POSITIVE TRAIN CONTROL & SAFETY

Amtrak Accident Renews Push for PTC

The fatal derailment of an Amtrak passenger train in Washington state has, once again, prompted calls for installation of GPS-aided positive train control (PTC) systems on board American trains.

On December 18, 2017, passenger train 501 — a Talgo Incorporated locomotive on its inaugural passenger service trip — went off the tracks at an estimated 78 mph in a 30-mph speed zone near Dupont, Washington, a small community between Tacoma and Olympia.

The train, consisting of a leading and trailing locomotive, a power car, 10 passenger railcars and a luggage car, was carrying 77 passengers, 5 Amtrak employees, and a Talgo Incorporated technician. Of these individuals, 3 passengers were killed and 62 passengers and crewmembers were injured. The resulting damage was estimated to be more than $40.4 million.

PTC continued on page 11

SHALL THE TWAIN EVER MEET?

E911, Commercial Positioning Mismatch

The answer reflects the fact that, when it comes to public applications with their associated policy development, the technology is the easy part. Commercial applications can just go ahead and develop and implement a solution and worry about policy or regulatory issues (such as privacy) later.

Funding, standardization, and re-equipage issues have long slowed the adoption of more accurate positioning capabilities by the emergency (911) services providers. But recent developments by handset technology providers, particularly Google’s Android and Apple’s iPhone, may bring a closer alignment between what mobile phone users can expect from non-emergency apps and E911 service.

The Institute of Navigation has seen interest grow in both smartphone-based applications and indoor positioning, with numerous papers and entire sessions at its technical conferences addressing advances in indoor location, applications of GNSS observables on smartphones, and ubiquitous positioning or positioning in challenging environments.

The 2017 ION GNSS+ conference included a tutorial on Android Raw Measurements — Theory and Application while papers in a technical session addressed “Applications of Raw GNSS Measurements from Smartphones,” inspired in large part by Google’s making GNSS observables available for Android phones. At the conference, Frank van Diggelen, leader of the Android Location Team, offered a presentation on E911 Mismatch continued on page 4

“Why can I find the pizza parlor using my mobile phone navigation app, but first responders to an emergency call cannot find me?”

The Scott County Sheriff’s Communications Division is the Public Safety Answering Point (PSAP) for the approximate 139,000 residents of Scott County, Minnesota.
I met recently with Lisa Beaty, ION’s Executive Director, to discuss candidates for an important volunteer position that needed to be filled at ION in the upcoming year. Lisa handed me a list of people who had been pre-vetted for said position, and, in my current role as ION president, my immediate question was, “Was I at one time on such a list as this, and if so, how did I get there?”

It turns out that there is a very natural progression to leadership in an organization like ION. Without realizing it, I had naturally followed this progression. Normally, it begins by serving as a session chair for an ION conference. In my case, there was a leader in our organization who was already involved in the ION and recommended that I be considered for upcoming roles. So, one day, to my great surprise, I got an email asking if I’d be willing to be a session chair for an upcoming conference. This led to future similar invitations. Eventually I was asked to be a track chair at the ION GPS conference, then a program chair for a different conference, and eventually ended up on the ION Council.

I suspect that if you ask any ION Council member, he or she would have a very similar story. Not that you are all as-spiring to become ION president (though I must admit it is a very rewarding experience!). However, if you are interested in getting more involved, here are a few ways to do so:

• Chair a technical session at an ION conference
• Volunteer to organize a workshop or session on an emerging application or technology
• Provide support to a local ION section
• Provide peer review for technical papers in your area of expertise
• Support student programs (as an awards committee member, competition organizer, or as a student mentor)

If you have a desire to volunteer, I would encourage you to communicate your specific interests using the volunteer form on the ION’s website: <https://www.ion.org/about/volunteer.cfm>. You are encouraged to be as specific as possible in your interests and technical specialties.

It is relatively straightforward to volunteer and be asked to do something along these lines for the first time. Please realize that whether you are asked again after that initial experience is highly dependent on how well you did in your previous role (i.e., fulfilling what was asked of you well and in a timely manner).

The ION is a volunteer-run organization, and we are ALWAYS looking to involve new people, but we need volunteers who are willing to do a good job and fully engage in the process. I would encourage you to consider increased involvement in the ION — while it does take some effort, the opportunity to work directly with other leaders in the navigation field is immensely rewarding!

Donate
For those of you who believe in the ION’s mission, but would prefer to contribute monetarily, the ION Council formally adopted a policy this past September whereby you may now donate to specific programs that you favor. Current member donation categories include:

**ION Reserve Fund:** helping us build a fund that will eventually enable us to endow important ION programs on a perpetual basis, while also keeping us protected for unexpected changes in expenses and revenue and in creating a financial safety net. The reserve fund gives the ION the much needed freedom to make the changes necessary to move the organization toward realizing our financial goals.

**New Initiatives:** allowing us to identify and provide timely support to new initiatives throughout the year.

**Student Programs:** continuing our outreach and support of the future generation of professionals in positioning, navigation, and timing (PNT). Our student programs include:

• Student Memberships
• Student Awards Program
• Student Registration Grants
• Section-sponsored Graduate Student Awards
• Student Registration Discounts
• Scholarships through Local ION Sections
• Bradford W. Parkinson Award (honoring outstanding graduate students in GNSS)

**Government Fellows:** providing a unique educational experience to an ION member to serve as either a Congressional or Executive Fellow, while also providing the government a resource with technical expertise that we hope will help foster effective public policy on the issues that affect our field. (This program is administered through a partnership with the American Association for the Advancement of Science.)

If you are new to ION, I assure you that participating in ION’s programs, either through volunteerism, financial contributions, or both, is a wonderful avenue by which to network within the PNT community, hone professional skills in service to an organization that serves our community well, and perhaps to develop or apply skill sets that you may not use in your day job. ION is also an organization where your efforts can have a direct, and often times immediate, impact, and the satisfaction of seeing the intrinsic reward of your contribution is substantial.

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Access More with Premium Professional Membership Upgrade

ION members enjoy several benefits: professional networking, the prestigious quarterly journal NAVIGATION, the quarterly ION Newsletter, discounts, access to a community of like-minded professionals and many other privileges.

One of the most valuable benefits of membership is access to the ION’s database of more than 17,000 technical papers, including peer-reviewed papers that have been published in ION’s journal, NAVIGATION, proceedings from years of technical conferences, and other special publishing initiatives. It is a hugely valuable resource for anyone involved in research and development.

For PNT professionals requiring more than the 12 complimentary technical paper downloads per year provided with a Professional Membership, ION now offers an upgrade to Premium Professional Membership, which increases the allotment to 25 downloads per month. These additional paper downloads are great for those involved in research, new product development, exploring specific technologies and experimental results, or anyone looking to further the progress of the field.

Searching the technical database is easy. Go to www.ion.org/publications and click on “Article Search.” You can search based on specific proceedings, by year, paper title, author, or any specific key words you’re looking for.

A Premium Professional Membership is $180 ($210 for addresses outside the U.S.) and gives you all the benefits of Professional Membership, with the added benefit of additional paper downloads. It’s a vital tool that shouldn’t be overlooked.

Receive up to 25 Complimentary Paper Downloads Each Month

The Institute of Navigation’s(ION) database has more than 15,000 highly-specialized technical papers, proceedings from Institute of Navigation technical conferences, and peer-reviewed articles related to the art and science and technology of positioning, navigation and timing.

www.ion.org
“Google Analysis Tools for GNSS Raw Measurements.”

**A Long and Winding Roadmap**

For GNSS and mobile phone users in the United States, the story began in 1996 with a Notice of Proposal Rule Making (NPRM) for what the Federal Communications Administration (FCC) calls Enhanced 911 (E911) service, which outlined an automatic location information (ALI) reporting capability for wireless carriers. In most cases, an E911 call must provide the ALI to emergency call centers — known formally as public safety answering points (PSAPs) — so that first responders can reach the caller’s location quickly even if callers are unable to provide that information.

The issue has become more pronounced as wireless telephone use came to eclipse wireline phones, which provided PSAPs with specific street addresses of 911 calls. According to the National Emergency Number Association (NENA, one of two main PSAP organizations), in 2015 only 20 percent of emergency phone calls were made on wired telephones, while 80 percent were made on wireless devices.

Initially, FCC and wireless carriers assumed that E911 requirements would be met using network-based techniques such as cell-ID and triangulation using cell towers. Positioning accuracy was correspondingly imprecise and could be hundreds of meters off, which undercut the efficacy of emergency response to mobile callers.

As GPS became fully operational and in wider use, it became the E911 positioning technology of choice for mobile phones, which could then have commercial location-based apps built in. Along the way, FCC ALI accuracy requirements increased, reflecting the capabilities of the new technology.

After a few years, however, the growing frequency of emergency calls made using mobile phones inside buildings — where GNSS signals are blocked, reflected, or otherwise impaired — prompted new regulatory efforts and a corresponding search for suitable technologies. To this was added the need for an accurate vertical (z-axis) component in a three-dimension position fix to determine the floor on which a call originates in a multi-story building.

In a 2015 report and order, the FCC acknowledged, “by focusing on outdoor requirements for verifying compliance, our rules currently provide no remedy to address poor performance of location technologies indoors.” The increase in wireless-only U.S. households — 44 percent by 2014, according to a National Health Interview Survey cited by the FCC — amplified the need for indoor positioning capability on mobile phones.

**GNSS+**

Wi-Fi and Bluetooth localization are probably the most popular solutions, taking advantage of sensors already on board most smart phones and the proliferation of Wi-Fi hotspots. Inertial and barometric pressure sensors, which are also common features on handsets, can also help out, including with the vertical dimension.

The 2015 FCC order established a new standard to supplement previous absolute positioning in terms of meters: “dispatchable location,” defined as location delivered to the PSAP by a wireless provider in a 911 call and consisting of the street address of the calling party, plus additional information such as suite, apartment, or similar information necessary to adequately identify the location of the calling party. Alternatively, carriers could provide x/y (horizontal) location within 50 meters.

The final order also incorporated an implementation schedule requiring that 80 percent of all wireless 911 calls met this standard within six years. Better E911 ALI can be a life or death matter. In a 2014 filing with the FCC, two wireless industry veterans, David Witkowski and John Vetter, wrote, “Using rough but reasonable assumptions, it can be estimated that improved location accuracy which results in reducing wireless E911 response time by one minute can result in saving over 10,000 lives annually.”

Meeting the new FCC E911 schedule, however, still demands a bridging of the gap between technical capability...
(increasingly a function of the handset) and PSAP and first responders operational performance.

“The commercial location solutions . . . are built for a different use case than 911,” Matthew Gerst, an assistant vice-president of regulatory affairs at CTIA, told the Wall Street Journal in a January 8 article. CTIA is the wireless industry trade group. Positions output by navigation apps don’t necessarily produce a street address.

Until recently, providers of mobile phone positioning have avoided getting involved with what they considered the domain of wireless carriers.

“I think there is an institutional reluctance by Big Tech to not want to formally enter into the public safety world,” former FCC emergency management director Rear Adm. (Ret.) David Simpson told the Wall Street Journal in the same article.

Advanced Mobile Location

A couple of years ago, however, engineers on Google’s location team launched a project called Thunderbird to find a way to provide more precise location data to 911 operators. They found a receptive partner in the United Kingdom’s BT telecom group responsible for that country’s emergency response system. Along with its partners EE, O2, Three, and Vodafone (British mobile network operators), BT had recently developed a method for improved, automatic reporting the whereabouts of emergency callers from mobile phones called Advanced Mobile Location (AML).

AML uses existing handset technologies with an already available short message service (SMS) solution to transport the information from the handset to BT PSAPs and match it with the voice call based on what are known as Calling Line Identity (CLI) details. According to a European Emergency Number Association (EENA) AML specifications document published in February 2016, BT was handling approximately 4000 emergency calls per week using the AML solution, which had been implemented for handsets of HTC, Alcatel, Sony Mobile, and Samsung in the UK.

Based on the 4,000 handset locations each week, BT determined that approximately 40 percent use assisted-GNSS/GNSS location information, 34 percent use Wi-Fi location information, and 8 percent cell location. In 87 percent of accepted handset locations, positioning accuracy was approximately within 50 meters and 90 percent of caller locations arrived at the PSAP within 30 seconds of the network location being provided. Those results suggest that the system could meet or exceed the FCC requirement still four or five years away.

AML required no significant investment by the mobile networks or handset providers. “The handset enhancement is invisible to handset users who simply call 112 as normal and do not need to download an App,” according to the EENA document.

Last July, Google announced that it had implemented AML technology — in its version called Emergency Location Service (ELS) — in Android phones. “This feature is solely for the use of emergency service providers, and your precise location is never seen or handled by Google. It is sent from your handset to emergency services only when you explicitly place an emergency call, either directly or through your mobile network,” Google engineer and product manager Akshay Kannan wrote in the company’s announcement of ELS. Kannan was a leader of the Thunderbird initiative.

ELS is supported by more than 99 percent of existing Android devices (version 2.3 out and upwards) through Google Play services, according to the company.

“This development will drastically improve emergency caller location,” said Gary Machado, EENA executive director. “I want to congratulate Google for this achievement, and thank them for our great cooperation during the last months.”

According to EENA, in addition to the UK, AML is fully deployed in Estonia, Lithuania, Belgium, Iceland, Finland, Ireland, New Zealand and Austria.

In the United States, the CTIA has created the National Emergency Address Database (NEAD) in collaboration with public safety community representatives as a way to provide carriers and PSAPs with “dispatchable addresses.” NEAD leverages commercially deployed Wi-Fi access points and Bluetooth beacons as reference points mapped to street addresses and additional location information.

When an E911 call is placed on a NEAD-capable device, it scans for nearby Wi-Fi access points and Bluetooth beacons to help determine an indoor location. If those access points are in the NEAD with a verified street address and any additional information such as the floor, office suite, or apartment number, that location information can be sent automatically to a PSAP.

The FCC’s “Indoor Location Fourth Report and Order” required the NEAD to be used solely for 911 location purposes and prohibited its use for commercial purposes. In November, the agency approved the NEAD Privacy and Security Plan.
More than 13 years after issuance of a Presidential Decision Directive on U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy and nearly five years after a similar directive on Critical Infrastructure Security and Resilience (PPD-21), federal agencies continue to advance efforts to ensure access to GPS capabilities.

Due to the crucial role of precise time for telecom, financial systems, and the national power grid, recent efforts have focused on building resilience into GPS timing and frequency receivers. (A forthcoming workshop on the subject is discussed in an article in this newsletter on page 21.) Those activities complement a more general, national and international effort to promote GNSS interference detection and mitigation, which includes spoofing as well.

Two related “guidances” issued by federal agencies are available on the National Coordination Office (NCO) for Space-Based PNT website (www.gps.gov): “Improving the Operation and Development of Global Positioning System (GPS) Equipment Used by Critical Infrastructure,” published last year by the Department for Homeland Security (DHS), and “Best Practices for Improved Robustness of Time and Frequency Sources in Fixed Locations,” released in 2015.

The former guidance covers installation and operation strategies for owners, operators, and installers of GPS systems and development strategies for manufacturers, as well as research opportunities. The latter publication focuses specifically on installing and maintaining time and frequency sources in fixed infrastructure locations for time and frequency operations.

The GPS system is considered a “cross-sector dependency” for the DHS’s 16 designated critical infrastructure sectors. DHS views 13 of the 16 critical infrastructures areas as critically dependent on PNT, while the three remaining sectors had some dependence.

In December, representatives of the U.S. government discussed the latest GPS-related efforts at the Critical Infrastructure Protection and Resilience North America conference held at Kennedy Space Center, Florida. Kevin Skey, a senior principal engineer and head of PNT, Wireless Communications and SIGINT at the MITRE Corporation, addressed “Responsible Use of GPS for Critical Infrastructure” and Robert Crane, DHS senior advisor to the PNT NCO, presented on the subject, “GPS Time – How would a disruption affect your operation?”

Skey is currently providing consulting and leading an advanced PNT protection technology development for the DHS Homeland Security Systems Engineering and Development Institute. Both presentations may be downloaded from the gps.gov website.

Future Shock
PPD-21 defines “resilience” as the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. It includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents. For GPS, that usually includes consideration of backup systems or “assured PNT.”

In his presentation, Skey noted how perspectives about PNT have changed profoundly in the relatively short time that GPS has been around.

The 20th-century perspective was essentially sanguine: GPS is like the
Internet — wonderful technology, nice people; GPS satellites are scarce, so receivers must be promiscuous; GPS receivers are radios.

A 21st-century perspective, however, must take a much more guarded approach, Skey says: GPS is like the Internet — wonderful technology, threats abound; since threats abound, receivers must be robust and discriminating; GPS receivers are networked computers with a wireless access point.

Some PNT-specific examples of building resilience and managing risks include operations contingency planning (practices and procedures for GPS disruptions), alternate PNT sources (clocks; inertial, GNSS, and vision-aided PNT; communication systems, RADAR, compass, and so forth), and improved equipment and systems (antennas, protection algorithms, security engineering, cyber-protections, and adaptable system architectures).

Skey argues for the need for organizations dependent on GPS technology to implement best practices to produce 21st-century equipment, installations, and operations that address 21st-century requirements and threats.

In his presentation, Skey discussed a "defense-in-depth" strategy for GPS timing receivers, elaborating on the following elements: better antennas (capable of anti-jam and anti-spoofing performance), "competent" receivers (capable of anti-jam, anti-measurement spoofing, anti-data spoofing, using modernized GPS signals), product integration (anomaly detection, enablers for alarms and holdover logic, support for atomic clocks), and installation and operation (assess GPS dependencies, proper use and configuration).

"Even with emerging threats, the GPS benefits still outweigh the risk [if] appropriate measures are taken," Skey concluded, noting that robust timing receivers and related protection devices are beginning to appear on the market.
Navigating Your Life

Many of the world's finest minds have spoken about the close relationship between knowing one's position, velocity, and attitude and navigating the vicissitudes of life. From their works, we may learn the importance of knowing not only where we are and where we are going, but perhaps how we should direct our lives.

In everyday language, we tie navigation terminology to the human psyche by using such mental state descriptive phrases as “finding oneself,” “losing oneself (in an activity),” “going nowhere,” “up in the air,” “attitude,” “off kilter,” “dead on” (as in dead reckoning), “high as a kite,” and “depths of depression.” Even “up” and “down” are used more often to describe one's mood than to indicate alignment or opposition with the force of gravity.

Below are some fascinating quotations that reflect the impact of navigation on the mind. They are offered in the spirit of the words of the late 19th century American essayist and poet Louise Guiney: “Quotations (such as have point and lack triteness) from the great authors are an act of reverence on the part of the quoter, and a blessing to a public grown superficial and external.”

“I am free to wander. Heading in the right direction. Not all those who wander are lost.”
— J.R.R. Tolkien in The Fellowship of the Ring

“Getting lost is just another way of saying ‘going exploring.’”
— Justina Chen, author of North of Beautiful

“Morality without religion is only a kind of dead reckoning — an endeavor to find our place on a cloudy sea by measuring the distance we have run, but without any observation of the heavenly bodies.”
— Henry Wadsworth Longfellow

“Here is my journey’s end, here is my butt, And very sea-mark of my utmost sail.”
— Shakespeare in Othello’s speech to the dead Desdemona

“At sea a fellow comes out. Saltwater is like wine, in that respect.”
— Herman Melville

“True navigation begins in the human heart. It is the most important map of all.”
— Elizabeth Kapu’uwasiwali Lindsey, anthropologist and filmmaker
“We all live inside the terrible engine of authority, and it grinds and shrieks and burns so that no one will say: lines on maps are silly.”

— Catherynne M. Valente, author of The Girl Who Circumnavigated Fairyland in a Ship of Her Own Making

“You weren’t thinking and you weren’t paying attention either. People who don’t pay attention often get stuck in the Doldrums.”

— A Lethargarian in The Phantom Tollbooth, by Norton Juster

“In the teaching of geography and history, a sympathetic understanding should be fostered for the characteristics of the different peoples of the world, especially for those whom we are in the habit of describing as ‘primitive.’”

— Albert Einstein

“But I am constant as the northern star,
Of whose true-fixed and resting quality
There is no fellow in the firmament.
The skies are painted with unnumbered sparks.
They are all fire and every one doth shine,
But there’s but one in all doth hold his place.
So in the world.”

— William Shakespeare in Julius Caesar

“The quiet sense of something lost”

— Alfred Tennyson

“We all seek for lost things within us.”

— Toba Beta (Master of Stupidity)

“Ignoranti quem portum petat, nullus suus ventus est.” (No wind is favorable to sailors who don’t know where they’re going.)

— Seneca the Younger

“Sometimes it’s hard to tell how fast the current’s moving until you’re headed over a waterfall.”

— Kimberly McCreight, author of Reconstructing Amelia

“When all else is lost, the future still remains.”

— Christian Nestell Bovee

“In the middle of the journey of our life I found myself within a dark woods where the straight way was lost.”

— Dante Alighieri, Inferno

“History is a guide to navigation in perilous times. History is who we are and why we are the way we are.”

— David McCullough

Image credits (left to right): iStockphoto/johnnorth; iStockphoto/photoalex; wikimedia commons/Oliver Herold; iStockphoto/lpopba
“In the middle of this journey, we lose a bit of ourselves. We do not know where we are or where we’re headed. We look for directions, seek for guidance, and if we’re lucky, we find it without too much time lost. And if we’re truly lucky, we gain our whole selves back, with an ounce of wisdom on top.”
— Joanne Crisner Alcayaga, author of Amazed

“The impatient idealist says: ‘Give me a place to stand and I shall move the earth.’ But such a place does not exist. We all have to stand on the earth itself and go with her at her pace.”
— Chinua Achebe in No Longer at Ease

“Your goals are the road maps that guide you and show you what is possible for your life.”
— Les Brown, motivational speaker

“Intuition goes before you, showing you the way. Emotion follows behind, to let you know when you go astray. Listen to your inner voice. It is the calling of your spiritual GPS system seeking to keep you on track towards your true destiny.”
— Anthon St. Maarten, psychic medium, in Divine Living: The Essential Guide To Your True Destiny

“There is no one to find me now, is there? This time I have to find our own way, and it is hard, so hard.”
— George R.R. Martin, author of the Game of Thrones series of books

“Writing is like driving at night in the fog. You can only see as far as your headlights, but you can make the whole trip that way.”
— E. L. Doctorow

“We men and women are all in the same boat, upon a stormy sea. We owe to each other a terrible and tragic loyalty.”
— Gilbert K. Chesterton

“If you do not change direction, you may end up where you are heading.”
— Lao Tzu

“When you follow a star you know you will never reach that star; rather it will guide you to where you want to go. ... So it is with the world. It will only ever lead you back to yourself.”
— Jeanette Winterson in Boating for Beginners

“It was a pity that there was no radar to guide one across the trackless seas of life. Every man had to find his own way, steered by some secret compass of the soul. And sometimes, late or early, the compass lost its power and spun aimlessly on its bearings.”
— Arthur C. Clarke in Glide Path

“(B)ut the greatness comes and you are really tested, when you take some knocks ... because only if you have been in the deepest valley can you ever know how magnificent it is to be on the highest mountain.”
— Richard M. Nixon’s farewell to the White House

“We have another chance to navigate, perhaps in a slightly different way than we did yesterday. We cannot go back. But we can learn.”
— Jeffrey R. Anderson, The Nature of Things

“If you don’t know where you are going, you might wind up someplace else.”
— Yogi Berra

“Watching a coast as it slips by the ship is like thinking about an enigma. There it is before you, smiling, frowning, inviting, grand, mean, insipid, or savage, and always mute with an air of whispering, ‘Come and find out’.”
— Joseph Conrad in Heart of Darkness

Most writings encourage one to learn navigation lessons to the best of one’s ability and then to apply them to your daily life. I’ll leave you, however, with a sobering challenge from an emerging area of study in the field of medical science: “Aging adversely affects the perception and integration of spatial information, the creation and storage of memory traces for spatial information, and the use of spatial information during navigational behavior.” (Speaking of aging and in the interests of full — and near real-time — disclosure, note my updated photo accompanying this column.)

So, with respect to navigation and life, perhaps a quote attributed to renowned British philosopher George Bernard Shaw is worth noting: “Youth is wasted on the young.”

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PTC continued from page 1

PTC is an advanced train control system that the Rail Safety Improvement Act of 2008 (RSIA) required to be installed on all Class 1 railroads and passenger railroads by the end of 2015. It is designed to prevent train-to-train collisions, overspeed derailments, incursions into established work zone limits, and the movement of a train through a switch left in the wrong position. GPS and other sensors are used to monitor train location and velocity, matched against a map database showing rail network layouts, signage, speed restrictions, and so forth.

Shortly before the equipage deadline, however, in the face of industry resistance and lack of progress on installing PTC on their locomotives and rail networks, Congress approved a three-year extension. Rail operators now have until the end of this year to upgrade their systems — plus another two years to actually get them working. (A Spring 2015 ION Newsletter article describes the basic architecture of PTC and the nearly 50-year effort by the National Transportation Safety Board, or NTSB, to see its incorporation into the U.S. rail system.)

Passenger train 501 was equipped with PTC and the associated trackside infrastructure was in place, but the system had not been activated, reportedly because that section of the line had not been tested. Properly equipped with PTC switched on, if a train does not slow for an upcoming speed restriction, PTC will alert the engineer to reduce the speed. If appropriate action is not taken, PTC will apply the train brakes before it violates the speed restriction.

In the Washington state Amtrak accident, an NTSB preliminary report stated that an operational PTC system would have notified the engineer of train 501 about the speed reduction for the curve. If the engineer did not take appropriate action to control the train’s speed, PTC would have applied the train brakes to maintain compliance with the speed restriction and to stop the train.

Ironically, Amtrak actually has a fairly good record at trying to meet the PTC mandate. In a January 8, 2018, letter to the heads of the Oregon and Washington departments of transportation, Amtrak’s President and CEO Richard Anderson said that 51 percent of Amtrak’s nationwide diesel locomotive fleet has PTC equipment installed, with 151 units commissioned and ready to operate.

After the Fact

As with past incidents, in the wake of the Dupont derailment agency officials and politicians weighed in on the need to implement PTC for real this time. In December 27 letters to the heads of the nation’s railroads, U.S. Department of Transportation (DoT) Secretary Elaine Chao sent a “reminder” to the rail officials of the PTC milestones and stating the department’s expectation that the companies “will meet the requirements specified by Congress on or before December 31, 2018.

In comments reflecting an initiative that has been getting ready to get started for nearly 50 years, Chao added that Federal Railroad Administration (FRA) officials responsible for overseeing the PTC mandate had been “directed to work with your organization’s leadership to help create an increased level of urgency to underscore the imperative of meeting existing timeline expectations for rolling out this critical rail-safety technology.”

Meanwhile, over on Capitol Hill, Peter DeFazio (D-Oregon), Ranking Member of the House Committee on Transportation and Infrastructure, and Michael Capuano (D-Massachusetts), Ranking Member of the Subcommittee on Railroads, Pipelines, and Hazardous Materials, sent a letter to Amtrak President and Chief Executive Officer Richard Anderson requesting a detailed update on Amtrak’s safety culture and implementation of Positive Train Control (PTC) on routes owned or operated by Amtrak.

Amtrak and other organizations responsible for the track where the accident occurred “should have . . . installed PTC, regardless of the December 31, 2018 deadline mandated by Congress,” DeFazio and Capuano wrote. In response to Amtrak’s defense that it does not own the locomotives or infrastructure over which Passenger Train 501 was operating, the congressmen said, “As the operator, you are responsible for safety,” adding that “Amtrak only reports on progress toward implementing PTC across routes and on equipment that Amtrak owns and controls, leaving out large portions of Amtrak’s operations.”

Earlier this year, DeFazio, Capuano, and seven cosponsors introduced a bill, H.R. 4766, the “Positive Train Control Implementation and Financing Act,” that would prohibit another extension of the PTC deadline, provide up to $2.5 billion in grants for intercity or commuter passenger rail companies to implement PTC, and require any new passenger routes to have PTC implemented before they begin service.

Of course, with its real-time positioning capability, PTC has benefits beyond passenger rail safety. It could help freight as well as passenger railroads to operate more efficiently, enabling the companies to increase track capacity and use their assets more productively. 

As members of the Institute of Navigation reading this article, you do not need to be convinced by me that the combination of positioning, navigation, and timing (PNT) services provided by GNSS and the ever-growing proliferation of software-level applications in smart-phones, satellite receivers, vehicle navigation services, mobile devices, etc., have made the art and science of determining one’s position commonplace in today’s society — it is an undisputable fact.

But this “push of the button” capability to locate oneself with high precision, in real-time, does continue to present real challenges when that location information needs to be shared with others. This is especially problematic in situations such as emergency response when the responding organization(s) may not be using the same spatial reference system, or when the normal reference system (i.e., street addresses) may be destroyed by the likes of hurricanes, floods, or fires.

By example, the three major hurricanes striking the United States last fall generated real emergency response challenges, with the Coast Guard indicating that they are now rethinking social media’s role in future rescue and response situations.

At the September 12, 2017, AFCEA Homeland Security Conference held in Washington D.C., Vice Adm. Sandra Stosz, the Coast Guard’s Deputy Commandant for Mission Support, said, “We need to come up with some kind of required national protocol for social media for geo-tracking and locating and targeting search and rescue. We don’t have that yet.” (See <https://federalnewsradio.com/management/2017/09/recent-hurricanes-have-the-coast-guard-rethinking-social-medias-role-in-rescue-and-responses/>.)

As noted in the aforementioned Federal News Radio article, “When 9-1-1 call centers were quickly overloaded in Houston, residents in the area quickly took advantage of social media tools such as Facebook and Twitter to ask for help.” Admiral Stosz goes on to state, “The Coast Guard isn’t accustomed to sending a helicopter or a flood punt boat to a rescue scene based on a single Facebook post or Tweet, but the agency quickly learned that it needed to adapt.”

Ultimately this ability to adapt resulted in the Coast Guard rescuing more than 11,000 people but the need to be better prepared next time should not be forgotten. That brings us to the question of which addressing convention best meets the need for regional (and national) interoperability among the may potential response organizations who may be called to help in a major emergency.
commonly used, resulting in critical time lost in responding to emergency calls. The ready answer to the foregoing question is the U.S. National Grid (USNG). The USNG is a point and area location grid reference system that provides a reliable and available geolocation capability that is easy to use and is an alternative to latitude and longitude for land-based operations. The USNG is supported by a government standard defined by the Federal Geographic Data Committee (FGDC) Standards Working Group (FGDC-STD-011-2001) dated December 2001. (Available online at <https://www.fgdc.gov/standards/projects/usng/fgdc_std_011_2001_usng.pdf>.)

The stated objective of the USNG standard is to “create a more interoperable environment for developing location-based services within the United States and to increase the interoperability of location services appliances with printed map products by establishing a nationally consistent grid reference system as the preferred grid for National Spatial Data Infrastructure (NSDI) applications.”

By design, the USNG is the civilian version of the Military Grid Reference System (MGRS) that the Department of Defense (DoD) uses for tactical operations. It is an alpha-numeric, two-dimensional (no vertical component), reference system that overlays the Universal Transverse Mercator (UTM) coordinate system. The standard’s datum is World Geodetic System 1984 (WGS-84) and, given that it is interoperable with MGRS, the USNG streamlines safety-of-life operations when defense platforms and personnel are called in to assist with national disaster relief operations. DoD policy on position reference procedures (CJCS Instruction 3900.01D) specifically states, “To support homeland security and homeland defense, the Federal Geographic Data Committee (FGDC) U.S. National Grid (USNG) standard is operationally equivalent to MGRS.”

USNG by the Numbers
A USNG address is broken down into three parts: a Grid Zone Designation for a world-wide unique address, a 100,000-meter Square Identification for regional areas, and Grid Coordinates for local areas. To plot USNG coordinates, they are readily applied by moving right and then up from the corner of the 100,000-meter Square Identification identifier — just like plotting a point on an X-Y Cartesian plane.

Avoiding a more detailed discussion of how the system specifies unique locations, I will simply state that the USNG coordinate with 10-meter precision for the Washington Monument is written as 18S UJ 23480647. Here, “18S” is the UTM Grid Zone locator covering the eastern mid-Atlantic region, “UJ” is the 100,000 meter square covering the D.C. area, and the two sets of four digits each, 2348 and 0647, indicate that the monument is located 2,348 meters east and 647 meters north from the origin of the 100,000-meter square carrying the designation “UJ” on a gridded map application displaying the USNG.
This past October, the Federal Emergency Management Association (FEMA) released its third edition of the National Incident Management System document [https://www.fema.gov/media-library/assets/documents/148019>, which states, “The United States National Grid is a point and area location reference system that FEMA and other incident management organizations use as an alternative to latitude/longitude. The National Grid is simple to apply to support risk assessment, planning, response, and recovery operations. Individuals, public agencies, voluntary organizations, and commercial enterprises can use the National Grid within and across diverse geographic areas and disciplines. The use of the National Grid promotes consistent situational awareness across all levels of government, disciplines, threats, and hazards, regardless of an individual or program’s role.”

**Latitude and longitude is not a reference system commonly used by land-based first responders, or by the general public, for that matter.**

Slow U.S. Adoption

FEMA Urban Search and Rescue (USAR) teams have been using the USNG for years, but many other first responder organizations and agencies have been slow in adopting it. This is hard to understand given its value and simplicity, as well as its ready availability through many mapping applications enabled by GPS. It is also hard to understand this organizational indifference because since 2008 the National SAR Committee, comprising the Department of Homeland Security, DoD, Department of Transportation, and four other federal agencies, has stated that “Land SAR responders must use U.S. National Grid” and “Aeronautical SAR responders working with Land SAR responders have the primary responsibility of coordinating SAR using USNG.” (Source: “Catastrophic Incident SAR Addendum to the National SAR Manual, Version 1.1,” August 2008)

Other areas of the world, e.g., Great Britain, have adopted a grid system similar to the USNG for their own use. In preparation of this article, I reached out to Terry Moore, (ION’s 2017 Johannes Kepler Award recipient recognized for numerous accolades in development of software tools for coordinate transformations and map projections) about his own experiences with the British National Grid (BNG).

Terry responded, “The British National Grid (BNG) is fundamental to positioning and mapping in Great Britain. Indeed, the public are only aware of BNG cords and would not recognise latitude or longitude or any other format of coordinate. The national mapping is all based on BNG, and all construction, and boundary surveys is based on BNG coordinates. The BNG forms the ‘legal’ framework of coordinates in GB.”

In my own view, the USNG may never become the “legal” framework of coordinates for construction and boundary surveys here in the United States, nor is it intended for those purposes. However, we clearly have a long way to go to get the public in general to recognize the USNG with the same degree of familiarity that the average British citizen apparently has with their grid system.

**Getting on the Map**

With that said, the USNG is receiving some added attention through the implementation of Emergency Location Marker (ELM) signs developed by SharedGeo, a federally recognized Minnesota-based nonprofit organization, [http://www.sharedgeo.org>. ELMs offer a way for communities in several states to mark locations such as trail intersections, camp sites, buildings, boat landings, and other potential response locations with a USNG designation that works with GPS, is location-specific, unique across jurisdictions, and nationally consistent. Nationwide, some 14 states with more than 1,500 ELM signs already in place and 700+ planned are beginning to extend the concept to locations where street addresses that would normally appear on mobile applications are not available.

Specifically related to smartphone applications, you can see and share your own USNG coordinates by doing a search for “US National Grid” and installing on your own mobile device a variety of available applications that are free or carry only a small fee. Some of these apps can be found at <http://usngcenter.org/portfolio-item/software>. In closing, the USNG is a federally recognized, easy-to-learn standard that uniquely identifies points on the surface of the earth, using grid coordinates to define geo-locations. These USNG coordinates are available as outputs on a growing number of mobile device applications and are also displayed by many GNSS receivers, either as USNG or MGRS values. The growing ability to determine and share USNG coordinates using social media provides a ready means to improve response times and save lives in emergency situations where other spatial references may not be available.

Members of the ION should readily recognize the value of this available and interoperable capability in improving efficiency of spatial operations of all kinds. I encourage you to become familiar with the U.S. National Grid.
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

ABSTRACTS DUE MARCH 8, 2018

ION
INSTITUTE OF NAVIGATION
www.ion.org
Welcome to the first installment of a new column in the ION Newsletter that will feature one of ION’s Technical Representatives each quarter. The goal is to highlight 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 (PNT) community during their two-year term.

— interview and writeup by Dr. Kyle Wesson

Dr. Andrey Soloviev is a founder and principal at Qunav, a PNT research and development company based in Florida. Andrey first became involved with ION when he was a student and has remained a major contributor in our community ever since. He previously worked at the University of Florida as a research faculty member and at the Ohio University Avionics Engineering Center as a senior research engineer.

Andrey is bullish on the future of autonomous vehicles and wants to play a major role in developing the sensor fusion algorithms that will offer us sub-meter, low-cost navigation based on combinations of inexpensive sensors and readily-available signals of opportunity. He also sees a future in which ION’s conferences become the go-to place for autonomous vehicle innovators to collaborate with the GNSS community.

When he is not innovating the future of PNT, Andrey enjoys surfing off of the coast of Florida and running along its beaches. To learn more about Andrey and his involvement with ION, please read his responses to the Tech Rep Spotlight questionnaire below.

1. How did you first get involved with ION?
I first attended the ION GPS conference through a student travel grant when I was a student in Moscow, Russia, working on Kalman filters and their applications. A friend mentioned ION’s student competition program that could potentially sponsor a trip to the ION conference in the United States. I submitted a paper, which was selected, and I traveled to the U.S. for the first time in my life, met Dr. Frank van Graas who would later become my academic advisor, and have stayed in the navigation field ever since. That trip was certainly one of my life’s turning points, and I am deeply grateful to the Institute for the opportunity it created.

2. What is your favorite aspect of being a member of ION?
Being connected to a unique group of professionals. Through the years, my ION colleagues and friends have encouraged, supported, and motivated me. I always return from ION meetings uplifted and inspired.

3. What type of GNSS work do you do currently or have you done in the past?
I’ve worked on many aspects of GNSS from signal processing to RTK positioning. My current focus is on software receiver design and the fusion of GNSS with other sensors. These two are closely related with each other. Specifically, sensor fusion achieves its maximum benefits when GNSS and other sensors’ data are combined at the signal processing level. An example is the deep integration of GNSS and inertial to detect and mitigate threats such as jamming and spoofing. The software receiver approach is indispensable for enabling such capabilities.

4. What do you consider some of the most important current research, education, policy, or technical topics in GNSS for the next year?
I think that this will be the development of a robust, reliable, and affordable navigation solution for autonomous vehicles, especially, drones and self-driving cars. Significant progress has been made for the augmentation of GNSS with other sensors including inertial, vision, lidar, signals of opportunity, maps, motion constraints, etc. This augmentation brings us closer to sub-meter navigation accuracy that can be maintained anywhere and anytime and with low-cost sensors. That said, the integrity of these sensor-fusion solutions will also be key. There are some very interesting initial efforts in this area that I certainly hope to see growing.
5. What areas of ION have you been involved in, and what areas do you hope to see grow in the future?

I am an associate editor of the ION journal, NAVIGATION, serve on the ION Council, and have been session co-chair and track chair for various ION conferences. For ION and our community to grow, I hope that key players from the autonomous vehicle field will become actively engaged. This January’s first-ever ION Cognizant Autonomous Systems workshop was a great step in this direction.

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

Surfing or long-distance running. This doesn’t sound very practical, but here is my rationale: I believe that we do our best work when it feels like a hobby; we do it because we truly enjoy doing it and getting paid is not a primary motivation. I am very fortunate since what I currently do feels that way, at least most of the time. For alternatives, I would go with two other top options from my hobby list.

Andrey rides the waves in Florida.
Corporate Profile

Masterclock, Inc.
www.masterclock.com

Masterclock designs and manufactures a variety of precise timekeeping products to keep both facilities and people synchronized. Since 1994 our portfolio of master clocks, time servers, IRIG generators, count controllers, digital displays, analog clocks, and PC cards have been trusted to support mission critical applications. Our products do everything from ensuring television studios make smooth programming transitions to providing precise counts for spacecraft launch operations.

By maintaining a true U.S. manufacturing presence in St. Louis, MO, Masterclock can control quality processes while taking advantage of internal technical knowledge to deliver hybrid solutions that combine Masterclock products with complementary equipment. This solutions-oriented approach broadens our ability to serve our customers and allows us to be a trusted, single source for all things timing related.

Masterclock can be found around the globe in time-sensitive environments such as research facilities, broadcasting stations, data centers, financial institutions, airports, and rocket-launch command centers. We have a worldwide distribution network supporting customers in over 100 countries on six continents.

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

Focus on Timing

Senate Bill Calls for GPS Backup

Two U.S. senators have introduced a bi-partisan bill giving the Department of Transportation (DoT) responsibility for launching a GPS timing backup and a two-year deadline to get such a system in place.

Sponsored by Senators Ted Cruz, R-Texas, and Ed Markey, D-Massachusetts, the National Timing Resilience and Security Act of 2017 (S 2220) mandates that the DoT come back to Congress with an implementation plan in 180 days and then gives the agency another 18 months to get the system up and running. DoT is to "provide for the establishment, sustainment and operations" of such a system — not

Calendar of Upcoming Events

**MARCH 2018**

5-7: Munich Satellite Navigation Summit, Alte Bayerische Staatsbank, Munich, Germany
Email: info@munich-satellite-navigation-summit.org
Tel: +49 89 6004 3425
Web: http://www.munich-satellite-navigation-summit.org/

**APRIL 2018**

16-20: ICASC International Flight Inspection Symposium, Hyatt Regency Monterey, Monterey, California
Sponsored by the International Committee for Airspace Standards and Calibration (ICASC) Hosted by ION
Contact: ION
Tel: +1 703-366-2723
Web: www.ion.org

23-26: IEEE/ION PLANS 2018, Hyatt Regency Monterey, Monterey, California
Contact: ION
Tel: +1 703-366-2723
Web: www.ion.org

**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: 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. 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
Capt. Sean Memmen Visits ION New England  
Cambridge, Massachusetts, November 1, 2017

Captain Sean Memmen was the guest speaker at the ION New England meeting held at Draper Laboratories. Originally from Long Island, New York, Captain Memmen is currently the Deputy Navigator of the Navy and leads the Positioning, Navigation, and Timing branch where he is responsible for PNT policy, investment, and operations.

During the meeting, Captain Memmen described how the role of Deputy Navigator has grown from one of purely overseeing electronic navigation activities to addressing threats to PNT, and the Navy’s overreliance on GPS in modern times. Captain Memmen explained how the Navy relies on GPS receivers not only for navigation but also for conducting warfare.

He said that the Navy has grown over-reliant on GPS for these capabilities and is now investing in technologies to rapidly diversify their PNT sources, including use of open architecture, traditional alternative navigation sources such as inertial and atomic clocks, as well as future GPS-independent technologies such as two-way satellite timing and frequency transfer (TWSTFT), multiband terminals, optical, celestial, and geophysical mapping techniques like sonar.

In addition to these developments, the Navy has been teaching celestial navigation capabilities, for example, use of sextants, to its sailors. Captain Memmen was highly engaging and addressed several questions from the ION New England members.
Snakes, Scorpions, and Sunfish

Robots explore the Destroyed Fukushima Nuclear Power Plant

The 2011 nuclear disaster at Fukushima Daiichi power plant after Japan’s massive earthquake and tsunami inspired a great deal of robotic innovation. Plutonium fuel rods in three reactors melted and sank through steel and concrete and disappeared somewhere far below into a flood of contaminated water, continuously pumped in to keep the area cool.

In six and a half years, no robot was able to survive the search for the missing fuel. And the fuel had to be found before decommissioning could officially begin.

One version of a Fukushima robot looked like a snake with a headlamp; its cameras failed because of radiation. Another that looked like a scorpion failed when it got tangled in debris.

Finally, one appeared that could survive the job. Last summer, a swimming robot named “Little Sunfish” sent back the first images of puddles of melted fuel partly obscured by debris in Reactor 3. It took four technicians to navigate the Little Sunfish on its three-day journey last July. A team of scientists is needed to control Little Sunfish, while a data cable connects the robot at all times with the team, sending back whatever pictures or data it can capture.

The scientists discovered that melted rods had pushed aside a grate on their fall to the bottom of the containment chamber and left a gaping hole.

Early this year, an improved version of the robot found more melted fuel in Reactor 2.

Here’s what it took to create a mobile tool for a hellish environment. First, the successful robot can tolerate 200 Sieverts of ionizing radiation — an amount that would kill a person instantly. (A one-Sievert dose makes you sick.) A sensor helps it avoid “hot spots” that have slowed its predecessors.

It fits through a 5½-inch pipe and maneuvers its way through a radioactive flood using five small propellers, making its trip look more like a flight than a swim.

LED lights enable it to peer into shadowed corners and two cameras and a dosimeter help it send back information to the watchers above.

The robot is a product of a cooperative effort between Toshiba and the government-funded International Research Institute for Nuclear Decommissioning.

Cleanup is expected to take 30 to 40 years and tens of billions of dollars. Meanwhile, a new generation of robots is being developed to capture the melted fuel and remove it.

What the Sunfish Saw:

A 3½-minute video of the Little Sunfish’s investigation of the interior of the meltdown area of the Fukushima Daiichi reactors on January 19, 2018. Video by TEPCO, the Japanese power company responsible for the nuclear plant. 
Down to the Sea in Ships
(or a reasonable facsimile)

By the time the Psalmist wrote about going down to the sea in ships, human culture was pretty far along. But ships — or their predecessors, reed rafts, dugout logs, and hide boats — have been around for at least one or two hundred thousand years. Actually, boats came about before Homo sapiens even showed up on the scene.

A few years ago, archaeologists discovered 45- to 130-thousand-year-old Neanderthal-made quartz hand axes near Plakias on Crete and other islands too far from the Greek or African mainland for a pleasant swim. Locating more than 100 knapped axes made of local stone on the geological remnants of an ancient beach led archaeologists to believe that these paleo people got there deliberately, stayed a while in sizeable numbers and were certainly not lost at sea.

Of course, their fragile all-organic watercraft are long gone and the tools are merely circumstantial evidence. But it’s highly likely that sailing into adventure has been in hominid blood for a very, very long time.

If it’s true, how did people do it and with what? The First Mariners, a group of researchers, craftspeople, and artists who try to reconstruct ancient sailing routes and techniques, tested a theory about why people wanted to sail to the islands and how they built their boats.

The islands were more alluring than the mainland 130 thousand years ago — lushly green and full of small hippos and elephants and other animals. In 2014, the mariners built a 36-foot raft with a simple sail out of local cane grass, native palm, and raffia rope. They used tools available to ancient hominids and plotted a route that would have been possible and attractive at the time.

Ten participants in a First Mariners trial sailed from Kythira island near the Peloponnesus and made it the 45 nautical miles to Chania in Crete in 46 hours — bingo! http://plakiasstoneageproject.com/ and https://thefirstmarinersexpeditions.com

21st Century GPS
Pulsar navigation in deep space

In January, a team of NASA engineers demonstrated fully autonomous X-ray navigation in space — a capability that could revolutionize our ability in the future to pilot robotic spacecraft to the far reaches of the solar system and beyond.

The experiment, called Station Explorer for X-ray Timing and Navigation Technology or SEXTANT, showed that millisecond pulsars could be used to accurately determine the location of an object moving at thousands of miles per hour in space — similar to GPS.

Radiation emanating from pulsars’ powerful magnetic fields is swept around much like a lighthouse. The narrow beams are seen as flashes of light when they cross our line of sight.

With these predictable pulsations, pulsars can provide high-precision timing information similar to the atomic-clock signals supplied through the GPS system.

— From the NASA newsroom

NASA demonstrates autonomous deep space navigation by tracking predictable x-ray signals from an array of pulsars.

NASA scientific visualization studio image
In December the China Satellite Navigation Office and the U.S. Department of State’s Office of Space and Advanced Technology issued a joint statement reflecting the following consensus conclusions regarding compatibility and interoperability between GPS and BDS:

The GPS L1C and BDS B1C civil signals, using two different types of multiplexed binary offset carrier (MBOC) waveforms are interoperable, which means users can receive better service by jointly using these civil signals without a significant increase in receiver cost or complexity.

**GPS**

A Government Accountability Office (GAO) report released in December, “Global Positioning System: Better Planning and Coordination Needed to Improve Prospects for Fielding Modernized Capability,” notes that current projections for how long the current constellation will be fully capable have increased by nearly two years to June 2021, affording some buffer to offset any additional satellite delays.

Although the first GPS III satellite has a known parts problem, six follow-on satellites — which do not — are currently scheduled to be launched by June 2021.

According to the GAO report, since the program’s original 2008 baseline, the first GPS III satellite’s planned launch date has been delayed by four years — from April 2014 to May 2018. The Next-Generation Operational Control System (OCX) Block I has fallen 63 months off its original schedule — from October 2016 to January 2022. The Air Force began military GPS user equipment (MGUE) technology development in April 2012, but the cost and schedule baseline for the program was not approved until January 2017, more than a year later than originally planned.

The prediction of greater spacecraft longevity is particularly encouraging, because the GPS modernization continues to lag behind deadline. Most recently, release of a request for proposals (RFP) for the second phase of the estimated $10-billion, 22-satellite GPS III contract is now four months behind schedule.

Following what members of the National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board described as a company presentation at the board’s with inadequate details, the board has drafted a letter to the National Space-Based PNT Executive Committee renewing its opposition to Ligado Network’s proposed terrestrial wireless broadband system that would operate in a radio frequency band near to GPS and other GNSS signals.

“The PNT Advisory Board strongly believes that approval of the new license modification application is not in the public interest and the proposed use should not be permitted.”

China launched two BeiDou-3 satellites into middle Earth orbit on January 12 using a single Long March-3B rocket. The two satellites are the 26th and 27th satellites in the BeiDou Navigation Satellite System (BDS).

China reportedly plans to send 18 BeiDou-3 satellites into space this year.

At the International Committee for GNSS annual meeting, held December 2–8 in Kyoto, Japan, Jiaqing Ma, representing the China Satellite Navigation Office (CSNO), described plans for deployment of the third-phase (BD-3) constellation: launch another 14 MEOSats this year to join 4 already in orbit, plus 1 geostationary orbit (GEO) spacecraft; in 2019 and 2020, launch another 6 MEOSats, 2 inclined synchronous orbit (IGSO) satellites, and 2 more GEOSats. The first two BD-3 satellites were launched November 5, 2017, for testing and network validation.

China is also planning to build a satellite-based augmentation system (BDSBAS) with the first launch of a GEO satellite this year to support system integration and testing. Building improved ground monitoring stations will occur in 2019, followed by launch of two more GEOSats in 2020 to enable initial operational capability of BDSBAS.

The CSNO recently released a signal-in-space interface control document (ICD) for new open service signals B1C and B2a (test version), which will transmitted by the BD-3 MEOSat and IGSO satellites. The B2a signal will replace the B2I signal.

The B1C signal will have a 1575.42 MHz center frequency (the same as GPS, Galileo, and new GLONASS CDMA signals) and will transmit a data component using a MBOC(1,1) modulation and a pilot component employing a
quadrature multiplexed BOC — QM-BOC(6,1,4/33) — modulation.

The B2a signal will be centered at 1176.45 MHz and use a binary phase shift keying (BPSK) modulation. The B1I signal with a center frequency of 1561.098 MHz will be retained from the regional system to offer service to legacy users. BD-3 satellites will also transmit the B1I signal for which an ICD (v 2.1) was released in November 2016. BD-3 GEO satellites will transmit augmentation signals for BDSBAS.

Galileo

Europe has four more Galileo navigation satellites in the sky following a December 12 launch on an Ariane 5 rocket. Only one more launch remains before the Galileo constellation is complete and delivering global coverage.

Ariane 5, operated by Arianespace under contract to the European Space Agency (ESA), lifted off from Europe’s Spaceport in Kourou, French Guiana, carrying Galileo satellites 19–22. The first pair of 715-kilogram satellites was released almost 3 hours 36 minutes after liftoff, while the second pair separated 20 minutes later.

They were released into their target 22,922 km-altitude orbit by the dispenser atop the Ariane 5 upper stage. The four satellites will undergo six months of tests — performed under the oversight of the European GNSS Agency (GSA) — to check they are ready to join the working Galileo constellation.

This mission brings the Galileo system to 22 satellites, although only 14 are currently usable. Two spacecraft were placed into incorrect orbits, two are undergoing testing, the latest four are being commissioned, and one was removed from active service in December for “constellation management purposes.” Initial Services began on December 15, 2016. Since then, the typical constellation average signal-in-space pseudorange accuracy has been 0.4–0.6 meters, 95 percent of the time.

Meanwhile, European Union agencies have been working out plans for the Galileo second generation (G2G). The European Commission established the mission needs for Galileo, ESA established the system scenarios, and GSA conducted cost/benefit analyses. In 2018 and 2019, a down-select to one scenario will occur and the budgetary elements determined, with design and development taking place after 2019.

GLONASS

The Russian space company Roscosmos, recently privatized, launched another GLONASS-M satellite on September 22, sustaining 24 operational satellites on orbit with another undergoing flight tests.

Progress in modernizing the space segment has reportedly been interrupted by trade embargos imposed on Russia, constraining access to critical parts needed for the GLONASS-K2 generation of satellites. The ISS-Reshetnev Company is now tasked with building nine modernized GLONASS-K1 satellites and two next-generation K2 spacecraft, capable of transmitting the system’s new CDMA signals.

Work on modernizing the GLONASS ground segment includes expanding the number of monitoring stations outside Russian territory and building out augmentation systems. Roscosmos has also released four interface control documents (ICDs) describing its CDMA signals for GLONASS L1, L2, and L3.

Two national mandates for GLONASS equipage — ERA-GLONASS, an emergency call reporting system for private land vehicles, and PLATON, a federal toll collection system for commercial cargo trucks weighing more than 12 tons — went fully into effect during 2017.

A presentation at the December meeting of the International Committee on GNSS (ICG), reported that about 88 percent of the commercial fleet (~900,000 trucks) has been equipped with PLATON devices and nearly 40 billion rubles (US$711 million) collected for road infrastructure support. As for ERA-GLONASS, more than 347,000 calls have been processed and 854,000 vehicles equipped.

QZSS

Japan’s program for a Quasi-Zenith Satellite System (QZSS) launched three satellites during 2017, bringing its constellation to four operational spacecraft — one GEO satellite located above the equator at 127 degrees East, and the quasi-zenith orbit (QZO) satellites. QZSS operational service will begin in 2018.

Three upgraded QZO satellites will be designed and launched by 2023, according to a presentation at the ICG annual meeting. They will feature intersatellite ranging and two-way ground-satellite ranging. Four navigation signals and a crisis management messaging channel will improve the percentage of time that positioning service is available, even in steep urban canyons.
IEEE/ION Position Location and Navigation Symposium (PLANS)

April 23–26, 2018
Hyatt Regency Monterey
Monterey, California

www.ion.org/plans