate
The U.S. Congress has taken a couple of shots at advancing APNT. In 2017, the National Defense Authorization Act tasked the Department of Defense (DoD), Department of Transportation (DoT), and Department of Homeland Security (DHS) to jointly conduct a technology demonstration of GPS backup technology.

Then, passage of the National Timing Resilience and Security Act in December 2018 required the DoT to establish a timing system to back up GPS by December 2020. The legislation specifies the backup system must be terrestrial, wireless, have wide area coverage, be difficult to disrupt, and be capable of expansion to provide positioning and navigation services.

Late last year, in response to the congressional mandate, the Office of the Deputy Assistant Secretary of Transportation for Research and Technology announced successful applicants responding to a request for information (RFI) for candidate GPS backup technologies. Twenty-two companies submitted responses, although some merely offered comments and observations rather than proposing prospective solutions.

The DoT awarded contracts to 11 companies to demonstrate their technologies’ ability to act as a backup for GPS. Many of the approaches could provide PNT in environments problematical for GPS even under normal conditions, including indoors, underground, and in dense urban areas.

The total amount allocated to the companies was $2,507,500. Working through the DoT Volpe National Transportation Systems Center, the agency hopes to wrap the demonstration by this March.

Diana Furchtgott-Roth, DoT deputy assistant secretary for research and technology, described the backup PNT undertaking to the Civil GPS Service Interface Committee meeting before the ION GNSS+ 2019 meeting in Miami.

“We are seeking the best solutions to ensure that America has a combination of PNT systems which, when used together, will be difficult to disrupt,” Furchtgott-Roth said. “This effort will inform implementation of a system that is, to the maximum extent possible, required to be terrestrial, wireless, have wide area coverage, be difficult to disrupt and capable of expansion to provide positioning and navigation services. We might not be able to do all those things but we are very much going to try our best possible.”

Two of the DoT contracts went to companies offering satellite-based APNT: Globalstar/Echo Ridge, which uses signals from 24 Globalstar low-Earth-
orbit (LEO) communications satellites to produce PNT using Echo Ridge software and user devices, and Satelles Satellite Time and Location (STL) service delivered over the Iridium constellation of 66 LEO satellites.

Two eLoran contenders received contracts: Middleburg, Virginia–based Hellen Systems and UrsaNav, headquartered in North Billerica, Massachusetts, which previously received an earlier contract to demonstrate wide-area UTC time synchronization and distribution using a former Loran site in Wildwood, New Jersey.

PhasorLab, of Nashua, New Hampshire, plans to demonstrate its Hyper Sync Net (HSN) technology, a self-organizing mobile mesh network capable of maintaining high-precision time and frequency synchronization as well as providing an instantaneous 3D locational map of the entire mesh network.

Skyhook Technology uses a proprietary database containing more than five billion geolocated access points and 200 million cell base station IDs, enabling it to accurately locate phones and devices worldwide.

Netherlands-based Optical Positioning, Navigation and Timing (OPNT) proposes its Global Terrestrial Timing Service (GTTS) to provide GPS-independent timing based on the White Rabbit Ethernet protocol developed at CERN (the European Organization for Nuclear Research) over the existing fiber optic communication infrastructure. Seven Solutions, a privately held company based in Germany and Spain, also proposes a CERN/White Rabbit/fiberoptic/Ethernet solution.

Serco will demonstrate its “R-Mode Navigation,” which uses ranging signals typically transmitted from existing maritime infrastructure such as medium frequency radio beacons and vessel automatic identification system (AIS) base stations.

TRX Systems, Greenbelt, Maryland, offers its NEON system, an Android application integrated with the NEON Location Service incorporating a suite of patented algorithms that fuse inertial sensor data, Bluetooth and Wi-Fi readings as well as inferred map and building data to deliver 3D location.

NextNav, of Sunnyvale, California, offers Metropolitan Beacon System, a 3GPP-compliant, terrestrial network of long-range broadcast beacons, transmitting a “GPS-like” signal in licensed spectrum in the sub-GHz range environments and outdoors; for barometer-equipped devices, MBS also enables floor-level altitude determination.

International Initiatives
At its 40th Assembly September 24–October 4, the International Civil Aviation Organization (ICAO) called for measures to manage and reduce the impact from harmful interference to GNSS on the safety and efficiency of aircraft and air traffic management operations. A working paper submitted to the assembly by the International Federation of Air Traffic Controllers’ Association, the International Federation of Air Line Pilots’ Associations, and the International Air Transport Association cited both unintended interference, such as caused by atmospheric phenomena as well as intentional interference, including GNSS jammers or spoofers.

The organizations called on ICAO and the International Telecommunications Union “to establish and ensure appropriate frequency regulations are in place and maintained to protect allocated GNSS frequencies from harmful interference in line with ITU Radio Regulations” and urged the assembly “to support the multi-disciplinary development of alternative positioning, navigation and timing (APNT) strategy and solutions to complement the use of GNSS in aviation.”

In the United States, the yearslong battle to prevent use of radio spectrum adjacent to the GPS L1 signal for a terrestrial wireless network continues before the Federal Communications Commission (FCC). Letters in late November and early December from Defense Secretary Mike Esper, and Douglas Kinkoph, acting deputy Assistant secretary for communications and information at the National Telecommunications and Information Administration (NTIA), argued against use of the 1526-1536 MHz band sought by Ligado Networks, the successor to Lightsquared.

“All independent and scientifically valid testing and technical data shows the potential for widespread disruption and degradation of GPS services from the proposed Ligado system,” Esper wrote in a November 18 letter to FCC Chair Ajit Pai. “I believe there are too many unknowns and the risks are far too great to federal operations to allow Ligado’s proposed system to proceed.”

In support of his agency’s position, Kinkoph cited the conclusions of a 2018 Adjacent Band Compatibility Study conducted by the U.S. Department of Transportation that indicated the Ligado transmissions would exceed the interference protection criterion of one-decibel degradation in GPS carrier-to-noise power density ratio.

Elsewhere, the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is developing Ranging Mode (R-Mode), which is a radionavigation system that is intended to provide a contingency system in case of temporary GNSS disruption. Under the concept of e-navigation, the International Maritime Organization is required to develop a ground-based World-Wide Radionavigation System (WWRNS) that backs up PNT systems using GNSS.

R-Mode is a concept of a new terrestrial radionavigation system that uses timing information provided by existing maritime radio systems to generate GNSS-independent PNT and serve as a possible candidate as a regional backup of GNSS. Two carriers are under consideration for providing the timing information, MF using existing Differential GNSS (DGNSS) radio beacon frequencies and VHF using existing VDES frequencies.
This column features one of ION’s Technical Representatives each quarter to highlight the depth and breadth of their work, research, and interests. During their two-year terms the ION’s Technical Representatives guide and advise The Institute of Navigation and the positioning, navigation, and timing (PNT) community. — Interview and write-up by Dr. Kyle Wesson

This month, I got the chance to talk to a former colleague of mine: Ms. Deborah Lawrence. She is the manager of Navigation Programs at the Federal Aviation Administration (FAA) where she heads their work across all of their navigation efforts, notably the Wide Area Augmentation System (WAAS).

One thing remains true – Deborah is busy! It takes a lot of work to coordinate the FAA’s navigation programs. I was lucky to get a few minutes on her calendar to find out more about life outside work, where Deborah is an ardent sports fan, supporting her local professional teams in football, baseball, and basketball. She has season tickets for the Redskins (but didn’t want to comment any further!) and for her college football team, North Carolina Agricultural and Technical State University, where she earned a B.S. in electrical engineering. When she has the time, she enjoys reading the Bible and watching any kind of adventure movie, such Captain America or the Avengers.

She plans on attending the 2020 ION International Technical Meeting in San Diego. In the meantime, to find out more about Deborah, please see her answers below:

1. How did you first get involved with ION?
I began with ION when I was assigned as the FAA’s Ground Segment Lead for WAAS in 2003. My mentors at the time told me that ION would be a good environment to learn more about GNSS. I joined then and haven’t looked back!

2. What is your favorite aspect of being an ION member?
What I really like about ION is that it introduces an audience to new ideas within GNSS. I get to hear other countries’ perspectives on the state-of-the-art, and also get data and opinions from different vantage points. Coming from the U.S. perspective, it’s nice to hear what other countries think or have a position on because it lets us consider that new information and work with it ourselves.

I also like the opportunities that ION gives us to work internationally, publish without politics, share data, collaborate and innovate in ways we couldn’t outside of ION.

Plus, ION is fun. It gives me the opportunity to think freely as opposed to the restrictions that are in place in a government working environment. That’s the beauty of ION!

3. What type of GNSS work do you currently do or have you done in the past?
I have worked on a wide range of programs here at FAA. I’ve worked on the development of WAAS, development of dual-frequency operations (L1, L2, and L5), GNSS augmentation development, and multi-constellation coordination with other countries. For me, an accomplishment that gave me a lot of satisfaction was getting WAAS down to LPV-200 [the “Localizer Performance with Vertical guidance at 200 meters altitude” standard for approach and landing] and actually publishing those procedures so that we could have users get benefits from lower minimums.

Ms. Deborah Lawrence
4. What do you consider some of the most important current research, education, policy, or technical topics in GNSS for the next year?

There are so many topics to consider. On my plate, I see multi-constellation and advanced RAIM [receiver autonomous integrity monitoring] as playing a major role in the next years. We are also looking at satellite navigation with low-earth orbiting satellites and GNSS interference detection. Also critical to GNSS are the methods and means to detect radio frequency interference and protect aviation users from its negative effects.

5. What areas of ION have you been involved in, and what areas do you hope to see grow in the future?

I've been involved with ION in a number of ways, including as an author, panelist, and track chair (and, of course, as a current ION technical representative!). A lot of my work has focused on SBAS [satellite-based augmentation systems] and WAAS, but that also extends to ARAIM, GNSS resilience, spectrum protection, and GNSS spoofing detection and mitigation. I hope to be at the next ION ITM in January to attend the conference and Council meeting.

6. If you were not in your current field, what would you want to do for a living?

I would be a math and science teacher in elementary school, because I used to be a Sunday School teacher and I really enjoyed it. I also tutored when I was in my sorority. I’ve seen a huge gap of inner city youth who cannot read and cannot count. They can’t count, and yet they do everything on the phone or a computer. I believe that it’s my civic duty to help this rising generation and hope to pursue this when I retire from civil service.

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MAGNETIC ATTRACTION

Polar Shift Puts Navigators Off the Map

A speed of 55 kilometers (34 miles) per year may just sound like a bad commute on a Los Angeles freeway, but it actually represents a headlong dash for the world’s magnetic poles. Twenty years ago the magnetic poles were moving only about 6.2 mpy.

And that can skew the way that maps and navigation apps work for amateur and professional navigators. So, publication of the latest version of the World Magnetic Model (WMM) on December 10 should restore dependable accuracy to compasses.

As Earth’s magnetic field varies over time, due to the dynamics of its molten iron core, the positions of the North and South Magnetic Poles gradually change relative to True North and South, the locations at which the magnetic point vertically downwards.

Magnetic declination — the angle between magnetic North and true North (the northern end of Earth’s axis) — at a given location also changes over time. The magnetic north pole is located within the Arctic Ocean and is heading from Canada toward Siberia. The magnetic south pole is located just off the coast of Antarctica in the direction of Australia.

After virtually chasing the poles across the northern and southern hemispheres for the past five years, NOAA’s National Centers for Environmental Information (NCEI) and the British Geological Survey, with support from the Cooperative Institute for Research in Environmental Sciences (CIRES), released WWM2020.

Data from a trio of European Space Agency Swarm satellites, which measure variations in Earth’s magnetic field, and 160 land-based magnetic observatories were used to create the map.

A new and updated version of the WMM is released every five years, although the organizations published an update to WWM2015 last February due to the increased velocity with which the magnet poles having been moving since the turn of the century. The latest WMM2020 model will extend to 2025.

Many smartphone and consumer electronics manufacturers incorporate the latest WMM in their products in order to create accurate compass apps, maps, and GPS services. The WMM is also the standard navigation tool for the Federal Aviation Administration, U.S. Department of Defense, NATO, and other organizations.

The WMM now includes “Blackout Zones” around the magnetic poles, defined by the strength of the horizontal field. A horizontal field strength between 2000 and 6000 nanotesla (nT) comprises the “Caution Zone” within which compasses may begin to generate errors. The area around the pole between 2000 and 0 nT contains the “Unreliable Zone” where compasses may become inaccurate.
This is the final article in a three-part series describing the development and growth of automotive navigation systems. As discussed in the previous articles, despite the fact that the automobile had become the engine of the American economy, by the fourth quarter of the 20th century, there were still no affordable, highly functional car navigation systems available to the public.

Etak Inc.’s Navigator, introduced in 1985, was the first commercially available automotive navigation system that significantly altered the course of car navigation.

The company’s startup funding — reportedly $500,000 — came from Russell Bushnell, the peripatetic founder of Atari (which produced the early digital game, Pong) and Chuck E’Cheese. He asked his sailing buddy, Stan Honey, a research at SRI International, to investigate what it would take to develop a car navigation system. Honey presented the keynote address at the ION GNSS+ 2017 meeting.

Honey’s original Etak Navigator incorporated an Intel 8088-based system in custom packaging with 256K RAM, 32K EPROM, 2K SRAM. An integrated cassette tape drive stored digital maps and some of the operating system. The tape drive had limited capacity, requiring, for instance, three or more cassettes to cover the Los Angeles area. When a vehicle reached the edge of one cassette’s map, drivers needed to swap the cassette for another in order for the Navigator to continue benefiting from the positioning accuracy of the system’s map-matching technology.

The tape drive was designed to be installed within easy reach of the driver so that cassettes could be replaced while the car was in motion. (Talk about distracted driving!) A moving map display used green vector indicators rather than the color raster graphics available today. Address geocoding enabled the Navigator to convert street addresses to a lat/lon points.

Technology-wise, the system was very advanced for the time and, naturally, quite expensive. Its $1,500 price tag represented roughly 15 percent of the cost of a new luxury Chrysler in this era and about 5 percent of the cost of a 5-series BMW. Nonetheless, Etak managed to sell several thousand units over several years.

General Motors’ Delco Division licensed the system (but never made any), as did Clarion (Japan), and Bosch’s Blaupunkt organization (Germany). By 1987 Etak stopped making its own hardware and focused more on digital mapping technology with its Etak Maps and EtakGuide products.

Etak became TeleAtlas and is now part of TomTom, headquartered in The Netherlands. Etak’s lasting legacy lies in its recognition that high accuracy digital maps would be the key to proliferation of car navigation systems. Etak began mapping Japanese cities in 1987 and licensed its map-matching navigation software to other developers. In 1995 it was acquired by the Sony corporation.

Enter GPS

In 1990, Mazda introduced the first ever GPS system for automotive navigational use. Offered for top-of-the-line Eunos Cosmos (known in North America as the Mazda Miata) roadster cars and only available in gadget-loving Japan, Mazda’s navigation system was built into the actual car. For the first time, absolute position on the road could be known in real time from satellites in space. Truly, the “space age” had finally arrived in the automobile, although
until May 2000 GPS positions were still degraded for the civil community due to the policy of Selective Availability.

In 1991, Garmin became the first company to introduce GPS navigation into general use in the United States. By 1998, Garmin launched their portable StreetPilot GPS navigation system designed for automotive use. It had a black and white screen and used cartridges with mapping. One cartridge could cover, for example, the entire Atlanta area.

The StreetPilot GPS represented a huge advance for car-owners, because now “anyone” could buy a GPS navigation system — if they could afford it. List price was initially about $550, less than 3 percent of a luxury Chrysler base price, and less than 1.5 percent of the BMW 528i base price. Best of all, the StreetPilot GPS unit could be moved from car to car, so that people could actually pack it in their luggage, fly to a distant destination, and use it in rental cars.

With the advent of the 21st century came the curtailment of the degradation of the civil GPS signal by Selective Availability, along with rapid advances in digital optical storage technology that enabled high-density map information to be displayed seamlessly covering large geographic areas. By 2004, virtually all automobile manufacturers offered, at least for their high-end models, integrated GPS navigation systems with color dashboard displays and driver assistance features.

**The Future of Car Navigation**

Smartphones’ meteoric proliferation beginning in about 2008 has actually served, at least temporarily, to separate the navigation system from the automobile — reversing the technology evolution that began with the StreetPilot. As a result, many consumers have chosen not to purchase an optional integrated navigation system with their car. Instead they rely on their smartphones with its real-time, crowd-sourced database capabilities and sophisticated apps such GoogleMap and Waze.

Going forward, with the emergence of 3D maps, LiDAR, inertial sensors, and other sensor technologies, future car navigation systems, sometimes referred to as E-horizon systems, could well have even tighter integration with the automobile IT systems, enabling safer and more eco-friendly transportation.

This series of articles has shown that, for the first 100 years of the automobile and roughly corresponding to the 20th century, car navigation systems were trailing far off in the rear view of the driver. Towards the beginning of the 21st century and casting an eye forward, the relationship between the automobile and the car’s navigation system will execute a U-turn whereby the advancements in absolute and relative navigation will pull the automobile towards enhanced economy and autonomy.

References for this series of articles were provided in the first installment of the series (summer 2019 issue). In addition to those sources, this article used excerpts from the Wikipedia entry on Etak’s navigation system: <https://en.wikipedia.org/wiki/Etak>.

Marvin B. May is the Chief Scientist of the Pennsylvania State University’s Applied Research Laboratory Navigation Research and Development Center in Warminster, Pa. He also teaches navigation courses; his emails are <mbm16@arl.psu.edu> and <mayven4@comcast.net>. Check out my rough draft video on the history of inertial navigation at <https://youtu.be/epdmOdLAhSc>.
On December 26, 2019, the day after Christmas, the Federal Aviation Administration (FAA) announced it will propose new rules requiring drone operators to incorporate a means to remotely identify drones operating in the national airspace.

The rulemaking process will begin with a 60-day public comment period and will include a three-year transition period to phase in the new operational requirements.

Under the proposed rules, all unmanned aerial vehicles (UAVs), more commonly referred to as “drones,” will be assigned unique identifiers. During each flight UAV operators will be required to transmit the identities and locations of their drones to an online service provider authorized by the FAA to be part of the location-tracking system. Drones flying more than 400 feet from their base stations will be required to broadcast location information directly from the aircraft.

The FAA’s press release noted that there are currently 1.5 million drones and 160,000 remote pilots registered with the FAA, and drone operations are the fastest growing transportation segment in the U.S.

The UAV rule will lay the foundation for more complex drone airspace integration to support beyond visual line of sight (BVLOS) operations at low altitudes. BVLOS operations are essential for envisioned drone delivery services to be established with acceptable risk when considering public safety requirements.

There is no doubt that readily available, accurate, reliable, and cheap positioning, navigation and timing (PNT) capabilities (or services) provided by systems such as GPS are critical enablers of the extended drone delivery services anticipated in the not too distant future.

Unfortunately, these activities will sooner or later capture the headlines much like the events of early 2019 when the United Kingdom’s Gatwick airport was temporarily closed to air traffic because of drone incursions.

Some readers may recall that one of the catalysts that factored into the actions that led to the Clinton era 1996 Presidential Decision Directive on GPS was the September 12, 1994, incident when a private plane crashed into the south lawn of the White House. In the wake of that incident, numerous press articles theorized about the challenges of dealing with piloted or unpiloted aircraft used as weapon delivery systems. Unpiloted aircraft (i.e., UAVs) would eventually benefit greatly from advances being made with the “new” capabilities provided by the U.S. Global Positioning System, which had begun its rise to stardom in the first Gulf War in 1991.

Although GPS had not as yet achieved the broad civil, commercial, and scientific uses that it has today, U.S. policy going back to the 1960s had already required that electronic forms of navigation, such as Loran-C, Omega, DMEs, radio beacons, VORs, TACAN, etc., (NAVAIDs) being provided by authorized government authorities like the Coast Guard, FAA, and Department of Defense (DoD), “remain responsive to the National Command Authorities.”

The 1960s’ policy for accomplishing this mandated NAVAID responsiveness to the National Command Authorities was called SCATANA. The acronym was derived from a national policy then in place called “Security Control of Air Traffic and Air Navigation Aids.” SCATANA, which was still in force on September 11, 2001 (9/11), was a legacy, Cold War-era policy dealing with emergency preparedness plans. These plans prescribed the joint actions that the DoD and FAA would take to effectively control air traffic and air navigation aids under emergency conditions affecting national security.
hostile use of an aircraft. Even in 2001, however, civil and defense leaders already recognized that a “total system shutdown” for a global system such as GPS wasn’t practical for a variety of reasons, including the already recognized reliance on it by both commercial and military users alike.


However, should an emergency be declared, the current ESCAT instruction defers specific details for its use, stating that “implementation of measures for mitigation of hostile use of NAVAID signals will be subject to separate agreement between DoD and other Departments and Agencies.”

Current experience, however, highlights the many challenges that factor into establishing any such agreement, particularly in high-stress situations. The DoD already confronts such challenges today when seeking to schedule, execute, and abide by the FAA’s operational “cease buzzer” constraints for open-air training exercises approved in the NAS that involve temporary and limited episodes of GPS jamming.

Bottom line: The challenge of how to deal with “drones” today can be traced back to a long-standing reluctance by government agencies to take on the hard issue of dealing with very available, real-time PNT capabilities. It won’t take long before some U.S. airports are faced with the same “challenges” recently experienced in the UK. When that happens, someone should start asking “Why have we hesitated to address this here in the United States?”

Cloaking oneself in the blanket of “it’s just too hard” won’t be a satisfactory answer.
ION Newsletter 18 Winter 2020

The 33rd International Technical Meeting of the Satellite Division of the Institute of Navigation

September 21-25, 2020
Exhibit Hall: September 23 and 24
St. Louis Union Station Hotel
St. Louis, Missouri

ion.org®

ABSTRACTS DUE MARCH 5

The 33rd International Technical Meeting of the Satellite Division of the Institute of Navigation

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Have you ever flown a drone, driven a car with built-in navigation, or worn a smart watch? If so, you’ve already experienced our technology.

With over half a billion receivers implemented worldwide, u-blox is a leading provider in global navigation satellite system (GNSS) solutions that are tailored to every customer’s needs. Because we use our own silicon, we can offer controlled quality, high performance, quick support, and stable product life cycles. Our positioning modules and chips set the benchmark in performance and cost effectiveness and incorporate our pioneering innovation in high precision, anti-spoofing, power efficiency, and small size.

Our wide portfolio includes standard precision receivers that deliver meter-level accuracy, and Super-E low power mode for small tracking devices. High precision receivers deliver sub-meter to centimeter-level accuracy which is key for automation. Dead reckoning technology provides 100% positioning coverage for the automotive industry, even in parking garages, tunnels, and deep urban canyons. And accurate timing and frequency technology round off our offering.

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

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Danish Prosecutors Suspend Use of Phone Tracking Data

Denmark released 32 prisoners, postponed nearly 40 new cases, and ordered a review of 10,700 criminal cases after questions arose last fall regarding the reliability of geolocation data obtained from the mobile phone of suspects.

Jan Reckendorff, the country’s director of public prosecutions imposed a two-month moratorium on the use of mobile phone records in trials after errors were found in the software that converts data from cell towers into evidence used in trials. Those cases stemmed from tracking data collected earlier in the year that omitted data in processing cell tower records, which resulted in less accurate calculations of the phones’ locations.

Another problem was discovered in tracking data that linked locations to the wrong cell towers. Taken together, the errors suggested that innocent people could potentially have been placed at crime scenes while the actual perpetrators were excluded from police investigations.

Mikael Sjoberg, the head of the Association of Danish Judges, told the New York Times that the errors, “puts us in a very uncomfortable situation that the foundation of our decisions is called into question,” he said.

Karoline Normann, the head of the Danish law society’s criminal law committee, told Agence-France Presse, “This situation has changed our mindset about cellphone data,” adding, “Until now, mobile data has had a high significance and value in courtrooms.”

Jakob Willer, the director of the country’s Telecom Industry Association, defended mobile phone network operators, noting that the use of cellphone tower data in court cases went beyond its original purpose. “We are not created to make surveillance systems, but to make phone networks.”

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Calendar of Upcoming Events

MARCH 2020
16-18: Munich Satellite Navigation Summit 2020, Alte Kongresshalle, Munich, Germany
Contact: Munich Satellite Navigation Summit
Web: www.munich-satellite-navigation-summit.org

APRIL 2020
Contact: ION
Web: ion.org

MAY 2020
11-14: European Navigation Conference (ENC 2020), International Congress Center, Dresden, Germany
Contact: German Institute of Navigation
Web: www.enc2020.eu

JUNE 2020
1-4: ION Joint Navigation Conference (JNC) 2020, Northern Kentucky Convention Center, Cincinnati, Ohio/Covington, Kentucky
Contact: ION
Web: ion.org

SEPTEMBER 2020
21-25: ION GNSS+ 2020, St. Louis Union Station Hotel, St. Louis, Missouri
Contact: ION
Web: ion.org

JANUARY 2021
Contact: ION
Web: www.ion.org

JUNE 2020
1-4: ION Joint Navigation Conference (JNC) 2020, Northern Kentucky Convention Center, Cincinnati, Ohio/Covington, Kentucky
Contact: ION
Web: ion.org

SEPTEMBER 2020
21-25: ION GNSS+ 2020, St. Louis Union Station Hotel, St. Louis, Missouri
Contact: ION
Web: ion.org

JANUARY 2021
Contact: ION
Web: www.ion.org
Navigation in GPS-Denied Conditions, LEO SV Program

CubeSats and vision-aided navigation headlined luncheon meetings of the ION Dayton Section during the final quarter of 2019. Dr. Clark Taylor, Air Force Institute of Technology, spoke to the group at its October gathering about using visual aids for navigating when GPS is absent. Because visual processing is not linear, an aircraft must execute controlled maneuvers to help the vision-aiding algorithms achieve accurate results. Dr. Taylor discussed two different vision-aided navigation scenarios and described the improvement in accuracy gained from controlling the aircraft.

In November, the section heard Ohio University professor Dr. Sabrina Ugazio describe OU’s Bobcat-1 CubeSat, a miniature satellite scheduled for launch into low earth orbit (LEO) in summer 2020. CubeSat can exploit the advantages of LEO receiver measurements, such as the excellent visibility of GNSS satellites and the low-multipath, low-interference environment. According to Dr. Ugazio, project objectives — in addition to the educational value for students — are to investigate its utility as an accurate time source from LEO. Accurate time can enable users to determine GNSS inter-constellation time offsets, improving geometric dilution of precision (GDOP) for high-altitude space service-volume platforms and measuring ionospheric total electron content (TEC).

On another subject, the Dayton Section is encouraging all college students in its area who are interested in positioning, navigation, and timing to consider applying for its 2020/21 navigation apprenticeship/scholarship. The deadline is April 3, 2020. Application forms and more information are available at <http://dayton.ion.org/wp-content/uploads/2019/11/ION-NavApprentScholarship_2020.pdf>.

ION @ INC

The Institute of Navigation exhibited during the Royal Institute of Navigation’s International Navigation Conference (INC) held November 18–21, 2019, in Edinburgh, Scotland, UK. The technical program focused on the societal benefits of navigation — from animals to autonomy — that incorporate a wide spectrum of disciplines and applications from innovative navigation solutions to maritime cyber-security. U.S. ION members presenting keynote addresses included Dana Goward of the Resilient Navigation and Timing Foundation; Dr. Todd Humphreys of the University of Texas at Austin; Diana Furchtgott-Roth, Deputy Assistant Secretary for Research and Technology, U.S. Department of Transportation; and Dr. Y. Jade Morton of the University of Colorado Boulder (and ION President).
Prof. David Last, 79, passed away in November while piloting a plane off the coast of Wales. An expert in terrestrial and space-based positioning, navigation, and timing (PNT) solutions, Prof. Last proposed and helped develop commercial tracking systems employed at sea and for high-security vehicles on land. He influenced the current mix of radionavigation systems in Europe and the United States as a contributor to the draft baseline European Radionavigation Plan.

Prof. Last served as a consultant to numerous companies and governmental and international organizations on the subject of radionavigation and communications technologies and their applications. He also made technical to navigation programs as diverse as Omega, Decca Navigator, Loran-C, enhanced Loran, Argos, differential GPS, and GNSS/GPS.

Later in his career, Prof. Last became renowned as an expert witness in diverse technologies, especially in forensic matters concerning GPS. He was one of the first to develop the technology to support such forensic analyses in a court of law and demonstrated a unique talent of being able to explain complex technical concepts to a non-technical audience. Part of this had to do with his dynamic and engaging speaking style, which also made him a popular presenter at ION events.

Prof. Last was a past president of the Royal Institute of Navigation (RIN, 2005–2008), an ION and RIN Fellow, and a recipient of the RIN’s Harold Spencer-Jones Gold Medal (2010), the International Association of Institutes of Navigation’s Necho Award (2015), and The Institute of Navigation’s Burka Award (1994). Prof. Last was a Professor Emeritus at the University of Wales where he continued to act as an external examiner for Ph.D. candidates.

Thomas B. McCaskill, 81, a former mathematician and research physicist at the U.S. Naval Research Laboratory (NRL) where he contributed to the design of GPS, including the first solution of the instantaneous positioning problem, determination of the optimal inclination for the GPS constellation, and verification of the effects of relativity on an orbiting cesium atomic clock. He received five NRL Research Publication Awards and one Patent Award before retiring in 2002.

McCaskill was a Senior Member of the Institute of Electrical and Electronic Engineers (IEEE) and a member of the Institute of Navigation (ION) where he was selected to serve as a Congressional Fellow in 2003. In 2005, he became a candidate for U.S. Senator in the Maryland primary election with the Campaign Motto: “GPS Saves Lives.”

Colin Beatty, past president of the Royal Institute of Navigation (RIN, 2011-13) and a regular participant at the ION Satellite Division’s GNSS conferences, passed away in October 2019 at the age of 76. Beatty started his career in the navigation and missile systems field with S. G. Brown Ltd, before serving with Cunard ocean cruise line as an electrical engineer officer for a couple of years.

In 1969 he joined Magnavox, working on the introduction of Transit satnav systems to navies and merchant fleets, and then progressed to Omega and GPS technologies. Beatty was marketing manager at Magnavox from 1977 to 1988. He later founded his own consulting company while serving as General Manager of Ashtech Europe Ltd. where he specialized in GPS and GLONASS products and applications.

In addition to his extensive volunteer service with the RIN, Beatty chaired the UK Satellite Coordinating Committee, linking industry and government on Galileo issues.
GNSS Program Updates
News from Systems Around the World

Modernization, Reorganization, Implementation

**GPS**

President Trump signed both the defense appropriations and authorization bills on December 20, which included funding of nearly all of the U.S. GPS program, and the U.S. Air Force announced the operational availability of a GPS III satellite in January.

Once again, Congress fully funded work on the new GPS ground system, the Next Generation Operational Control System (OCX), and the GPS Enterprise Integrator. The $445.3 million request for fiscal year 2020 (FY20) was substantially lower than the $513.2 allocated in FY19 and the $510.9 million in FY18.

GPS III satellite program also received its full requested amount, including $31.5 million for procurement and $42.4 million for research, testing, development and evaluation (RTD&E). The program is wrapping up as the Air Force and its contractors continue work on the next generation of satellites, the GPS III Follow On spacecraft or GPS IIIIFs.

After cutting $20 million from the procurement request, the GPS IIIIF program was approved for $394.6 million, down 8 percent from the $426.9 million in FY19. The Military GPS User Equipment (MGUE) program will receive $320.6 million.

After a trouble beginning, the next-generation GPS OCX has stabilized over the last two and a half years and program managers are looking forward to the delivery of OCX Block 1 and 2 over the next 18 months, according to Lt. Gen. John F. Thompson, commander of the Space and Missile Systems Center, Air Force Space Command, Los Angeles Air Force Base, California.

The OCX program was years behind its original schedule and tens of millions of dollars overbudget in 2016, which forced the Air Force to declare a Nunn-McCurdy breach and work to avoid automatic closure of the program.

On October 21, the GPS III Contingency Operations Program successfully connected with the first GPS III satellite on orbit on October 21, allowing the Air Force to operationally command and control the two GPS III satellites on orbit as well as earlier generations of operation GPS satellites currently in the constellation. On January 13, the 2nd Space Operations Squadron at Schriever Air Force Base, Colorado, set the first GPS III satellite vehicle number 74 (SVN) healthy, with its signals now available for civilian and military users.

In 2020, the AEP OCS hopes to implement the M-Code Early Use upgrade, which will enable use of advanced military signal designed to improve anti-jamming and anti-spoofing.

**GLONASS**

A new GLONASS-M navigation satellite, launched December 11, became on orbit on October 21, allowing the Air Force to operationally command and control the two GPS III satellites on orbit as well as earlier generations of operation GPS satellites currently in the constellation. On January 13, the 2nd Space Operations Squadron at Schriever Air Force Base, Colorado, set the first GPS III satellite vehicle number 74 (SVN) healthy, with its signals now available for civilian and military users.

In 2020, the AEP OCS hopes to implement the M-Code Early Use upgrade, which will enable use of advanced military signal designed to improve anti-jamming and anti-spoofing.
operational on January 3. Designated GLONASS 759, it will replace an aging spacecraft in the fleet.

Russia has completed testing of its System for Differential Correction and Monitoring (SDCM), which is “at the initial stage of certification,” according to a presentation at the International Committee on Global Navigation Satellite Systems (ICG) by Dr. Ivan Revnivyk, head of the GLONASS Application Division for ROSCOSMOS State Space Corporation. The augmentation system currently includes 35 ground stations (including 10 outside Russian territory) and three Luch satellites broadcasting differential corrections on GLONASS L1 and L5 signals.

**BeiDou**

China launched two BeiDou satellites into space on December 16, completing the middle Earth orbit (MEO) component of the constellation with 24 spacecraft.

According to the current BeiDou Navigation Satellite System (BDS) plan, two more GEO satellites will be launched in the first half of this year, and the launch of all BDS-3 satellites will be completed half a year ahead of the target completion date for the constellation at the end of 2020.

In a press conference on December 27, Ran Chengqi, director of the China Satellite Navigation Office (CSNO), said, “Before June 2020, we plan to launch two more satellites into geostationary orbit and the BeiDou-3 system will be fully completed.”

Ran also noted that more than 70 percent of smartphones in China use BeiDou signals for navigation, although China’s users tend to call all satellite navigation systems “GPS” because the U.S. system was the first and most widely adopted.

The full constellation of the BeiDou system (BDS-3) will include 3 GEO satellites, 3 IGSO satellites, and 24 MEO satellites. The Chinese program is finishing in accelerated fashion, with 28 satellite launches in the past two years.

On December 9, the CSNO released technical documents outlining the specifications of BDS-2 satellites for use for high-precision applications and the approved BeiDou coordinate system (BDCS) parameters. The BDS-2 parameters are provided by the BDS satellite manufacturers. The documents are available for download from the BDS website at <http://en.beidou.gov.cn>.

The Civil Aviation Administration of China (CAAC) recently released a Roadmap for Application of BeiDou Navigation Satellite System (BDS) in China’s Civil Aviation. Also in December, the CSNO published its fourth edition of a white paper on “Development of the BeiDou Navigation Satellite System,” available online at the CSNO website.

**Galileo**

On November 19, the European Commission (EC) released the findings and recommendations of an Independent Inquiry Board established to investigate a lengthy Galileo service outage that began July 10, 2019, and continued for six days.

Composed of European Union (EU) experts with significant experience in complex operational transport, space and defense projects confirmed the Galileo program, that is, that the incident was triggered by a combination of events in the course of an upgrade of Galileo ground infrastructure. This included mishandling and non-standard configuration of temporary equipment installed for the upgrade leading to a performance anomaly that produced erroneous data in Galileo signals.

The Inquiry Board recommended a review of Galileo’s operational management to better meet the needs of a service-driven exploitation phase and parallel evolution, while ensuring service continuity and integrating an oversight function. The program should enhance operation, maintenance and configuration management, including training, and create a means for prompt and structured institutional communication to users and EU member states in crisis situations.

Together with the European GNSS Agency (GSA) and the support of the European Space Agency (ESA), the EC is developing an action plan for the implementation of the Board’s recommendations, which was scheduled to be presented to member states in December.

An EC reorganization following EU elections last year, will place Galileo and related programs into a new directorate general for Defense Industry and Space (DEFIS). It will be led by Director-General Timo Pesonen, formerly head of DG GROW (Internal Market, Industry, Entrepreneurship and SMEs) under which the Galileo program previously operated.

The core Galileo management will be in a DEFIS Space section provisionally headed by Matthias Petschke, a long-time political leader in the EU’s space programs. His section will include units for satellite navigation headed by Paul Flament and his deputy Jeremie Godet, two familiar names among Galileo program leaders, as well as units for space observation and space policy. A separate Development & Innovation section includes a unit on Space Research, Innovation & Start-ups.

The commission will implement a unified space program for 2021-27 with funding of €16 billion (US$17.85 billion). Under the new initiative, the GSA — now responsible for overseeing services and security of European satellite navigation programs — will become the European Agency for the Space Program (EUSPA). In its new incarnation, the agency will have an expanded mandate to manage the market uptake and communications of the Copernicus Earth observation program, helping to exploit the synergies between Galileo and Copernicus.

The unified Space Program will also introduce new security-related space initiatives Space and Situational Awareness (SSA) and Governmental Satellite Communication (GOVSATCOM).
January 25–28, 2021
Hyatt Regency Mission Bay
San Diego, CA

2021
One Registration Fee, Two Technical Events and a Commercial Exhibit

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