Volume 32 No1 **Winter 2022**

ION®
INSTITUTE OF NAVIGATION
Quarterly Newsletter

ION GNSS+ 2022 will Spotlight Emerging Applications, Technologies, and Concerns

This fall's ION GNSS+ conference will highlight emerging sectors and advanced technologies with the potential to change how positioning, navigation, and timing (PNT) data is provided, protected, and used.

In addition to the wide-ranging technical sessions where PNT researchers will present the latest developments, there will be half a dozen expert panels focused on subjects such as the location and timing capabilities needed to support emerging applications like extended-reality headsets. New devices like these—which can incorporate augmented reality (AR), virtual reality (VR), and mixed reality (MR)—will stretch current PNT technology. Experts will be on hand to

Photo courtesy Hammer &Tusk

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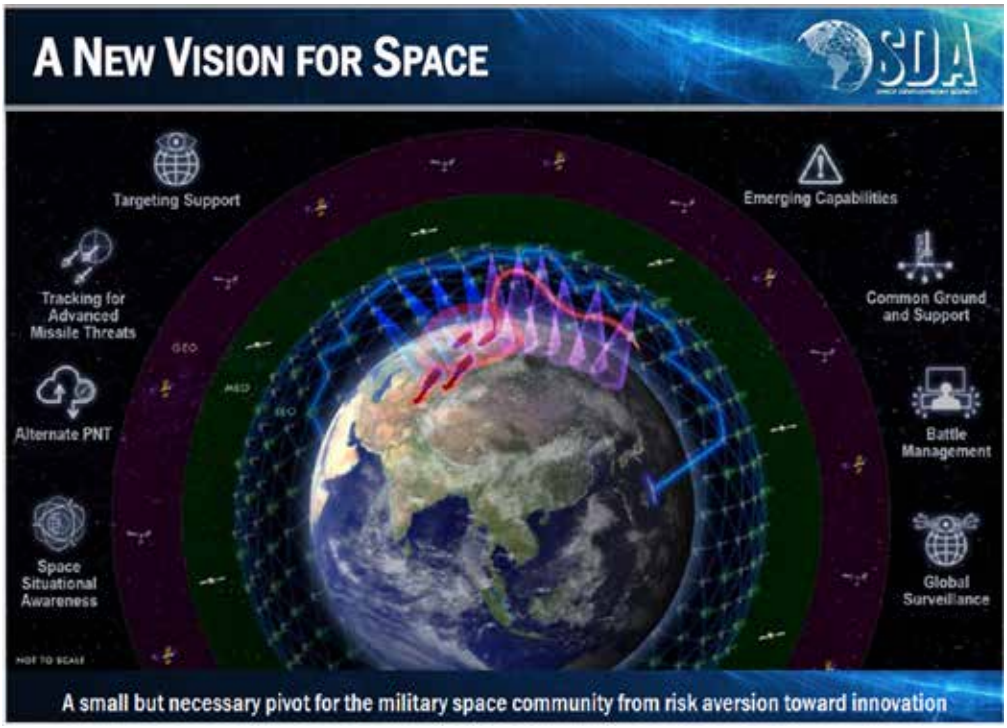
GPS-Independent Navigation Central to Space Development Agency's New LEO Constellation



The new LEO constellation, and its self-generated PNT capability, would support a range of military missions.
Art courtesy of the Space Development Agency

The Space Development Agency (SDA) is building a new satellite constellation with a self-generated navigation capability that, if successful, will enable it to support military missions with early warning and tracking information, even beyond-line-of-sight targeting, without input from GPS.

The still-unnamed Department of Defense network will use a proliferated architecture comprised of hundreds of small spacecraft instead of dozens of larger, perhaps more-tempting-to-target satellites like those in the GPS constellation. Set in low Earth orbit (LEO), the relatively petite spacecraft will be far less expensive to build, launch, and update and the signal latency from space to the ground will be less.

The SDA satellites will incorporate optical crosslinks creating a resilient, mesh

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PRESIDENT'S COLUMN | DR. FRANK VAN DIGGELEN

Advocating for PNT

National Space-Based PNT Advisory Board

The National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board met in early December; its mission is to provide independent advice to the U.S. government on GPS-related policy, planning, management, and funding. The advisory board advocates to protect, toughen, and augment GPS, and to improve GPS performance (https://www.gps.gov/governance/advisory).

While ION does not lobby lawmakers or regulatory agencies, we at ION advance the art and science of navigation by publishing information in our leading technical journal, *NAVIGATION: Journal of the Institute of Navigation,* and our various technical conferences. The ION database currently has over 19,000 papers related to PNT. All are available to ION members.

This got me thinking of recent activities taking place by other organizations advocating for PNT: the IEEE, the Resilient Navigation and Timing Foundation (RNTF), and the GPS Innovation Alliance.

Developing a Technical PNT Standard

In the Fall 2021 issue of the *ION Newsletter,* Doug Taggart reported that the Department of Homeland Security (DHS) had asked the IEEE to develop industry standards for resilient PNT user equipment.

The IEEE effort, led by the IEEE Communications Society, is called Project 1952 and commenced activity in September to specify "technical requirements and expected behaviors for resilient PNT user equipment."

The stakeholders include manufacturers and users of PNT user equipment and providers of PNT services focused on critical infrastructure. If this impacts you, please consider joining the IEEE P1952 Standards Working Group by visiting https://sagroups.ieee.org/p1952.

PNT and America's Supply Chain

The Resilient Navigation and Timing Foundation (RNTF) is an affiliate organization of ION. The RNTF responded to the Department of Transportation's (DOT) request for comment about operations supporting the supply chain. The RNTF asserts that GPS and PNT are critical parts of the supply chain, and that America has an over-reliance on GPS signals for PNT services. The RNTF urged the DOT to establish national alternatives and backups for GPS signals, as required by the National Timing Resilience and Security Act of 2018.

Like GPS, alternatives should include systems that are wireless, easily accessed and adopted, and reach all parts of the nation. The RNTF asserted that alternatives would provide PNT during GPS disruptions and help validate GPS services when used in the same receiver.

These are just the latest efforts of the RNTF whose mission is to promote resilient navigation and timing worldwide. The RNTF believes that navigation and timing services should be protected as critical infrastructure. Enforcement and penalties for interfering with PNT services should be appropriate to the potential harm. Multiple sources of wide-area and localized navigation and timing are needed for a healthy and balanced "ecosystem." These sources should have different failure modes making it less likely a single event could impact all users. To learn more on current threats and proposed protections, visit https://rntfnd.org/membership.

Spectrum Protection

The GPS Innovation Alliance directly advocates on behalf of businesses reliant on GPS, including manufacturing, aviation, agriculture, construction, transportation, first responders, surveying, and mapping. The organization strives to inform policymakers and GPS users about the centrality of GPS in the USA's national economy.

Spectrum protection has been a key ad-

National PNT Advisory Board member, Dr. Frank van Diggelen, addressing the Advisory Board virtually during their meeting held December 9-10, 2021 in Pentagon City, Virginia.
Photo courtesy of Al Feinberg, NASA

vocacy item. The Alliance communicates directly with Congress, congressional committees, regulatory agencies like the Federal Communications Commission (FCC), and federal agencies that manage or use GPS.

The Alliance provides these institutions with the correct scientific details to make accurate and informed decisions. To learn more, visit https://www.gpsalliance.org/about-us.

As you can see, there is a lot going on beyond the scenes to ensure the future of reliable, robust, and accurate PNT.

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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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Last GPS III Satellite Named For Inventor, Film Star Hedy Lamarr

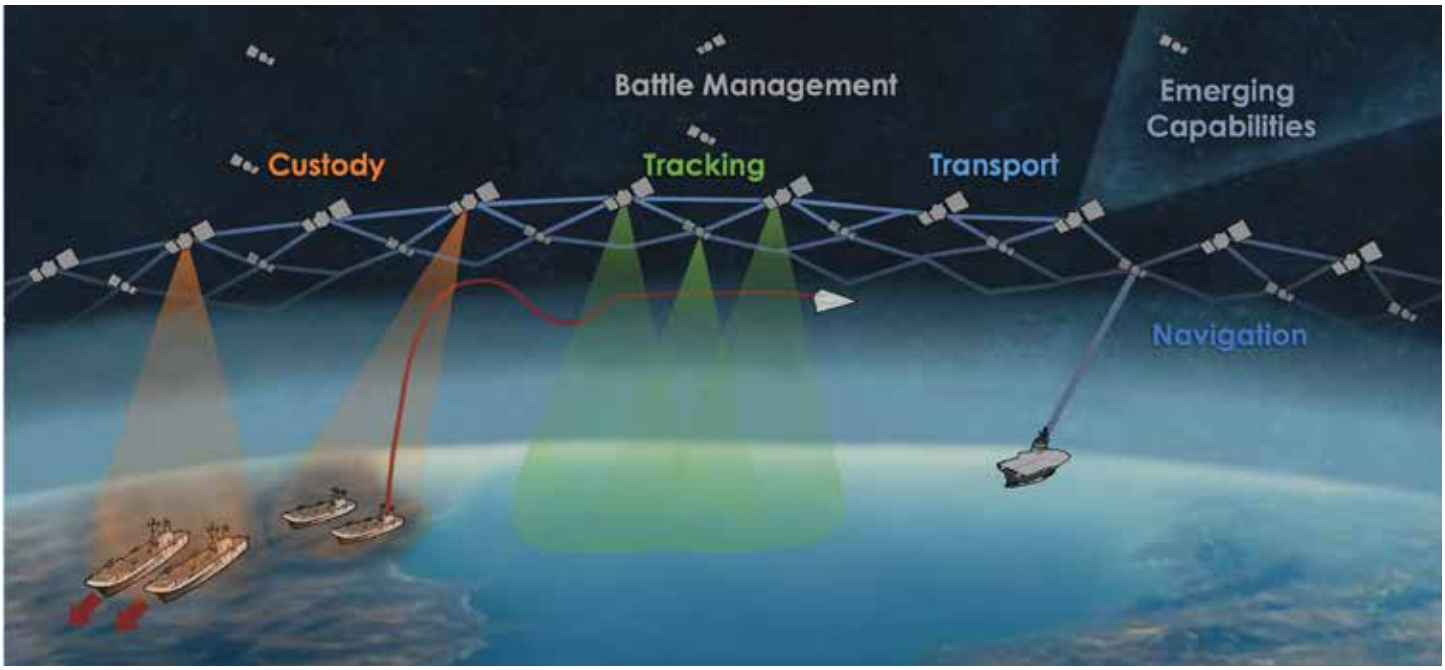
The last of the ten GPS III spacecraft has been named "Hedy Lamarr" to honor the inventive film star who co-developed a frequency-skipping technology that laid the foundation for WiFi, Bluetooth, and GPS.

The nickname was given to the satellite at the completion of the "core mate" production milestone, the point at which a satellite is fully assembled or "born."

Lamarr became fascinated as a child by the way machines worked, according to the National Women's History Museum website. Though her film career took off, her interest in technology continued. She dated Howard Hughes who encouraged her inventive genius and for whom she designed a new airplane wing. What she learned about weapons during her first marriage to a munitions dealer informed the spread spectrum technology she

Photo courtesy of Wikimedia

patented with musician and inventor George Antheil as a radio guidance system for Allied torpedoes. The technique aimed to make it impossible to jam guidance signals by using a piano roll to randomly change frequencies.



The navigation and communication capabilities of the SDA constellation reside in the Transport Layer. The Tracking and Custody Layers are where sensors are located.
Art courtesy of the Space Development Agency

continued from page 1

network of connections that should enable the system to move information through the constellation from one side of the globe to another without interim downlinks to the Earth's surface. The cross-links will also enable the satellites to share clock data and determine their position relative to each other. With this capability, and a link to the ground to add an Earth-centered reference frame, the constellation has the potential to generate its own positioning, navigation and timing (PNT) information and be truly independent of GPS.

Layer Upon Layer

The primary purpose of the new SDA network is to enable beyond-line-of-sight pinpointing of ground and maritime targets as well as advanced warning and tracking of hypersonic and missile launches. The system's sensors will detect and track threats, feeding that information to warfighters and defense systems via the mesh of spacecraft and downlinks to the military's Link 16 military tactical data link network.

The capability to move and transmit data, and to generate PNT information, will reside in the constellation's Transport Layer. The sensing satellites that support missile warning, tracking, and targeting are in the Tracking and Custody Layers at other levels of an overall architecture comprised of multiple layers.

"Basically, we detect a missile; we calculate a track on that missile—send that to the Transport Layer and then the Transport Layer can get that to an interceptor or get that to a shooter," SDA Director Derek Tournear told the FY2022 Defense Programs Conference produced by McAleese and Associates in May.

The initial Transport Layer will be comprised of roughly 150 satellites. The first 20 of those spacecraft are already being built by Lockheed Martin and York Space Systems as a part of Tranche 0 (zero)—also called T0. The plan is to launch those first 20 Transport Layer satellites into 1,000-km orbits in two different planes in September 2022 and March 2023.

With Tranche 0, the SDA plans to demonstrate some of the capabilities it intends to provide beginning with Tranche 1 (T1), said SDA Technical Director Frank Turner.

Tranche 1 of the Transport Layer (TLT1 for short) is already in the works. The SDA is seeking up to three contractors to build as many as 144 more satellites to be launched into six planes in late fiscal year 2024.

Self-Navigating

Though the SDA will lean on GPS during the development of its new constellation, the crosslinks connecting the satellites are the foundation for what the agency hopes will be a fully-independent navigation capability.

The two-way links enable independent ranging, "so, each node (satellite) will be able to range to its nearest neighbor," said an SDA technical adviser who spoke on background. Each satellite will also be able to do time transfer of its clock data with its nearest neighbor's clock.

"The fact that you've got this crosslink capability—that's the core requirement," said satellite navigation expert Logan Scott of LS Consulting. The crosslinks enable the satellites to establish where they are on their own. "There's some good thought put into this," he said.

"Once we tie in the space-to-ground links," the adviser said, "we now have absolute position and time because we'll be bringing in the UTC-USNO (Coordinated Universal Time - U.S. Naval Observatory) and we'll be bringing in the information to tie into an Earth-cen-

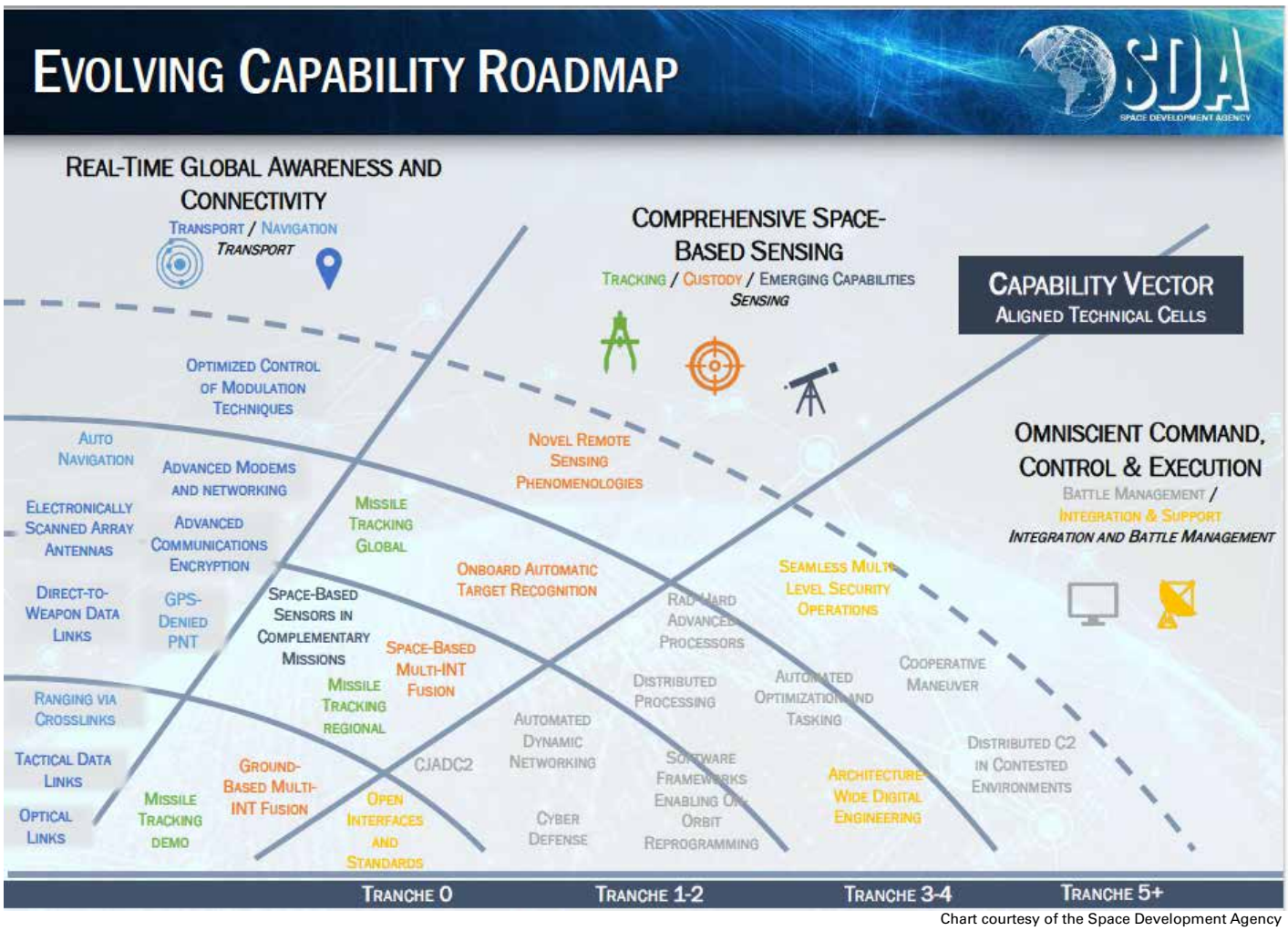


Chart courtesy of the Space Development Agency

tered, Earth-fixed coordinate system."

The goal with the Tranche 0 satellites, said the SDA adviser, is to determine if they can successfully do independent ranging and time transfer between first-level satellites. With Tranche 1, "we will then start to execute the navigation filter on a ground basis."

GPS, however, will remain the primary navigation system for Tranche 1, the technical expert said.

"GPS will be a high-quality input to the navigation filter. So even though we will have the intended GPS-independent navigation filter starting to be prototyped, GPS will truly provide the time and the positioning of each satellite—and then it will also be brought into the filter to give us a sense of truth," said the adviser. "By the time we get to T2 (Tranche 2), then we expect to take GPS out as a primary navigator, but it will always exist as one of the inputs into the sensor fusion engine."

Will this approach be able to provide the same accuracy and reliability as GPS? It's too early to know, said Turner.

"If you look at what the SDA is doing right this minute, we're still trying to understand and trying to work out, really, what the concepts of reliability and things like that mean for a proliferated LEO architecture," Turner said.

Partners Sought

The SDA's plans for the constellation stretch into fiscal year (FY) 2030 with the goal of adding more PNT capabilities already penciled in for Tranche 3—which would launch around FY28.

Exactly what those additions will be remain to be determined though the SDA has a broad wish list of improvements it wants for the constellation. That list includes candidate navigation signals (waveforms) and frequency bands with included concepts of operations designed to maximize performance, availability, and integrity. They are also seeking cryptographic systems to protect PNT integrity, confidentiality, and/or availability. They want timekeeping systems and atomic clocks that offer better SWaP (size, weight, and power) characteristics as well as better orbit and timing prediction applications, hardware or software to support alternate PNT, and satellite-to-satellite/ground ranging via optical crosslinks.

The door is open for potential partners, Turner said, be they commercial, other government agencies, mission partners, or the war fighters themselves.

"We have not settled on anything," Turner said, "…we're still in discussions about everything."

This is a shortened version of a story that first appeared in Navigation Outlook. *To read the full story and learn more about* Navigation Outlook, *please visit navigationoutlook.com.*

Art courtesy of ACEINNA

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discuss cutting-edge techniques including lighthouse-based and GNSS-IMU-based tracking as well as inside-out systems founded on visual SLAM.

Automation will be at the heart of two other panels. The first weighs the implications of advances in autonomy-focused fields like robotics and the tradeoffs developers and users face involving cost, complexity, maturity, reliability, and long-term viability. The second will look at how automated navigation intersects with real life including issues such as the level of trust people can place in autonomous drones and what challenges are preventing the deployment of driverless vehicles and impacting other systems like autonomous ships.

The meeting will also host a panel on new signals for PNT including the emerging Wi-Fi round-trip time (RTT) standard (which will provide 1-meter accuracy) and the location capabilities being incorporated into 5G signal standards. The panel's experts will also discuss integrating signals from the emerging flock of low-Earth-orbit constellations including those built specifically to provide position and time services as well as those where PNT is a secondary mission.

With connected devices ranging from cell phones and automobiles to Internet of Things (IoT) appliances now incorporating PNT, it only makes sense to examine how to protect those networks. ION GNSS+ will feature a discussion on the algorithms and techniques needed for GNSS cyber-physical security. Panelists will examine the possible vulnerabilities of PNT-networked systems including how to address issues raised by cooperative use of network resources and centralized, large-scale network processing. They will also discuss the development of cyber-physical standards for sensor certification and fraud prevention.

ION GNSS+ will also, of course, be hosting one of the event's most popular annual panels on the status of the world's primary satellite navigation systems. A representative for each system—GPS, GLONASS, Galileo, BDS, QZSS, and UK GNSS—will describe developments over the last year and take questions about their program's accomplishments, performance, system updates, and plans.

Come join us in person or virtually at ION GNSS+ in Denver, CO, September 19-23, 2022. The call for abstracts is still open, with abstracts due March 4.


Tommy Fawcett via Unsplash


ION
GNSS+
2022
September 19-23, 2022
Show Dates: September 21 and 22
Hyatt Regency Denver at Colorado Convention Center
Denver, Colorado
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ION's American Association for the Advancement of Science (AAAS)

Congressional Fellow

Dr. Benjamin Ashman

Anyone familiar with Congress will tell you it takes years to understand the Senate. As this year's ION Congressional Fellow, I've been in Senator Sherrod Brown's (D-OH) office for a mere three months. All I can offer here are initial impressions, but I can already say that it's been quite a departure from engineering.

Half of my portfolio involves NASA and the aerospace industry, the other half manufacturing and labor. I work closely with other legislative staff focused on these topics. We meet with stakeholders from Ohio (the senator's home state—and mine too), and strategize about how to achieve our policy goals. We regularly coordinate with the senator's communications team—one of my first assignments was to help write a press release about the Supply Chain Resiliency Act. We also write a lot of letters for the senator. I drafted a letter asking a non-profit to voluntarily recognize its workers' union; the letter was signed by fourteen senators, sent to the organization's president, and shared publicly on Twitter.

During the first year of an administration, a great deal of the Senate's time is devoted to confirming the president's nominees. I've watched nominations proceed through the committee process all the way to confirmation on the Senate floor. Shortly after the start of my fellowship, Senator Brown requested that I be granted floor privileges. This request must be made verbally by the senator from the Senate floor (meaning I'm mentioned in the Congressional Record and on C-SPAN for that day). Having been approved, I'm allowed to be on the Senate floor itself (or at least the benches around the perimeter reserved for staff). In mid-December, I watched from the floor as Vice President Kamala Harris cast the tie-breaking vote to confirm a U.S. Attorney.

The Senate floor can be something of an enigma to the casual observer. One colleague explained that learning Senate rules is like learning about fouls in basketball: the rules themselves don't tell you much about how they work in practice. For example, a quorum call (essentially the clerk taking attendance) is often used as a holding pattern. If you ever check C-SPAN and it looks like nothing is happening on the floor, you're probably right—the Senate is likely in a quorum call while deal-making and coordination are happening elsewhere. Senators can use this time in between the day's business to make floor speeches by suspending the quorum call. Floor speeches may be related to some business at hand, but they're often on a recurring topic of importance to the senator; Senator Brown has given regular speeches on the Child Tax Credit since I started my fellowship. If you think this use of a quorum call is strange, you're not alone: the presiding officer often has to remind senators to suspend the quorum call when they begin their speeches.

Senate rules create a slower and more deliberative process than in the House. Floor dynamics are guided by the principle that few limitations are placed on how long a senator may speak. Senators can, in theory, speak indefinitely, so proceeding to a vote requires first setting a time limit on debate. Limiting speaking time before forcing a vote is known as "invoking cloture." This typically requires approval by 2/3 of the Senate (you may be familiar with this as the threshold for ending a filibuster). A floor staffer told me that 80% of understanding the Senate is understanding cloture, but that complex topic is beyond the scope of this short column!

Very few people understand all of the Senate rules. Senators themselves often rely on the Senate parliamentarian for this expertise. These rules are ultimately

Outside the Senate wing of the U.S. Capitol
Photo courtesy of Benjamin Ashman

just one part of the overall process to pass (or obstruct) legislation. *Inside Congress,* by Corning, Dodin, and Nevins, identifies three types of legislation in the Senate: boutique bills, deadline-driven bills, and messaging bills. The first of these refers to relatively rare, issue-driven bills, usually requiring bi-partisan support. The so-called "Bi-Partisan Infrastructure Bill" (H.R.3684) is a recent example. Deadline-driven legislation is more common, like a bill to raise the debt limit or a continuing resolution on the budget to keep the government running. Both of these money-related issues had to be addressed during my fellowship.

Most bills, however, are messaging bills. These bills are not expected to pass, but they aren't just political theater. In addition to broadcasting a senator's position (and providing cause for committee hearings or press releases), messaging bills can be a first draft of language to address a problem. Such bills are also well-positioned for inclusion in a larger piece of high-priority legislation that is more likely to pass. As one colleague told me, "The only things that pass Congress are the things that have to pass."

The National Defense Authorization Act (NDAA) is an annual piece of must-pass legislation that gave me firsthand experience with the circuitous route a bill can take to become law. The House passed a version in late September (H.R.4350), then the Senate introduced its version in mid-November by way of an amendment, S.Amdt.3867, entirely replacing the text of H.R.4350. The passage of this bill was stopped by a single senator in early December. The House and Senate informally conferenced to arrive at an acceptable compromise on the NDAA's language. Then the House amended an unrelated bill (S.1605) to replace its text with a revised version of H.R.4350, simply because that bill was at a convenient stage in the legislative process for expedited passage (a "moving vehicle"). The Senate passed the revised bill a week later and it was soon signed by the president.

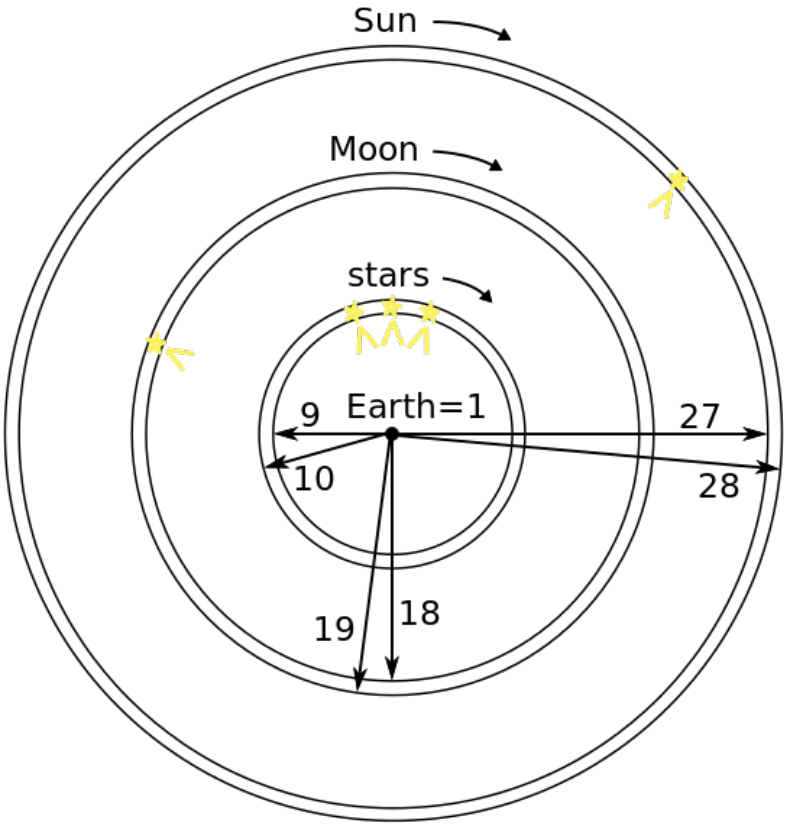
When the Senate introduced its version of the NDAA, senators proposed hundreds of amendments. I helped author an amendment (S.Amdt.4759) directing the Department of Defense to consider NASA facilities for hypersonics research. Legislation must be introduced manually in the Senate: I printed the amendment text, got Senator Brown's signature, rode the miniature subway to the Capitol Building, and walked the paper through its richly ornamented halls to the Democratic Cloakroom—each party has a cloakroom adjacent to the Senate floor where staff receive legislation and coordinate its introduction.

Our amendment to the NDAA wasn't included in the final version passed by Congress, but our work with the armed services committees throughout the process may have achieved our goal anyway. We drew attention to the issue and conveyed that it's important to members of Congress, a fact taken seriously by agencies even when not enforced by law. This is just one example of the unexpected and subtle ways that work is accomplished in a Senate office. As I become more familiar with how things are done here, I'll tell you more in my next column about *what* I've done. Don't hesitate to reach out: ben_ashman@brown.senate.gov.

The Milesian School (Part II)

Marvin B. May

This is the second of two articles about the Pre-Socratic Miletian School founded by Thales (624-546 BC) in the city of Miletus in the Ionian peninsula of what is now Turkey. The material composition of the world and the motions of the celestial bodies preoccupied the scientists of ancient civilizations. The leaders of Ancient Greece's Miletian School—Thales, his successor Anaximander (610-546 BC), and his student Anaximenes (585-528 BC)—are credited with injecting scientific observations and mathematical calculations into these topics which had been previously dominated by mythological beliefs.



A map of the universe as envisioned by Anaximander

Courtesy of Wikimedia. The map of the universe is by Bibi Saint-Pol and is based on the text and GIF by Dirk L. Couprie for The Internet Encyclopedia of Philosophy

Succeeding Thales, Anaximander was the second master of the Miletian School. Unlike Thales, whose accomplishments were not documented but were described by Aristotle two centuries later, Anaximander is the first Greek sage known to have written down his studies. Although only one fragment of his work remains, testimonies found in many documents after his death provide a portrait of a scientist/philosopher who used rational thought to find his way through problems in astronomy, cosmology, sociology, and horology.

Most aspects of life in the Ionia region, including agriculture, commerce, and navigation, depended on a knowledge of the sun's movements. Anaximander employed a gnomon to quantify and develop a mathematical representation of the sun's apparent motions. A gnomon* is an object that, by the position or length of its shadow, serves as an indicator of its orientation with respect to the sun—for example the shadow edge of a sundial that is used to determine the time of day. [The gnomon was widely used in ancient China. An excavation near the archeological site of Taosi uncovered a painted stick dating from 2300 BC—about 1,700 years before Anaximander introduced it to the Greeks.]

Anaximander used the length of the shadow of a vertical gnomon to learn about the diurnal and seasonal changes in the altitude and declination of the sun. He observed that the shadow cast by the vertical gnomon of a horizontal sundial would be the shortest at solar noon on the day of the summer solstice. At any other time and date, the shadow would be longer.

A measurement significant to the use of gnomons as indicators is the ratio of the length of shadow cast by the vertical gnomon with the length of the gnomon itself. This ratio varies from hour to hour, from season to season, and from place to place.

"The length of its shadow divided by the

Anaximander was one of first early scientists to record his research. This image is a detail from Raphael's The School of Athens, *1510–1511 and could be a representation of Anaximander leaning towards Pythagoras on his left.*
Courtesy of Wikimedia.

length of the gnomon itself would give the arc tangent of the sun's elevation (altitude) at that moment," wrote Thomas Worthen in his paper, *Anaximander's Gnomon*. Anaximander could not know how useful a knowledge of arc tangents (and other trigonometric ratios) would become, but he surely had a table of what we now call tangents, wrote Worthen. "He would have known, for example, that at the latitude of Miletus, 37.5 degrees, the noon shadow of the gnomon on equinox day would be almost exactly in the ratio of three to four with the length of the gnomon itself. This noon-time ratio would, of course, vary from season to season. This ratio at apparent noon on the equinoctial days is especially significant, as it gives the arc tangent of the geographic latitude of the place."

His astronomical observations together with his gnomon measurements indicate that Anaximander understood the inclination of the celestial sphere in relation to the plane of the Earth to explain the changing of the seasons.**

Among Anaximander's other major contributions to science were the writing of the oldest documents about the universe and the origins of life; for this he is sometimes referred to as the "Father of Cosmology," originator of evolutionary theory, and founder of astronomy.

He was the first person to conjecture that celestial bodies traveled in orbits and furthermore that these bodies were at different distances from the Earth. He also made the conceptual leap that the Earth did not rest in or on anything but instead floated free. The famous Austrian philosopher Sir Karl Popper (1902-1994) said that this insight was, in his opinion, "one of the boldest, most revolutionary, and most portentous ideas in the whole history of human thought."

As noted, Anaximander held an evolutionary view of living things. He believed that the first creatures originated from the moist element by evaporation. Man originated from some other kind of animal, such as fish, since man needs a long period of nurture and could not have survived if he had always been what he is today.

Subsequent Greek geographers claim that Anaximander was the first to publish a map of the world, according to the geographer Eratosthenes, who famously closely estimated the size of the Earth. Anaximander's innovation was to represent the entire inhabited Earth, including the ocean(s), as they were known to the ancient Greeks. In this map, the Aegean Sea was depicted near the map's center, while the three continents, Europe, Asia, and Libya (as Africa was then known), were circumscribed by a singular ocean. Europe was separated from Africa by the Mediterranean Sea and from Asia by the Black Sea and Rioni River, which is the main river of western Georgia. The Nile River separated the continent of Asia from Libya. This map, although primitive by today's standards, was a quantum leap in

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Smartphone Decimeter Challenge

An ION/Google competition yields fascinating insights into the future of GNSS and machine learning. New contest with new data to begin in April.

In 2021, ION and Google organized and ran the "Smartphone Decimeter Challenge," a GNSS competition open to anyone. Competitors had to process raw GNSS and IMU data from smartphones to obtain the most accurate solutions. Cash prizes totaling $10,000 went to the winners. Each competitor submitted their location solutions for the datasets which were then compared to ground truth calculated from a Novatel RTK-IMU reference system (details in the sidebar). Each team was judged by a single numeric score: the mean of the 50th and 95th percentile distance errors.

The data was gathered from Android phones in cars, driving on roads in the San Francisco Bay area, including in open sky areas on freeways, in light urban/suburban areas, and in the denser urban area of San Jose. The winners produced results well under one-meter accuracy when in open areas.

The top teams presented their results at ION GNSS+ 2021. One of the most interesting things about the competition was the prevalence of AI and machine learning. The competition was hosted by kaggle.com, a site that specializes in data science. Most of the top competitors took an AI-centric approach, and many competitors had no GNSS background or training. The results provided fascinating insights to the ION audience more used to GNSS-focused approaches. Good news for anyone nostalgic for classic GNSS: the overall winner, Taro Suzuki, is a GNSS professional who has published extensively. However, even his approach was strong on data science: using factor graph optimization (FGO), a technique common in robotics.

Care was taken to provide ground truth for the location of each phone, with lever arms between the reference system and the phones accounted for. Nonetheless, in some datasets the ground truth seemed to be inaccurate, particularly when RTK reference stations were farther away. This had a negative impact on the training data, especially for those using machine learning algorithms, and on the accuracy of the test results. In a strange way this made the challenge more like real life, where the same issue exists. The fact that data from smartphones is now accurate enough to detect errors in industrial-grade-GNSS reference systems is interesting. The ground truth collection will be improved in 2022 to increase fidelity.

Following the overall success of this first smartphone challenge, Google and ION plan another for 2022, starting in April (check back at g.co/gnsstools for updates). There will be new datasets to challenge contestants but, in the meantime, the datasets from the 2021 event will remain available to all at kaggle.com. Brush up on your machine learning skills, start working on your solution now, and we'll see you at ION GNSS+ 2022.

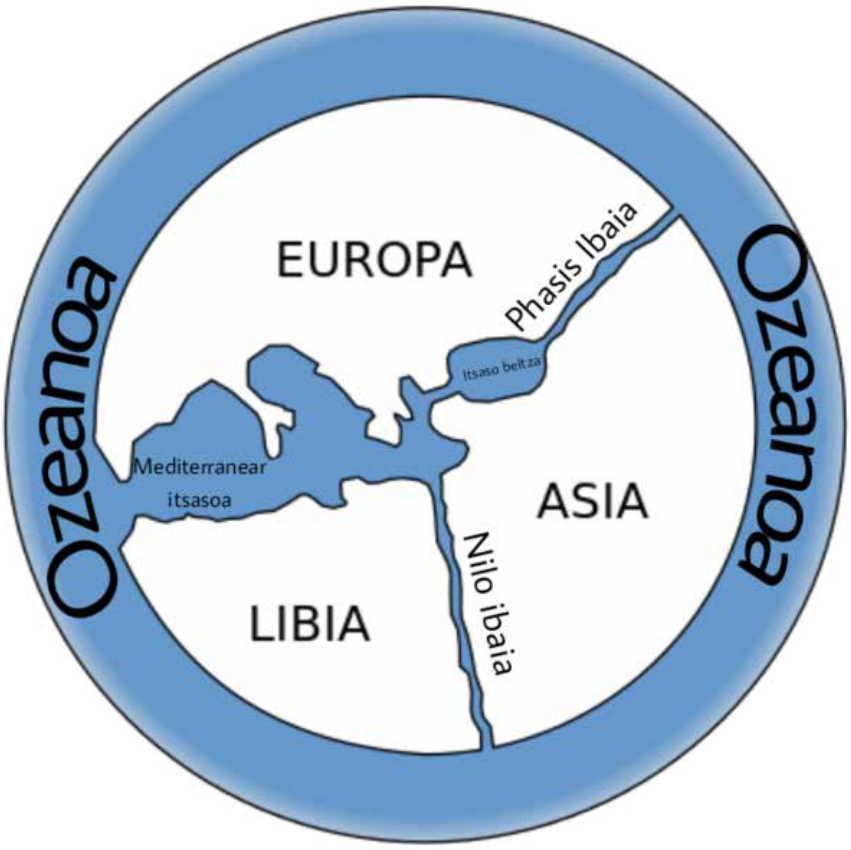
Number of competing teams:	810
Number of teams' countries:	63
Number of submissions:	16,802
Number of training and test datasets:	121
Percentage of urban environments:	27.2%
Total amount of data:	62 hours and 4,086 km
Total prizes amount:	$10,000

Winners:

First Place:	Taro Suzuki, Japan
Second Place:	Wojtek Rosa, Poland
Third Place:	Ilya Elenik, Russia

What's new in 2022:

- New training and test data
- Higher percentage of highway traces
- Higher fidelity ground truth



This map of the world by Anaximander was the most advanced of its day.
Courtesy of Wikimedia

continued from page 11

accuracy and extent over previous maps, and formed a basis for other cartographers, geographers, and historians upon which to build.

**Note that "gnomon" is another good word to use in the game Jotto per the Historian article of Spring 2001 Newsletter.*

***For further information on the apparent path of the sun, see the Historian Article on the Analemma from the Fall 2000 Newsletter.*

Websites used in the preparation of this article were:

www.mysundial.ca.

First Map of Known World Created by Ancient Greek Anaximander (greekreporter.com)

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Defense Matters

Russian Anti-Satellite Threats Against GPS

Just Saber Rattling? – It is…until it isn't.

On November 15th, Russia tested a direct-ascent, anti-satellite (DA-ASAT) missile that struck one of its own satellites in low Earth orbit (LEO) and created a large debris field. The U.S. Space Command's Public Affairs Office reported that the test had "…generated more than 1,500 pieces of trackable orbital debris and will likely generate hundreds of thousands of pieces of smaller debris."

"Russia has demonstrated a deliberate disregard for the security, safety, stability, and long-term sustainability of the space domain for all nations," said U.S. Army Gen. James Dickinson, U.S. Space Command commander in the statement. "The debris created by Russia's DA-ASAT will continue to pose a threat to activities in outer space for years to come, putting satellites and space missions at risk, as well as forcing more collision avoidance maneuvers. Space activities underpin our way of life and this kind of behavior is simply irresponsible."

Later the same day, the International Space Station (ISS) Mission Control, located at the National Aeronautics and Space Administration (NASA) Johnson Space Center in Houston, reported that the debris field posed a threat to the astronauts and cosmonauts aboard the ISS. In response, they directed the ISS crew to close various hatches on the station and to shelter in their docked crew spacecraft (there is always at least one attached to ISS for use as a lifeboat) for two orbital passes (the ISS orbits the Earth every 90 minutes) through the vicinity of the debris cloud. NASA indicated that they would continue to monitor the situation going forward.

NASA's Orbital Debris Program Office (ODPO) has published a graph (included here) that depicts the number of objects greater than 10 centimeters (cm) that are currently tracked at LEO. Highlighted on the chart are the instantaneous large increases of trackable objects resulting from the 2007 Chinese ASAT test and the 2009 accidental collision of an Iridium satellite with an inactive Russian military communications satellite—Cosmos 2251. The 2007 Chinese ASAT test created over 3,000 trackable pieces of debris, and the 2009 collision created almost 2,000 pieces.

Although the ODPO hasn't as of yet posted data for 2020 or 2021, extrapolating the slope of the Total Objects line through 2021, and including just 1,500 pieces of new debris from the Russian ASAT test lends credence to the projection that there are now upwards of 23,000+ pieces of trackable debris in LEO.

ODPO notes that ground-based radars, optical telescopes, and space-based sensors provide a means to track objects in LEO that are over 10 cm, or about 4 inches, in size. The ODPO also forecasts that there are approximately 500,000 marble-size objects and over 100,000,000 objects of 1 millimeter or smaller orbiting the earth.

A 2005 ODPO study indicated that even if there were no further space launches, collisions between existing objects (e.g., both operational satellites, as well as retired/non-functional satellites that have not been deorbited, intact rocket bodies, etc.) would increase the 10-cm or larger debris population faster than atmospheric drag and reentry would decrease debris. Clearly space debris is not something that can be discounted.

One week after the ASAT test, there was a report by a British online tabloid (DailyMail.com), picked up and reported by news sources here in the U.S., suggesting that Russia's State TV had claimed that new Russian ASAT missiles could "destroy 32 NATO satellites" and "blind all their missiles, planes, and ships, not to mention the ground forces."

This reference to "32 NATO satellites" is quite likely a reference to GPS, and the timing of the Russian ASAT demonstration leaves little doubt that Russia is seeking to raise the stakes of any NATO or U.S. reaction to a possible Russian military invasion of Ukraine in early 2022. But is this threat simply geopolitical saber rattling by Russia, or would Russia actually take steps to extend into the space domain a direct attack on a U.S. satellite such as a GPS spacecraft?

There is no question that Russia's leadership understands the vital role that GPS plays in military effectiveness, and for that matter, critical infrastructure and national security purposes in general. For over 20 years, U.S. national space-based PNT policy has proclaimed awareness that there are vulnerabilities associated

Doug Taggart
President
Overlook Systems Technologies, Inc.

with over-reliance on GPS while stressing the need for investment in alternative sources of PNT for national security purposes.

In May 2021, a Resilient Navigation and Timing Foundation blog posted in reaction to a Department of Transportation webinar on GPS Backup Technology Demonstrations, "…take the bullseye off GPS before it's too late." Has our own reporting on the need for a backup provided added awareness that GPS is a very lucrative target to attack? This begs the question of whether Russia would really consider conducting an ASAT attack at medium Earth orbit (MEO) where not only GPS, but also Galileo, GLONASS, and BeiDou navigation satellites reside?

At the inaugural meeting of the Biden Administration's National Space Council on December 1, the Russian ASAT test was clearly an issue of concern highlighted when Deputy Secretary of Defense Kathleen Hicks stated, "We would like to see all nations agree to refrain from anti-satellite weapons testing that creates debris."

The domain of space, much like the new domain of cyber-space, presents many new complications in developing responses to attacks. Space has no borders and is becoming increasingly congested with debris moving at speeds of 10 kilometers-per-second—much of it too small to track but still capable of causing catastrophic damage even to our largest spacecraft. For example, when the space shuttle Challenger returned to Earth in June 1983, its windshield was cracked by a flake-size debris fragment, suspected to be of human origin.

Over time, debris at LEO slowed by atmospheric drag will eventually reenter the atmosphere and burn up. Orbits of objects at or below a 400-km altitude may decay in a few months, whereas objects above a 600-km altitude decay in tens, hundreds, or potentially as long as thousands of years. Debris objects at geosynchronous orbit (GEO), where atmospheric drag is low, may have orbital lifetimes measured in millions of years.

Diplomatically we can take steps with other spacefaring nations to try and limit the creation of more debris in orbit. However, this most recent Russian ASAT test shows that it is within the realm of the possible for a nation with the technology and malicious intent to reach into space and aggravate the problem by disregarding the threat of collateral damage.

Here on Earth, we can exist within different countries, different cultures, and different approaches to how we manage our borders, manage our waste/our debris, etc., but when it comes to the domain of space, we must not fall into the mindset that the vastness of space carries with it the false security that orbital debris is someone else's problem.

ION TECHNICAL REPRESENTATIVE SPOTLIGHT

Dr. Joe J. Rushanan

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.

Dr. Joe J. Rushanan is a principal mathematician in the Communications, SIGINT (signal intelligence), and PNT Department of The MITRE Corporation. He received a B.S. and M.S. in 1982 from Ohio State University and a Ph.D. from the California Institute of Technology in 1986, all in mathematics. Amazingly, Joe has been at MITRE for 35 years—since grad school at the California Institute of Technology. He also teaches part-time for Northeastern University's Khoury College of Computer Science's cybersecurity program.

His background in cryptography, signal processing, and communications makes him a natural fit for the ongoing GNSS authentication efforts. MITRE asked him to help "solve the PNT assurance problem," which he has spent the last four to five years supporting. This included helping to develop the GPS signal-authentication standard called Chimera, which is a joint, multi-organization effort led by the Air Force Research Lab. The vision is that "everyone could receive these signals in space," since the authentication specification for the spread-spectrum, public key waveform is open to everyone. Joe is excited to see the actual signals fly on the NTS-3 satellite lined up for launch in 2023.

Outside of the office, Joe says he has three big hobbies: board gaming, fencing, and woodworking. And when Joe says he has a board game hobby, he means it! He owns over 3,000 board games and is a regular on "Board Game Geek," the standard web forum for all things board games. You can find his username "jjrbedford" to find out Joe's favorite games and highest ranked series.

Joe started fencing around 16 years ago. Admittedly, the pandemic has made it hard to compete against others with bladed weapons during the past two years, but he keeps swords displayed prominently on the walls of his game room. Finally, Joe enjoys making gifts out of wood for family (wife Valerie and two grown children) and friends, and has even designed his own bookcases to house his many board games.

A man of many talents, Joe summed up his interests succinctly: "I've always preferred breadth to depth, being a math major." I can only imagine what hobby Joe will turn to next! Read on to learn more about Joe and his connection to ION.

– Kyle Wesson

How did you first get involved with ION?

I started attending ION perhaps in 2007 as part of my L1C work. But I had been working on GPS since 1998, when I was (happily) recruited to be part of the M-code team.

What is your favorite aspect of being a member of ION?

I like being exposed to the breadth of navigation, i.e., not just GNSS. I think this goes back to childhood, where I had a strong love for maps and geography. There are so many different mission needs for navigation, and it is fascinating to see the variety of solutions.

What type of GNSS work do you do currently or have you done in the past?

My main effort has been in signal design (M-code, L1C, Chimera), especially applying new cryptographic methods. My other current big interest is in assurance: How do we quantify trust in our position and time?

What do you consider to be some of the most important research, education, policy, or technical topics in GNSS for the next year?

I think the trust problem is paramount. The navigation world is moving towards integrating all types of information together to facilitate navigation. How do we do that securely? What attack surfaces are opened up? And how does greater autonomy complicate things?

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

Besides the usual paper presentations, I have been privileged to give tutorials on cryptography and its use in navigation. One area of growth I'd like to see is in education: more tutorials, especially accessible, even pre-college.

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

Well, I can't imagine that it would not involve math in some ways. Probably something data driven. I have been intrigued in the last few years learning about inference techniques and the universal problem of understanding data.

GAO to Build on 2021 Technology Assessment with New Studies on DOD and Civil Use of PNT

The watchdogs in the Government Accountability Office (GAO) will continue their analysis of U.S. GPS programs with reports in the works about how the Department of Defense is handling the acquisition of alternative positioning, navigation, and timing (PNT) capability and upgrades to military equipment. There is also a just-launched evaluation of civil agency use of PNT.

The studies build on previous research including a technology assessment released in May that found the Department of Defense (DOD) did not prioritize alternative PNT solutions and continued to rely, perhaps unnecessarily, on GPS despite an understanding of its vulnerabilities. To help address this, GAO developed six policy options for policymakers, explained two GAO senior systems engineers who worked on the report: Jenn Beddor, who led the assessment and her colleague, Chi Mai. They discussed the findings in three webinars co-sponsored by ION and the Resilient Navigation and Timing Foundation held virtually in May and during ION's JNC and GNSS+ conferences.

The ongoing examination of alt-PNT acquisition has a trio of objectives, said Beddor during the webinars, the first of which is assessing the threats to GPS and whether the PNT alternatives have the capability to meet those threats.

Photo courtesy of the Government Accountability Office

GAO analysts were not able to look fully at the threat environment for the May report, she said, because they were teleworking and did not have access to classified documents. "So, we're hoping to kind of catch up on that in this current work."

The second objective, she said, is to look more closely at the alternative PNT programs in the DOD's acquisition portfolio, for example the Army's Mounted and Dismounted Assured PNT System (MAPS, DAPS) programs. Unlike the May 2021 report, which focused more on research and development, the emphasis now will be on programs of record, Beddor explained.

The third objective is to examine how DOD is overseeing its programs. "So, we're hoping to continue that conversation that we started about leadership and that sort of thing in this report."

GAO is also looking at the Pentagon's GPS modernization work and the integration of M-code, said Beddor. "It's another look at the GPS end-user equipment."

Not to leave out research on the use of GPS for civilian applications, Beddor said during GNSS+ in September that they were just starting to assess how non-military agencies were handing GPS issues and alternatives.

"It is early on," said Mai, agreeing that it was too soon to describe the scope of the work though he noted that it included looking at the Department of Transportation and some concerns brought up by a Volpe Center study report.

MEMBER NEWS

Prof. Terry Moore was honored with the John Harrison Award for outstanding contributions to navigation by the International Association of Institutes of Navigation (IAIN).

The award was bestowed during a special session of the combined International Navigation 2021 Conference and European Navigation Conference in Edinburgh in November 2021. Her Royal Highness, the Princess Anne, attended via Zoom to present the award and had a one-to-one conversation with Professor Moore.

"It's a great honor to be recognized by the global navigation community and I feel quite humbled," Moore said in a statement. "John Harrison was a simple country carpenter in the 18th century who solved the major problem of measuring longitude at sea through his remarkable marine chronometers. Despite his genius he struggled for acceptance by the scientific establishment and it took many years until he received the recognition (and financial reward) he deserved. It is sad that over 200 years later we are still fighting for improved equality, diversity, and inclusion throughout scientific disciplines. I am absolutely delighted to receive the award in his name."

A professor of satellite navigation for 20 years at the University of Nottingham, Moore has taken a leading role in national and European initiatives aimed at integrating academic research and teaching activities in GNSS. He was the founding director of GRACE, the GNSS Research and Applications Centre of Excellence, and has supervised almost 40 successful Ph.D. students.

Moore is a Fellow of the ION and the Royal Institute of Navigation (RIN), of which he is also the immediate past president. He is also a fellow of the Chartered Institution of Civil Engineering Surveyors, the Royal Astronomical Society, and the Remote Sensing and Photogrammetry Society. In 2013 he was awarded the RIN Harold Spencer-Jones Gold Medal and, in 2017, the ION Johannes Kepler Award.

Professor Terry Moore pictured with his 2022 IAIN Harrison Award

Brian Ramsay

Brian Ramsay passed away on November 21, 2021. A retired Principal Engineer for The MITRE Corporation, he specialized in domestic and international spectrum policy and regulatory matters. Ramsay had over 25 years of spectrum management and regulatory experience, including participation as a U.S. Delegation member at numerous International Telecommunication Union (ITU) World Radiocommunication Conferences (WRCs). He also served as a regulator at the National Telecommunications and Information Administration (NTIA), dealing with issues such as GPS spectrum protection, Mobile-Satellite Service (MSS) spectrum sharing, and third-generation wireless spectrum issues. Ramsay previously served at the U.S. State Department and as NASA's representative to the PNT National Coordination Office (NCO). He also held several positions in the private sector where he specialized in domestic and international spectrum management, policy, and regulatory issues. Mr. Ramsay was a veteran of the United States Air Force.

ION Members Collaborate in Comprehensive PNT Text/Reference Guide

Position, Navigation, and Timing Technologies in the 21st Century: Integrated Satellite Navigation, Sensor Systems, and Civil Applications by Y. Jade Morton (Editor), Frank van Diggelen (Editor), James J. Spilker Jr. (Editor), Bradford W. Parkinson (Editor), Sherman Lo (Co-Editor), and Grace Gao (Co-Editor) covers the latest developments in positioning, navigation, and timing (PNT) technologies, including integrated satellite navigation, sensor systems, and civil applications. The PNT "tome" is the most com-

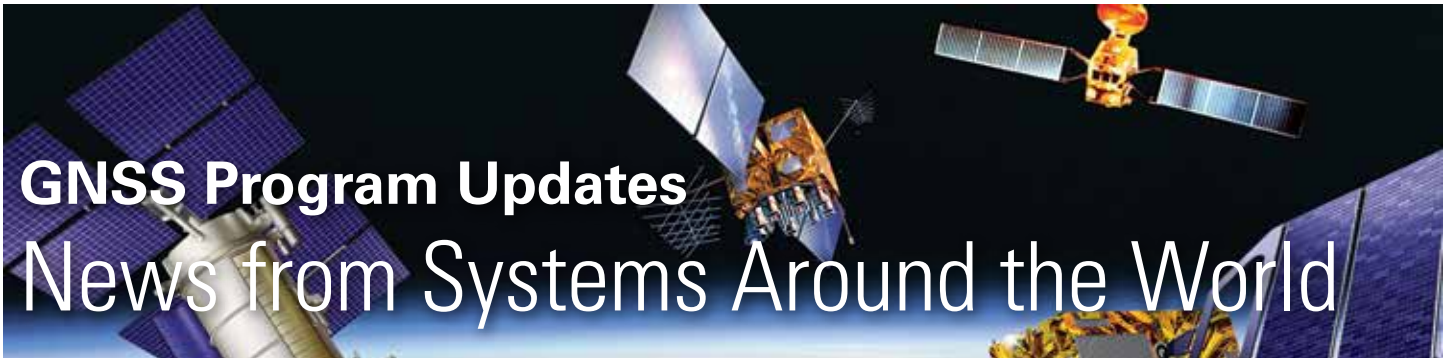
prehensive PNT text available today featuring 64 chapters and text from many ION-member experts. Divided into six parts, the book provides comprehensive coverage of the state-of-the-art in satellite-based PNT technologies and civilian applications. It also examines alternative navigation technologies based on signals-of-opportunity and sensors and offers a comprehensive treatment on integrated PNT systems for consumer and commercial applications. For a full descriptive outline, and publisher discount code, please see pnt-21book.com.

All Source Position Navigation (ASPN) DOD Standard Activity

All Source Position Navigation (ASPN) is an Open Architecture Collaborative initiative supported by the Office of the Undersecretary of Defense for Research and Engineering [OUSD (R&E)]. The goal is to mature a Department of Defense standard with an overarching objective of enabling PNT sensor and software interoperability across the U.S. military.

ASPN accomplishes this by standardizing the information content found in measurements of navigation-related quantities from sensors, estimates of navigation-related quantities from estimators, metadata about these measurements (including sensor error models), and messages that describe events common to the implementation of a navigation-state estimation workflow.

The OUSD R&E Open Architecture Collaborative held its first meeting at ION's August 2021 Joint Navigation Conference. ASPN 3.1 is currently in development and community input is needed to mature this user-community developed set of standards. Participation is open to U.S. government employees and contractors. Please contact Meghan Bentz, C5ISR Center (meghan.e.bentz.civ@army.mil) if you would like to participate.



GNSS Program Updates
News from Systems Around the World

Russia Readies GLONASS Launches

Russia is poised to add two spacecraft to its GLONASS constellation.

The GLONASS system currently has 25 satellites of which 22 are operational, according to the Information and Analytical Center in Korolyov, Russia. Of the three remaining spacecraft, one is being flight tested and two are undergoing maintenance. Another satellite had been in maintenance status but was upgraded to operational the first week in January.

There soon could be more changes in the network's composition. The last of Russia's GLONASS-M class of satellites is nearly ready for launch soon, a source told the Russian news agency TASS.

"By now, the last GLONASS-M satellite from the ground spare has been removed from storage," the space industry source told the news agency TASS in December. "Technologically, it will be ready for a launch from mid-March."

In addition, the first of the next-generation GLONASS-K2 spacecraft is tentatively scheduled for launch in the middle of the second quarter of 2022, an unnamed source, also in the Russian rocket and space industry, told TASS.

Sergey Karutin, GLONASS's chief designer said in October 2020 that the GLONASS-K2 satellites would provide navigation precision of better than 30 centimeters (11.8 inches), TASS reported.

The GLONASS-K2 launch has been delayed at least twice. Most recently it had been expected to launch toward the end of 2021. Prior to that there had been a launch planned for 2020 that was put off after on-the-ground testing showed that some of the onboard equipment needed further work, according to TASS.

Helping keep an eye on those satellites will be new GLONASS monitoring stations in Brazil, China, Indonesia, India, and Angola. The monitoring equipment from Precision Instrument-Making Systems should enhance the accuracy and improve other system parameters.

The Russians plan to build their China-based, non-request measuring station in Shanghai. As part of the deal, said TASS, Moscow is going to allow China to put a BeiDou monitoring station in Russian territory.

China Builds Market for BeiDou

In addition to expanding its monitoring network, China has been working

Arianespace successfully launches two Galileo satellites from the Guiana Space Center in French Guiana on December 4, 2021.
Photo courtesy of Arianespace

earnestly to enhance and expand the market for its BeiDou navigation constellation (BDS).

The China Satellite Navigation Office (CSNO) announced in December that it had created an industrial chain of BDS products including basic chips, modules, boards, and antennas, and what it called "leapfrog development" in performance and large-scale application, according to the Xinhau news agency. During the first half of 2021, Xinhau reported, nearly 80% of the smartphones put into use in China supported BeiDou.

An action plan signed during the third China-Arab States BDS Cooperation Forum, Xinhua reported in early December, could serve to expand use of the system in the Middle-East. In the works for 2022 and 2023 are jointly implemented pilot projects in key satellite navigation applications, said Xinhau. BDS already has been providing position and time information via Continuously Operating Reference Stations (CORS) in Tunisia, Algeria, and other places.

The forum, which attracted more than 300 participants from 17 Arab states and China, was sponsored jointly by the China Satellite Navigation Office and the Arab Information and Communication Technologies Organization.

The organizations agreed to facilitate the establishment of BDS/GNSS centers in the Arab states, hold training courses on satellite navigation technologies, and exchange visiting scholars. Each year, China will offer scholarships to three to five students majoring in navigation and communications from the Arab countries. China and the Arab states will also do joint BDS/GNSS tests and evaluations and promote the application of BDS in international search and rescue, among other initiatives, said Xinhau.

China held at least two other international meetings in 2021. One in October in Lanzhou, China, had in-person and virtual attendees from Central Asian countries including Turkmenistan, Uzbekistan, and Kazakhstan, as well as international organizations

"The completion of the China-Kyrgyzstan-Uzbekistan highway, the completion and operations of the China-Kazakhstan crude oil pipelines, and the regular and efficient operations of the China-Europe freight trains have offered broad prospects for the innovative application of the BDS," Ran Chengqi, director of the China Satellite Navigation System Management Office, told Xinhua.

The first cooperation forum with Africa was held in Beijing in November and attended by representatives of nearly 50 African nations, according to the BeiDou website.

Galileo Nears Full Operations

Arianespace has been chosen by the European Union Agency for the Space Programme (EUSPA) to launch four Galileo satellites from the Guiana Space

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Center in Kourou, French Guiana 6. The new deal is in addition to an October 2021 agreement with the European Space Agency (ESA) to launch four Galileo satellites.

"After a first launch this year for Galileo, carrying satellites from a previous order, in the first half of 2022, a second Soyuz launch in 2022 will orbit the first two satellites from this latest order," the company said in a January 6 press release. "The next three missions will orbit two satellites each on Ariane 62, in 2023, 2024, and 2025."

The launches in 2022 will lead to full operational capability of Galileo's open service.

EUSPA also recently released an updated version of its Galileo Open Service Definition Document (OS SDD). Version 1.2 incorporates information on upgrades in the Galileo system since the publication of the previous version in May 2019. The SDD "provides better minimum performance levels (MPLs) for signal and position availability, updated definitions of some timing MPLs, and establishes a more stringent commitment on the time to publish Notice Advisories to Galileo Users (NAGUs)," wrote EUSPA on its website. "In addition, the concept of auxiliary satellites has been added, while some sections have been reworded to improve clarity."

This latest version can be found at https://www.euspa.europa.eu/newsroom/news/galileo-open-service-definition-document-version-12-now-available-download

GPS Resilience a Congressional Priority

While the U.S. Congress continues to work on finalizing the funding bills needed to pay for programs across government, lawmakers on both sides of the Capitol have made very clear their desire for more resiliency in U.S. positioning, navigation, and timing infrastructure.

Civil—On the civilian side, the House and Senate largely agree on the total budget number for the Department of Transportation's PNT programs, though the final language remains to be worked out.

Still on the table is a Senate proposal to shift $5 million of the $97 million proposed by the White House for the Wide Area Augmentation System to instead support the implementation of a variety of PNT backup technologies to support the widely varying needs of different users. The money would be used to develop modeling standards and do other research needed for DOT to integrate the technologies that government tests and demonstrations have already shown "could provide a backup to the GPS service in case of a major disruption," DOT said in its budget request.

Both bodies of Congress also included language in their reports accompanying the DOT funding bill that underscored the need for such an effort.

Defense—Lawmakers working to fund Defense Department programs focused all their attention on the money budgeted for the constellation itself and related programs like the ground segment and military user equipment.

The House and Senate Armed Services Committees, however—the members of congress who authorize defense spending—made it very clear that PNT resiliency was vital.

Both the House and Senate included report language calling for a briefing on an alternate PNT constellation. The House also called for a briefing on how the DOD intended to address the "current and projected vulnerabilities."

"The committee is aware of significant vulnerabilities to the Global Positioning System (GPS) enterprise [and] its associated position, navigation, and timing (PNT) infrastructure," the House wrote in its report. "As the threats to this critical infrastructure continue to grow, the committee affirms the urgency of ensuring the resiliency and survivability of this vital asset and urges the Department of Defense to fully leverage technologies to harden and reinforce PNT infrastructure."

Locata and UrsaNav Partner on Combined Service

With the risks to PNT services rising, and the efforts to make them more resilient bogged down, some in the commercial sector are stepping up with services to fill the gap. Locata and UrsaNav announced in December they were partnering to create a high-accuracy PNT service with extensive geographic range to provide resilient PNT solutions to national governmental and commercial interests globally.

The U.S. Capitol Building
Photo courtesy of Louis Velazquez via Unsplash

Corporate Profile

Psionic

Psionic.ai/defense

PSIONIC

Psionic (psionic.ai) was founded in 2016 by senior executives and engineers from NASA.

In 2021, the company announced Psionic SurePath, a self-contained system that provides long-range, precision navigation without external signals of any kind.

- Functions side-by-side with existing navigation systems
- Detects when GPS is spoofed or jammed
- Provides "grade-jumping" performance over other INS-based navigation solutions
- Suitable for all platforms (mounted, dismounted, and rotary and fixed wing aircraft)
- Plug-and-play, data can be output to any device in any format
- Does not require a map or knowledge of the terrain

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

Calendar of Upcoming Events

MARCH 2022

7-9: Munich Satellite Navigation Summit, Munich, Germany
Web: munich-satellite-navigation-summit.org/

APRIL 2022

12-14, 9:00 a.m. JST/**April 11-13,** 5:00 p.m. PDT: ION Pacific PNT 2022, Hosted Virtually
Contact: ION
Web: ion.org

MAY 2022

6-9: 13th China Satellite Navigation Conference (CSNC) 2022, Beijing, China
Contact: CSNC
Web: http://english.aircas.ac.cn/ne/events/202109/t20210903_282415.html

JUNE 2022

6-9: ION Joint Navigation Conference (JNC) 2022, Town and Country Hotel, San Diego, California
Contact: ION
Web: ion.org

SEPTEMBER 2022

19-23: ION GNSS+ 2022, Hyatt Regency Denver at Colorado Convention Center, Denver, Colorado
Contact: ION
Web: ion.org

JANUARY 2023

23-26: ION International Technical Meeting (ITM) & ION Precise Time and Time Interval (PTTI) Meeting 2023, Hyatt Regency Long Beach, Long Beach, California
Contact: ION
Web: ion.org

John Deere Introduces Fully Autonomous Tractor at CES

John Deere introduced a fully autonomous tractor at the 2022 Consumer Electronics Show that is intended to operate without a driver in the cab.

To work with the new tractor, a farmer transports it to the field and then configures it through John Deere Operations Center Mobile. The center provides access to live video, images, data, and metrics which enables the farmer to adjust and troubleshoot the tractor's operation via his or her cell phone. The center also stores data about the farm and its crops gathered as it traverses the fields—data farmers can then use to improve their planning and operations.

The company highlighted the system as a possible answer to labor shortages in the agriculture sector and emphasized how it would free farmers to take care of other tasks.

The tractor, which combines new technologies with Deere's 8R tractor, a TruSet-enabled chisel plow, and a GPS guidance system, is production-ready and will be available for purchase in the Fall 2022.

Photo Courtesy of John Deere

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