Volume 36 No 1 **Winter 2026**

Quarterly Newsletter

ION®
INSTITUTE OF NAVIGATION

ION GNSS+ 2025

International GNSS Community Returned to Baltimore, Looking to Orlando in 2026, and the Division's 40th Anniversary

Nine-hundred attendees gathered at the Hilton Baltimore Inner Harbor in Baltimore, Maryland for ION GNSS+ 2025. The full-sized technical program and commercial exhibit highlighted: autonomous and safety critical applications; status and future trends in navigation; navigation for mass market; multisensor and autonomous navigation; algorithms and methods; and advanced GNSS technologies. An additional 70 attendees registered for on-demand only.

The conference featured more than 400 technical presentations (offered in-person

Satellite Division Officers Hosting ION GNSS+ 2025: Dr. Allison Kealy, International Technical Advisor; Dr. José-Ángel Ávila-Rodríguez, Vice Chair; Dr. Dorota Grejner-Brzezinska, Chair; Dr. Gary McGraw, ION President; and Dr. Okuary Osechas, International Technical Advisor. Not pictured: Dr. Juan Blanch, Secretary; Dr. Seebany Datta-Barua, Treasurer; and Sandy Kennedy, Immediate Past Chair.

continued on page 8

GALILEO LEADERS REFLECT ON 30-YEAR JOURNEY

Building Europe's Satellite Navigation System

Kevin Dennehy

Marco Falcone and Jeremie Godet open ION GNSS+ 2025 as keynote speakers, celebrating the 30th anniversary of Galileo

Two architects of Europe's Galileo satellite navigation system chronicled a three-decade saga of political battles, technical breakthroughs and near-catastrophic failures that transformed a bold vision into a global service now used by billions.

Jeremie Godet, current Head of Secure Connectivity and Space Surveillance at the European Commission, and Marco Falcone, who leads the Future Navigation Department at the European Space Agency (ESA), gave the keynote address at the Institute of Navigation's GNSS+ 2025 conference in Baltimore to mark Galileo's 30th anniversary.

"Galileo today is delivering world-class services to billions of users," Falcone said, citing one-meter accuracy for its open service.

The speakers recalled setbacks, including skepticism from member states and governance disputes, but emphasized perseverance, political leadership, and collaboration across agencies as crucial to Galileo's success.

The story began in the early 1990s, when the U.S. GPS was nearing full operational capability and Europe lacked an independent system. By later in the decade, and after many meetings, political backing crystallized with a European Commission communication naming the program after Italian astronomer Galileo Galilei, a choice Falcone said partly irritated acronym-loving engineers but symbolized "perseverance and scientific

continued on page 4

The Institute of Navigation
8551 Rixlew Lane, Suite 360
Manassas, Virginia 20109

PRESIDENT'S COLUMN | DR. GARY MCGRAW

30-Years of Galileo

The ION's Satellite Division hosted ION GNSS+ 2025, September 8-12, with a celebratory theme of the 30-year anniversary of Galileo. It was a delight to celebrate with the European Space Agency (ESA), the European Commission (EC), and all of the international partners that made Galileo a reality. It is a point of pride for the ION that our programs and publications were a place where Galileo technical developments were shared with the wider navigation community and we look forward to continuing this relationship for years to come.

Other highlights of ION GNSS+ included Monday's free short courses: GPS/GNSS 101 taught by Dr. John Raquet; Space Applications of GNSS taught by Dr. Penina Axelrad; Signals of Opportunity Based Navigation taught by Dr. Christian Gentner; GNSS Jamming and Spoofing – LEO as Fallback taught by Dr. Todd Humphreys; Indoor Positioning and Indoor Navigation Systems taught by Dr. Li-Ta Hsu; and Ionospheric Effects taught by Dr. Jade Morton. We learned from last year's "standing-room-only crowds" and expanded the space this year. ION extends its gratitude for the selfless dedication of teaching and time donated by these talented and inspiring instructors.

I want to personally thank all the volunteers that made the technical event possible, including the Satellite Division officers and committee chairs, the technical program and publications committees, all the tutorial and short course instructors, session chairs, technical reviewers, exhibitors, sponsors, and the many speakers. Also, I'd like to thank all of the attendees for coming and making ION GNSS+ such a lively event. Also, I'd like to thank the ION staff for making the conference run so smoothly.

For me, there were many highlights to the ION GNSS+ event, but the plenary session was perhaps my favorite of all time! Marco Falcone and Jeremie Godet's presentation on the 30 years of Galileo history was engaging and offered new insights into the ups and downs of Galileo's development. During the Q&A, I asked what major challenges they anticipated maintaining the current operational system in the long term. Falcone's response communicated the need to guarantee the continuity and robustness of the service, always keeping in mind Galileo's millions of users. Godet followed up that ESA and the EC need to maintain and grow the intellectual talent and technical skills of those entering the industry, and the political and economic leadership for Galileo's programmatic health. This comment also applies to the PNT community more broadly where the ION serves a role.

I encourage those of you who were not able to join us in person in Baltimore to view the ION GNSS+ plenary session on the ION's YouTube channel.

Early Career Chair Appointed

Sergio Vicenzo, ION's Early Career Chair

Other highlights of the ION GNSS+ week included greeting students and early career professionals from around the world. ION was pleased to help publicize an informal gathering of ESA's "Young Navigators" which drew close to 100 participants!

ION is also pleased to welcome Sergio Vicenzo, of The Hong Kong Polytechnic University, as an ad hoc member to Council as ION's Early Career Chair. Sergio will be representing early career professionals (including students), strengthening representation and involvement from this membership segment; serve as the voice of early career members within ION; and serve as ION's liaison between other international young professional groups (ESA, RIN, etc.). We hope you will see more of Sergio in future issues of this newsletter.

Marco Falcone and Jeremie Godet recount never before heard details of the trials and achievements of the Galileo program during the ION GNSS+ 2025 plenary session.

ION President, Gary McGraw, poses a post-plenary session question to the speakers.

ION GNSS+ 2025 Program Committee: Dr. John Raquet, Tutorials Chair; Dr. Michael Fu, Dr. Omar Garcia Crespillo, and Dr. Sophie Damy, Track Chairs Commercial and Policy Tracks; Dr. Ilaria Martini, Program Chair Commercial and Policy Tracks; Dr. Jason Gross, Program Chair Research Tracks; Dr. Aurore Sibois, Dr. Clark Taylor, and Dr. Aboelmagd Noureldin, Track Chairs Research Tracks; Dr. Eva Buchmayer and Dr. Terry Moore, Publication Chairs. Not pictured: Cécile Deprez, Publication Chair

Changes in ION GNSS+ 2026 Publication and Presentation Requirements

The ION Council met prior to the commencement of ION GNSS+ and reviewed the activities of the past eight months. In order to ensure the future publication of ION GNSS+ papers in the Web of Science, important decisions were made concerning the future publication of peer reviewed manuscripts. It is important to note that the changes approved by the Council concerning manuscription publication will also impact the acceptance and presentation of abstracts for next year's ION GNSS+ meeting, most notably:

In the ION GNSS+ 2026 Research Tracks – All papers will be required to pass peer review in order to be presented at the conference and published in the official conference proceedings. Papers not received by the peer review deadline of June 30, or papers failing peer review, will be withdrawn from the conference program.

In the ION GNSS+ 2026 Commercial Tracks – Peer review will be made available for the first time in 2026, but will be optional. Authors not opting for peer review, or authors that fail peer review in the commercial sessions, will still be able to present, but only papers that pass peer review will be included in the official conference proceedings.

All non-peer reviewed materials will be made available to conference attendees and will be distributed with the official proceedings after the conference as supplemental materials.

These changes are being implemented as the ION GNSS+ meeting has a high rejection rate (averages 50% in the majority of sessions) and the goal is to ensure only papers of the highest quality are provided with coveted presentation slots. Session chairs will be looking for expanded, novel, and well-developed abstracts when making acceptance decisions for 2026 in the spring. You can expect detailed information to be provided online and in the call for abstracts brochure.

Other Council Business

Council reviewed membership achievements over the past year with ION Membership Chair, Dr. Melania Susi, that included an increase in ION's international presence and plans for continued international outreach, as well as continued student/early career support. Results from the past year's ION membership survey were shared.

Additional reports were received from ION's Publication Chair, Dr. Richard Langley (who also serves as the editor of NAVIGATION) and ION Meetings Chair, Ernesto Etienne.

Later in the week the ION Executive Committee met and approved the ION's 2024-25 Audited Financial Statements and auditor management letter. A transfer of funds from the ION's operating fund to the ION's long-term investment fund was authorized.

Looking to ION's ITM/PTTI 2026

The ION's next Council meeting will be held Monday, January 27, 2026, in Anaheim, California in association with the ION's International Technical Meeting (ITM) and Precise Time and Time Interval Systems and Applications (PTTI) Meeting. See you there!

Follow us on Facebook, Instagram, LinkedIn, find us on X (formerly Twitter) at @ionavigation, and subscribe to youtube.com/@ionavigation

Galileo started with many meetings and experiments defining its architecture. Marco Falcone pictured at ION GPS 2000.
ESA

from page 1

integrity."

Galileo's first test satellite, known as GIOVE-A, was launched in 2005 aboard a Soyuz rocket, Falcone said. It transmitted the first Galileo navigation signals in early 2006. The second test satellite, GIOVE-B, was launched in 2008. As with GIOVE-A, it operated in medium-Earth orbit (MEO) to help refine Galileo signal standards.

Overcoming Obstacles and Political Battles

The program's history is defined by pivotal moments, including the need to secure a budget and political will. According to Godet, there was "actually one real mother of the Galileo program," referring to former European Commissioner Loyola de Palacio. When her initial proposal was met with "lukewarm reactions if not icy" from certain member states, Godet remembers her saying, "the only negotiation that you lose is the one that you do not start" and "we have heard the objections of the member states and we are going to address them one by one."

De Palacio pressed member states to fund the program despite skepticism about its costs and purpose. At one point, the project shifted from a public-private partnership model to full public financing, requiring billions of euros in new commitments.

A 2001 letter from the U.S. Deputy Secretary of Defense Paul Wolfowitz warning of signal interference with NATO operations forced transatlantic talks. This challenge led to a "marathon of meetings" on both sides of the Atlantic to jointly define compatibility and interoperability criteria, which Godet said laid the "ground for the next generation of civilian signal in spirit of mutual trust and sincere cooperation."

Years of technical talks followed, eventually producing compatibility standards between GPS and Galileo. "The Galileo journey was like rocky climbs, sometimes with wild weather," Godet said. "We made it to the top just to discover that the next peak was even more impressive."

Galileo's Climb: A Story of Highs and Lows

The Galileo journey began with innovation and collaboration as many of the constellation's innovations became international standards. Yet, not everything went smoothly. Between 2010 and 2015, in-orbit testing revealed unexpected problems. The ambitious Global Integrity Service, meant to provide six-second alerts worldwide, had to be abandoned due to difficulty achieving the necessary global coverage and security, as well as complex liability issues.

However, Godet said that this design failure ultimately created new opportunities. "Many of the new services of Galileo are kind of born out of this design failure of the safety of life which became an opportunity. Learn from the past and look to the future," he said.

One was the unused data rate capacity was repurposed to develop the Open Service Navigation Message Authentication (OSNMA), the search and rescue return link, and the future Emergency Warning Satellite Service.

A big high came in 2012, when the first Galileo-only position fix was achieved—a historic moment for Europe. The in-orbit validation phase confirmed that the constellation could indeed deliver accurate positioning. "This was a historical achievement for Europe. It was the first time we knew Galileo worked," Falcone said.

The ingenuity of system engineers also became a high point for Galileo. One

Not everything went well for Galileo; the system faced an outage in 2019.
ESA

evening, the engineers gathered at a restaurant, frustrated with slow progress on civil aviation planning. On a simple napkin, they sketched a plan. "We took a napkin and we wrote it down and presented it to our delegates," Falcone said. That plan laid the foundation for the civil open service, adopted by the International Civil Aviation Organization in 2023.

Atomic Clock and Launch Mishaps

Even early successes were followed by unexpected technical hurdles. During the In-Orbit Validation phase, which included the launch of the second in-orbit demonstrator, the team encountered a critical issue involving the satellite's highly precise timing equipment. The satellite was flying the first passive hydrogen maser clock in orbit, an essential component for the system's performance, but this did not go smoothly.

Falcone recalled that during the launch and early orbit phase, "the satellite was not behaving normally after injection," noting that they were having difficulty stabilizing the attitude control. This forced the team to implement a recovery plan to correct the error.

Setbacks persisted. In 2014, a launch anomaly placed satellites 4,000 kilometers off their intended orbit. However, the team could broadcast navigation signals even in test mode. Godet said at the time, "oh gosh, we have a problem to solve" that required quick thinking and problem solving to recover the aircraft. Eventually, ESA teams rewrote procedures to recover two stranded satellites to turn the mishap into a scientific asset for future experiments.

Similarly, atomic clock failures in 2016–2017 posed a severe challenge,

Galileo announced an Initial Service Declaration in 2016.
François de Ribaucourt

Galileo currently offers several services that are used by 5 billion users.
ESA

with satellites flying 23,000 kilometers above the Earth—conditions hard to reproduce and correct. Through careful analysis and industrial collaboration, these issues were resolved, turning failures into learning opportunities, Falcone said.

Another mishap occurred in 2019, when a ground system failure caused a week-long navigation outage, shocking the program. However, a crisis was turned into system-wide improvements, Falcone said. "A failure makes you stronger—we introduced faster convergence and graceful degradation in case of system failure," he said.

Successes and Launch Disruption… And the Future

Despite setbacks, Galileo also set records. Between 2015 and 2016, six satellites were launched in a single year, including a historic four-satellite launch on Ariane 5. The successful deployment paved the way for the Galileo Initial Service declaration on Dec. 15, 2016, triggering widespread adoption of Galileo-enabled devices.

The Initial Service declaration included 18 satellites in orbit, which were accelerated by Soyuz and Ariane 5 launches. After this declaration, 95 percent of new smartphones included Galileo chips, Falcone said.

The last disruption, a geopolitical one, occurred in 2022 when access to the Ariane 5 launch base was cut off because of the Russian invasion of Ukraine. Galileo's satellites were stored in containers, a situation that had never happened before. However, thanks to EU-U.S. cooperation, two satellites were successfully launched aboard SpaceX Falcon 9, giving the Galileo team a first-time view of direct orbital injection.

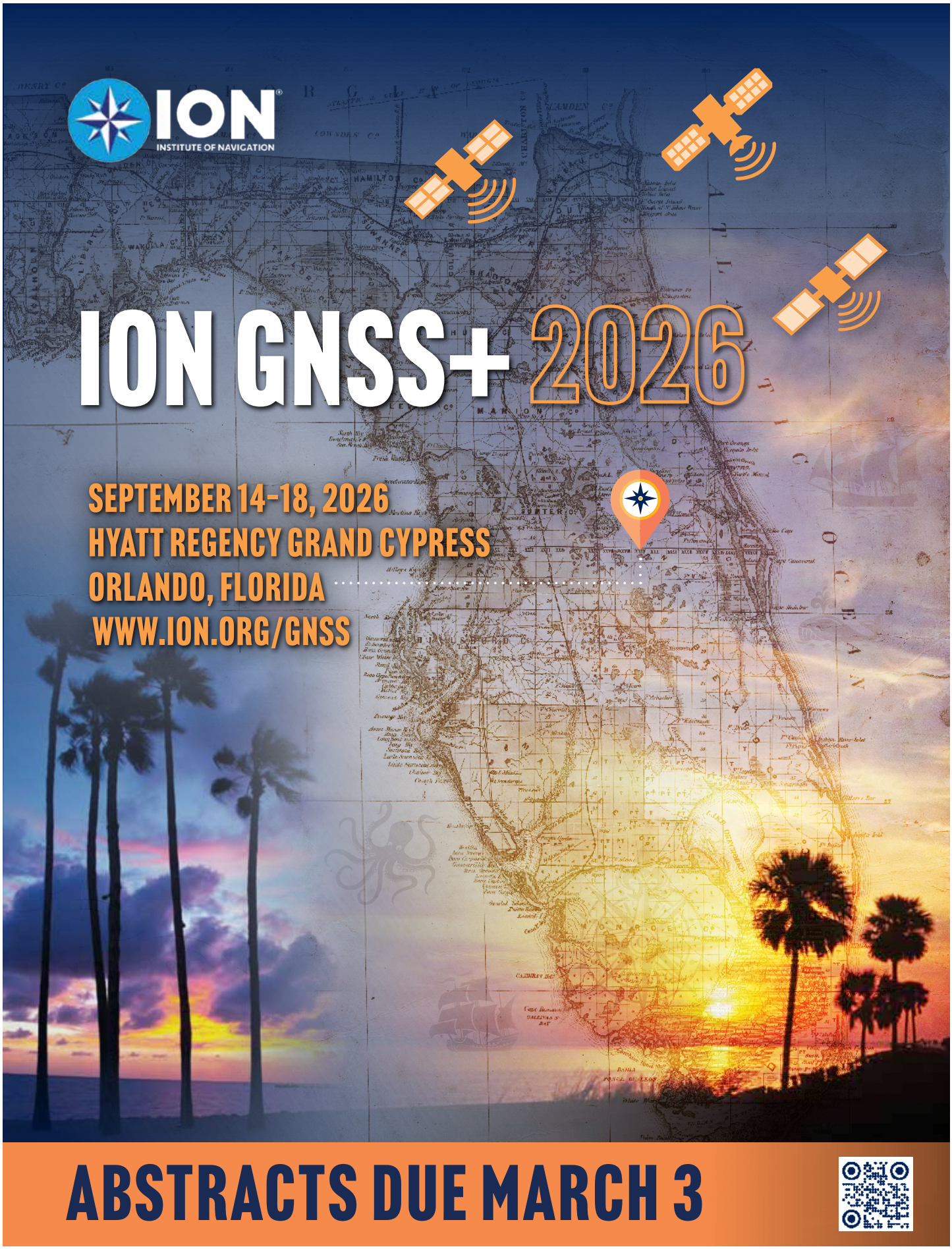
Today, Galileo's success has strengthened Europe's role in global navigation alongside GPS, GLONASS, and BeiDou. The constellation is delivering such services as centimeter-level high accuracy service (HAS), the Search and Rescue (SAR) service with almost real-time acknowledgment messages, an emergency warning system slated for 2026, and OSNMA to prevent spoofing. Its services extend beyond terrestrial users to support space missions, and its secure, government-only Public Regulated Service is expected to reach initial operational capability soon.

Keynote audience member and GPS pioneer Dr. Brad Parkinson recalled advocating for Galileo in Washington despite opposition. "There was a group in Washington who were deadly opposed to [Galileo]. They called me in, assuming I would say 'it's a terrible idea, let's shoot it down," he said. "On the contrary, from the standpoint of the user community, Galileo is one of the greatest ideas I've ever heard."

Looking to the future, Galileo's second generation (G2) satellites promise fully flexible payloads, electric propulsion, advanced clocks, and inter-satellite links. With upcoming low Earth orbit (LEO) pathfinders and projects like Moonlight, Galileo aims to extend its capabilities to lunar and Martian navigation for space-based PNT.

In addition, the Galileo pioneers identified continuity, workforce retention, backward compatibility and political support as enduring challenges. Both emphasized in-orbit demonstration of emerging technologies – quantum, AI, optical links – to maintain momentum.

For Godet and Falcone, who joined the effort in its early days, Galileo's endurance proves the value of perseverance. Reflecting on the past 30 years, Falcone said that working in GNSS is like climbing a mountain. "There are highs and lows. There are moments of glory and moments of pain," he said. "To get to the top you need a lot of passion, a lot of motivation, a lot of fun – because if you don't have fun, you are going to give up."


ION
INSTITUTE OF NAVIGATION
ION GNSS+ 2026
SEPTEMBER 14-18, 2026
HYATT REGENCY GRAND CYPRESS
ORLANDO, FLORIDA
WWW.ION.ORG/GNSS
ABSTRACTS DUE MARCH 3

ION GNSS+ 2025 Status of the Systems Panel Members: Eric Châtre and Miguel Manteiga, Galileo; Dr. Christopher Erickson, GPS; Motohisa Kishimoto, QZSS; Dr. Byoung-Sun Lee, KPS; and Dr. José Ángel Ávila Rodríguez and Dr. Chris Hegarty, Moderators

GNSS Integrated High-Precision Positioning: Current Challenges and Future Trends panel members Dr. Todd Humphreys, University of Texas at Austin; Yi-Fen Tseng, AUROXAT Inc.; Bryan Chan, Xona Space Systems; and Dr. Bruno Bougard, Septentrio. Not pictured: Dr. Sunil Bisnath, York University; Sandy Kennedy, Hexagon; and moderators Dr. Naser El-Sheimy, University of Calgary and Dr. Mohammed Khider, Google

from page 1

and on-demand), a tutorial program, and 45 exhibitors in a dynamic commercial exhibit.

The panel discussions continued to be a highlight and were well attended as an annual favorite. Other popular panels included two new LEO panels that covered LEO services, opportunities, and challenges; and a second panel on how LEO is revolutionizing PNT, which generated lively debate.

An innovative session, the Latest Advancement from GNSS Receiver and Localization Algorithm Manufacturers, chaired by Dr. Paul McBurney and Joseph Dennis, allowed industry to make 10-minute pitches about their products. These included low-Earth orbit systems, a PPP-AR correction service for centimeter-level accuracy, and barometric integration for wearable GNSS receivers in dense-urban environments, to name a few. A highlight for authors presenting in this session was session chair Dr. McBurney who set the speakers' introductions to pop-melodies and literally "sang their introductions" to the delight of the audience.

In addition to the plenary session (see cover article), attendees enjoyed a special commemorative celebration of thirty years of Galileo, complete with European themed food and beverage stations, in the exhibit hall Wednesday evening.

Mark your calendars for next year when ION GNSS+ 2026 moves to the sunshine state of Florida, where the Division will also be celebrating its 40th Anniversary, September 14-18, 2026, at the Hyatt Regency Grand Cypress, Orlando, Florida.

Session chair Dr. Paul McBurney introduces speakers with a song.

ION's GALILEO PLAYERS

At the conclusion of the ION GNSS+ plenary session the "Galileo Players" treated the audience to a parody of the Queen song "Bohemian Rapsody" composed and conducted by Dr. Ignacio Fernández-Hernández. Below are the lyrics to the song that was performed live at ION GNSS+ 2025:

Is this the real life? Is this just fantasy?
We need our system, no U.S. dependency
Open your eyes, look up to the skies and see
One constellation, twenty-four satellites (choir: "twenty-four")
To give us latitude, longitude, frequencies more than two
any way iono blows doesn't really matter too much to me

[Verse 1]
Mama, see the launch pad,
put a rocket in the sky,
got my first two satellites
Mama, we have just begun
But now we need another twenty-two!
Mama, ooh (choir: "don't forget a few spares…")
There will be delays, clock failures, and many other problems too
carry on, carry on

[Verse 2]
I see a little correlation peak
Tracking loop, tracking loop, will you give me good ranging
CBOC modulation, synchronization…
T!
Galileo (Galileo) Galileo (Galileo) Galileo
PVT!
Magnifico! oh-oh-oh-oh-oh – no no no no no no
Mama mia, we're so many! Twenty-seven Member States!
But somehow we could make it work, worldwide, for you, for me, for free...!

Left: Dr. Terry Moore, Galileo Players soloist, parodying Freddy Mercury

Above: Galileo Players composer and conductor, Dr. Ignacio Fernández-Hernández









THANK YOU TO OUR EXHIBITORS and SPONSORS

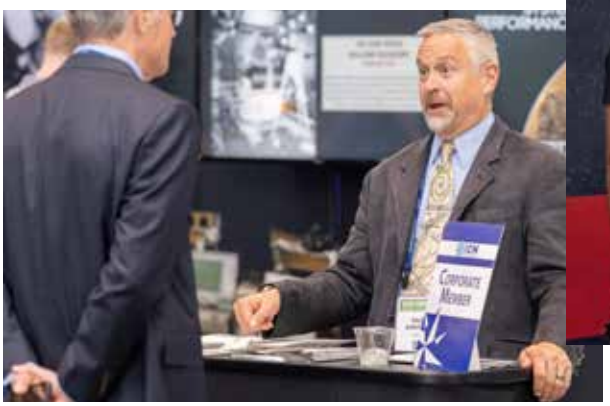
746th Test Squadron
Acutronic USA Inc.
Analog Devices
CAST Navigation, LLC
ComNav Technology, Ltd.
Epson America, Inc.
European Space Agency
FIBERPRO, Inc.
German Aerospace Center
GMV Aerospace and Defence S.A.U.
Hanwha Aerospace
Hemisphere GNSS
Hexagon | NovAtel
IAI
Ideal Aerosmith
IFEN GmbH
Indra
Inertial Labs
Inside GNSS
Institute of Navigation
LabSat
Microchip Technology Inc.
Munich Satellite Navigation Summit
NAVPATH
NavtechGPS
onocoy Association
Optical Zonu Corporation
Oscilloquartz
OXTS
Qascom
Q-Tech Corporation
Rakon
Resilient Navigation & Timing Foundation
Rohde & Schwarz USA, Inc.
Rx Networks, Inc.
Safran – Electronics & Defense
SBG Systems
Silicon Sensing Systems Ltd.
SiTime
Spirent Communications PLC
Spirent Federal Systems
Syntony GNSS
Trimble Inc.
TUALCOM USA LLC
UHU Technologies LLC
Xona Space Systems


CAST
NAVIGATION


LabSat
BY RACELOGIC


NAVIGATION
SHAPING THE FUTURE


TECHN
IS YOUR GPS
SPOOF-


Corporate
Member

ION GNSS+ Award Winners

2025 Kepler Award

Logan Scott, 2025 Kepler Award Winner

The Institute of Navigation's (ION) Satellite Division awarded Logan Scott its Johannes Kepler Award on September 12, 2025, during the ION GNSS+ 2025 conference in Baltimore, Maryland, for sustained contributions to satellite navigation signal design, recognition and mitigation of interference and spoofing threats to GPS, and advocacy for civil GNSS assurance.

Scott's seminal contributions to satellite navigation over his 45+ year career include digital receiver design; early recognition of threats to GPS from interference and spoofing; invention of location-based encryption, "J911" crowd-sourced geolocation of interference sources; and use of cryptographic signal authentication for civil radionavigation signals.

Scott was a key technical leader in pioneering receiver designs at Texas Instruments, including signal acquisition and tracking, adaptive arrays, jamming, and fade resistance. In 1985, Scott and his team developed the world's first all-digital GPS receiver, paving the way towards the low-cost, compact, lightweight, and energy efficient receivers now numbering in the billions.

Scott was the first to describe methods for civil signal authentication. He invented a new and fundamental delayed-key asymmetric navigation security paradigm now embodied in the GPS Chimera signal, next generation WAAS, and Galileo systems; and he participated in the creation of the Chimera authentication signal.

Scott discovered and described how an adaptive array can bias phase and pseudorange measurements to adversely affect high precision receivers; particularly how such biases could cause real-time kinematic (RTK) ambiguity resolution to fail. This work became essential to the success of the Joint Precision Approach and Landing System (JPALS) program.

Since 2015, Scott has been a core member of the NTS-3 Advanced Signals Team, originating multiple signal design concepts, at least nine of which will be tested on-orbit. His signal designs focus on civil signal assurance, optimization of the navigation data message by leveraging concepts from the communications industry, and advanced waveforms to enhance military receiver performance.

As a member of the U.S. National PNT Advisory Board, Scott promoted the need and methods for resilient and robust PNT, and required spectrum protection. In 2010-2011 he developed and quantified the performance of crowdsourced interference detection and geolocation using cell phones.

Logan Scott received his BSEE from Columbia University in 1978. From 1978 to 1991 he was a signal processing specialist and RF systems architect at Texas Instruments (TI). Since 1991 Scott has been an independent consultant, providing innovative approaches and solutions for building advanced RF systems including GPS, RFID, navigation, communications, radar, and emitter location systems. He is an ION Fellow (2014) and the recipient of the ION Captain P.V.H. Weems Award (2022), GPS World Signals Award (2018), and is an IEEE Senior Member.

2025 Parkinson Award

The 2025 Parkinson Award was awarded to Dr. Jason Anderson, Stanford University, for his thesis, Designing Cryptography Systems for GNSS Data and Ranging Authentication.

The Bradford W. Parkinson Award is awarded annually to an outstanding graduate student in the field of GNSS. This award, which honors Dr. Parkinson for his leadership in establishing both the U.S. GPS and the Satellite Division of the Institute of Navigation, includes a personalized plaque and a $2,500 honorarium.

2025 Parkinson Award winner, Dr. Jason Anderson (center), pictured with Dr. Bradford Parkinson (left), and Anderson's thesis advisor, Dr. Todd Walter (right), Stanford University

ION GNSS+ 2025 Student Paper Competition Winners Recognized

In 2025 the Satellite Division modified the student paper competition to make it more competitive. To ensure the highest quality applicants, each academic institution was limited to one application, or the best technical paper to the student competition. Each student who was sponsored by their school in the Student Paper Competition received a complimentary conference registration. All the Student Paper Competition entries were then judged by an esteemed group of experts for the Best Student Paper Award. In the end the Satellite Division made the decision to award two honorariums: Axel Koppert, Graz University of Technology, supervised by Prof. Philipp Berglez; and Daniel Choate, Tufts University, supervised by Prof. Jason Rife.

Student Paper Award Winners: Daniel Choate, Tufts University and Axel Koppert, Graz University of Technology

Red Pencil Recognition

Red pencil recipients are recognized with a bouquet of red pencils and an Amazon gift card for their outstanding contributions to the Institute this past year in their role as a peer reviewer for various ION activities. The ION would like to thank each of them for providing high-quality, timely reviews when called upon.

Red Pencil Winners: Dr. Seebany Datta-Barua, Illinois Institute of Technology and Dr. Juan Blanch, Stanford University. (Winners not pictured included: Dr. Penina Axelrad, University of Colorado Boulder; Dr. Élisa Gallon, Airbus Defense and Space; and Dr. Jihye Park, Oregon State University.)

ION GNSS+ 2025 Best Presentation Awards

Session C1: AI-Driven Positioning and Navigation

Machine Learning-Driven Long-Term Ephemeris Error Correction for Improved LEO PNT: Joe Saroufim, Paul El Kouba, Samer Hayek, and Zaher M. Kassas; *The Ohio State University*

Session E1: Emerging Technologies for Alternative, Resilient, & Intelligent PNT Systems

Opportunistic LEO PNT via Ground Segment Ephemeris Product Provision: Samer Hayek, Joe Saroufim, and Zaher M. Kassas, *The Ohio State University*

Session F1: Lunar Positioning, Navigation, and Timing

Preliminary Navigation System Design for the First LCRNS Satellite Providing Lunar PNT Services: Tara Mina, Ava Thrasher, Mark Hartigan, Jason Leonard, Shaun Stewart, Peter Antreasian, Kevin Pipich, Daniel Brack, David Gaylor, Barrett Bedford-Dillow, E. Glenn Lightsey, John Christian, *Georgia Institute of Technology*

Session A2: Future Augmentation Systems, Correction Services and Integrity 1

Multi-Process Stochastic Error Models for DFMC GBAS Carrier Smoothed Code Processing and Preliminary Airborne Results: Gary A. McGraw, *Genova Technologies/Consultant to the German Aerospace Center (DLR);* Maria Caamano, *DLR*

Session C2: High Accuracy Positioning and Correction for Mass Market Devices

Striking a Georeferenced Pose: RTK and ARKit Fusion in Learned 3D Map Reconstruction: Daniel Neamati, Mira Partha, Lance Legel, Grace Gao, *Stanford University*

Session D2: Alternative Technologies for GNSS-Denied Environments – Non-Optical Approaches

Experimental Evaluation of Collaborative Navigation Through Shared Motion Constraints During GNSS Outages: Hasan Kinatas and Mathieu Joerger, *Virginia Tech*

Session E2: Accurate Navigation in GNSS Challenging Environments 1

Exploring and Utilizing Multipath Effects on L5 for Multi-Frequency Machine Learning-Based Positioning: Nesreen I. Ziedan, *Zagazig University*

Session F2: Advanced Software and Hardware Technologies for GNSS Receivers

Analysis of a Centralized Filter Design for a Multi-Receiver Vector Tracking Architecture Under Challenging Conditions: Stefan Laller, *Graz University of Technology;* Mohamed Bochkati, *University of the Bundeswehr Munich - LRT Satellite Navigation);* Philipp Berglez, *Graz University of Technology - Institute of Geodesy;* Thomas Pany, *University of the Bundeswehr Munich*

Session A3: Aviation, Aeronautics, and Uncrewed Aerial Applications 1

Overbounding Time-Correlated Errors for Precise Point Positioning Integrity Service with an Extended Kalman Filter Demonstration: Rebecca Wang, Juan Blanch, and Todd Walter, *Stanford University*

Session B3: Future of Space, Lunar, and Extraterrestrial Navigation 1

Initial Results of the Lunar GNSS Receiver Experiment (LuGRE): Joel J. K. Parker, Lauren Konitzer, Nathan Esantsi, Benjamin Ashman, *NASA;* Fabio Dovis, Alex Minetto, Andrea Nardin, Oliviero Vouch, Simone Zocca, *Politecnico di Torino;* Fabio Bernardi, Matilde Boschiero, Samuele Fantinato, Efer Miotti, *Qascom S.r.l.;* Claudia Facchinetti, Mario Musmeci, Giancarlo Varacalli, *Italian Space Agency (ASI)*

Session C3: Positioning Challenges and Solutions for Smartphones and Wearables

Assisted NMA with Secure Time Synchronization on Android Smartphones: Cillian O'Driscoll, *O'Driscoll Consulting Ltd;* Ignacio Fernandez-Hernandez, *European Commission;* Jon Winkel, *Independent Consultant*; Tom Willems, *European Commission Advisor;* Aleix Galan, *KU Leuven*

Session E3a: LEO Satellites for Positioning, Navigation, and Timing

Direction-of-Arrival and Doppler-Based Positioning with Starlink and OneWeb LEO Satellites: Paul El-Kouba, Sharbel Kozhaya, and Zaher M. Kassas, *The Ohio State University*

Session F3: Remote Sensing, Timing, Space and Scientific Applications

Ionospheric and Plasmaspheric Delay Characterization and Migitation Methodologies for Lunar Terrestrial GNSS Receivers: Keidai Iiyama and Grace Gao, *Stanford University*

Session A4b: Aviation, Aeronautics, and Uncrewed Aerial Applications 2

GNSS Spoofing Detection Using Cumulative Vector Sums: Liam Carey and Mathieu Joerger, *Virginia Tech*

Session B4a: Navigation Resilience to Interference and Cyber-Attacks

The OpsGroup Report into GPS Spoofing, One Year on. Where are we Now and Where are we Going?: Ramsey Faragher, Royal Institute of Navigation; Okuary Osechas, *ZHAW;* Mitch Narins, *Strategic Synergies LLC;* Gary McGraw, *Genova Technologies*

Session B4b: Future of Space, Lunar, and Extraterrestrial Navigation 2

Optimal Lunar Rover Navigation with LANS: Leveraging 3D PNT Simulation and Nonlinear Optimization for Enhanced Trajectory Planning: Ricardo Verdeguer Moreno, Ivan Acosta Bayona, *Spirent Communications PLC;* Cesar Enselme, *Oktal-SE*

Session D4: Robust Navigation Using Alternative Navigation Sensors and Solutions

Computational Aspects of Underwater and Underground Navigation using Muons: Jaron Samson, Marnix F.L. Meersman, and Jose A. Garcia Molina, *European Space Agency*

Session F4: Atmospheric Effects on GNSS and LEO-PNT Systems

A Stochastic Modeling Approach for Phase Transition-Induced Errors in GBAS under Ionospheric Scintillation: Andrew K. Sun, Jiyun Lee, *Korea Advanced Institute of Science and Technology;* Sam Pullen, *Stanford University;* Maria Caamano, *German Aerospace Center (DLR)*

Session B5: Design and Optimizing Signal for the Future

Impact of Replica Matching on Distortion-Optimized Multilevel Coded Spreading Signals: Florian C. Beck, *German Aerospace Center (DLR) & RWTH Aachen University;* Christoph Enneking, *DLR;* Steffen Thölert, and Michael Meurer, *DLR & RWTH Aachen University*

Session C5: Integrating LEO for Enhanced Positioning

Unified Navigation and Communication Hybrid Terminal: Enrique Domínguez, Francisco José Mata, Freddy Albert Pinto, Marcelo Meneses, David García, Javier Fidalgo, *GMV;* Domenico Giustiniano, Giuseppe Santaromita, Timothy Otim, Francesco Pigato, *IMDEA;* José A. López-Salcedo, Gonzalo Seco-Granados, Fran Fabra, Antoni Reus, Marc Fernández, *UAB*

Session D5: Navigation in Dynamic Environments

Autocalibration of Camera Extrinsics Using Aircraft Approach and Landing Imagery: Asta Wu, Hayes Edwards, and Grace Gao, *Stanford University*

Session E5: Accurate Navigation in GNSS Challenging Environments 2

Mitigating Single Source Partial Spoofing by Applying Outlier Detection to a Two Antenna Baseline Spoofing Detector: Michael Blois, *University of Calgary;* John Studenny, *CMC Electronics;* Kyle O'Keefe, *University of Calgary*

Session C6: Open-Source Data and Tools for GNSS Research and Development

INSTINCT - Flow-Based Programming Replaces Hard-Coded Navigation Solutions: Thomas Hobiger, Thomas Topp, Doris Becker, and Marcel Maier, *Institute of Navigation, University of Stuttgart*

Session D6: Alternative Technologies for GNSS-Denied Environments – Optical Approaches

Distributional Robustness of Learned Features for 3D Map Localization: Daniel Neamati, Adam Dai, Mira Partha, *Stanford University;* Lance Legel, *Ecodash.ai and 3co.ai*; and Grace Gao, *Stanford University*

Session E6: Advanced Processing of Terrestrial and Non-Terrestrial Signals of Opportunity

Demonstration of Cognitive Navigation with Terrestrial Digital Television, LTE, and 5G Signals of Opportunity: Shaghayegh Shahcheraghi and Zaher M. Kassas, *The Ohio State University*

Session F6: Beyond GNSS: Emerging Trends in LEO-Based and Terrestrial Signals of Opportunity for PNT

Use Cases, System-Level Approaches, and Achievable Performance of Fused PNT with NTN in FR2 and FR3: Ivan Lapin, Samuele Larese, Tommaso Panicciari, Rui Sarnadas, Václav Valenta, Florin-Catalin Grec, Felix Abel, Jose Antonio Garcia Molina, Lionel Ries, Roberto Prieto-Cerdeira, *European Space Agency*

Advice to Younger Engineers; How to Attend a Conference, and Why

Logan Scott
GNSS/GPS Expert

I attended my first Institute of Navigation (ION) conference in 1983. It was held in Anaheim, CA during the week leading up to Super Bowl XVII. This was the conference where all of us were mistaken for reporters and invited to a press conference featuring John Madden, Roone Arlidge, Pat Summerall, and numerous other sports luminaries of the day. We all went. We asked a lot of questions. We ate all their snacks. At the end, Roone Arlidge thanked us all for attending and said it was the best turnout he'd ever seen from the press for one of these pregame meetings. The mistake? We were all staying at the press hotel so there was an assumption that anyone staying there was press. Invitations were slipped under the door to our rooms the night before. Cool, we're invited, let's go!

That early experience taught me that unexpected opportunities happen when you show up, you must be present to win. Since then, I've attended many more conferences. Here are a few thoughts on how to get the most out of them.

Be there. Conference settings are an opportunity to network and share ideas and insights. Talk with people, introduce yourself, jump in. Have lunch with strangers, you'll be amazed at some of the people you meet. Over time, you can develop a network of world class experts who can answer difficult questions. Put off those e-mails and work tasks that can be left for later.

Look at the toys. Vendors like to talk about what they are doing. Often, the people manning the booth are senior engineers with many years of real-world experience. You can learn a lot talking with them. I usually spend 2 or 3 hours talking with vendors during less busy times, e.g., during presentations. When I see something interesting, I make sure to bring over colleagues to take a look. Connecting people is important and satisfying.

Be selective. Don't try and see all the papers. Instead, choose sessions and papers based on who is talking or your interest in the topic. Try some topics you know nothing about. You can read the more technical papers afterwards.

Give a presentation. Being able to communicate effectively is an incredibly important career skill. Having a great idea is not enough. You must be able to convey your vision to others from diverse backgrounds. Not just engineers. Public speaking is one of the best ways to gain this skill. With practice you develop confidence. Watch other people's speaking style. What works, what doesn't. Succinctness is important. My mantra when preparing a talk is "Less is More"

Many organizations, especially industry and government, make the mistake of not sending their people to conferences, thinking them a waste of resources. They question how attendance contributes to the bottom line or how it promotes mission objectives. This perspective ignores the importance of serendipity and collaboration in invention. Alexander Fleming wasn't looking to invent penicillin in 1928, and in fact it wasn't until 1938 that Florey and Chain's collaboration turned a laboratory curiosity into the world's first effective antibiotic.

In a closed culture, the spectrum of ideas is smaller and there is less opportunity for transformative collisions. So, if you get the chance to attend a conference, go. Be there. Talk to people. You never know which conversation will spark your career.

Author Acknowledgement: Thanks to Ramsey Faragher for getting me thinking on this topic.

Resilient Navigation and Timing Foundation

PNT Leadership Summit Held to Develop Recommendations

"How do we protect America's GPS and PNT?" was the question of the day at a PNT Leadership Summit sponsored by the Resilient Navigation and Timing Foundation and Inside GNSS in Baltimore on the 9th of September.

More than 100 GNSS and PNT professionals from the United States, United Kingdom, and Europe gathered to discuss a wide variety of issues from threats and solutions to governance.

And while there were a number of short presentations, the focus of the event was gathering the expertise and experience of attendees to help answer the question about protecting GPS and PNT.

The day began with short introductory remarks by the Hon. Steven Bradbury, Deputy Secretary of Transportation, and the Hon. David Norquist, former Deputy Secretary of Defense. The deputy secretaries of Transportation and Defense co-chair the National Space-based PNT Executive Committee, which is responsible for national coordination and policy.

ADM Thad Allen, USCG (ret), the most recent Chair of the National Space-based PNT Advisory Board, also helped kick off the meeting with his observations on the summit's theme.

The first morning session included a short update from Prof. Todd Humphreys, University of Texas at Austin, on space-based interference with L1 signals, and a brief "Report from the Frontlines of Jamming and Spoofing" by Locata's Nunzio Gambale.

Dr. Brad Parkinson then introduced sessions on "Protecting GPS Signals," "Toughening Signals and Receivers," and "Augment/Alternative Systems." Parkinson's remarks followed closely his comments and observations recently published by Inside GNSS (see: https://insidegnss.com/the-path-to-assured-pnt-a-framework-for-national-leadership/ for the full article). Speakers at the sessions included representatives from the U.S. Space Force, the Department of Transportation, the Royal Institute of Navigation, and the European Space Agency.

Two afternoon sessions discussed governance. Dr. Scott Pace from George Washington University's Space Policy Institute, a representative from the United Kingdom's National PNT Office, and former and current congressional staff were among the speakers.

Following each presentation, attendees were given the opportunity to ask questions and were themselves asked questions. A web tool which attendees accessed with their mobile devices posed a series of questions on each topic.

Richard Fischer, co-host of the PNT Leadership Summit and Publisher of Inside GNSS magazine, addressing the audience.
RNT Foundation

It also provided the opportunity for unstructured comments and observations.

"Our goal was to harness the extraordinary expertise in the room and channel it into meaningful dialogue," said Richard Fischer, co-host and publisher of Inside GNSS. "The brief presentations provided valuable context, but their real purpose was to spark discussion and surface insights that can guide future PNT policy and practice."

Attendees were also given the opportunity to provide additional responses to questions and offer more feedback for two weeks after the event.

"Our goal was to keep the public discussion of important PNT issues going and gather the group's wisdom," said co-host and President of the RNT Foundation, Dana A. Goward. "Once we collate all the comments and feedback on various issues, we expect to have some powerful recommendations for government, device manufacturers, and PNT users."

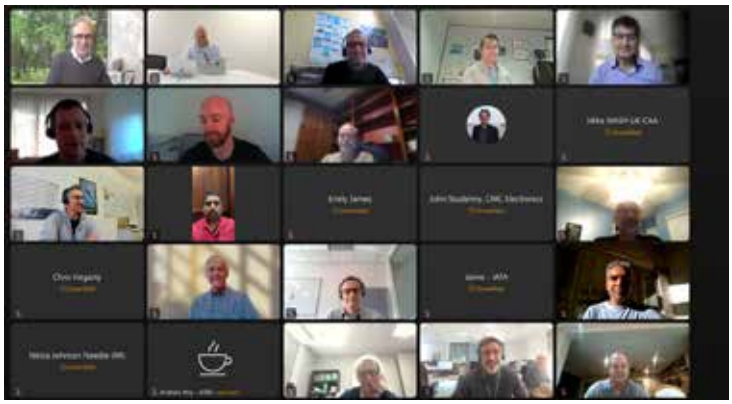
The event was held under Chatham House rules, meaning that attendees were free to discuss things that were said at the summit, but not attribute comments to any individual or organization.

The November/December issue of Inside GNSS presented the proceedings, capturing the full depth of perspectives and recommendations that emerged from the summit.


PNT 2026
POSITIONING, NAVIGATION & TIMING
4-6 February 2026
Royal Randwick Racecourse,
Sydney NSW
Organised by IGNSS and AIN
IGNSS


ENC
EUROPEAN
NAVIGATION
CONFERENCE
2026
SAVE THE DATE:
28 - 30 April 2026
VIENNA | AUSTRIA
European Navigation Conference 2026
> Gain insights
> Grow your network
> Foster new collaborations
enc-series.org
Sign up via the QR code above to receive regular updates by email and follow us on LinkedIn

MITRE Corporation: Dr. Joseph J. Rushanan (left) Dr. Keith McDonald (right)



GNSS Resilience Virtual Seminar, hosted by EUROCAE

Prof. Kai-Wei Chiang from NCKU delivered a lecture to the Geomatics Engineering University of Calgary Schulich School of Engineering, University of Calgary

Interdepartmental- The University of Alabama Civil, Construction and Environmental Engineering and Department of Aerospace Engineering and Mechanics at The University of Alabama, organized by Dr. Thejesh N. Bandi

Syntony GNSS – Toulouse, France

UNB Geodesy & Geomatics Engineering - New Brunswick, Canada (Dr. Richard Langley)

NavSAS – Politecnico di Torino university in Turin, Italy

ESA Navigation - Photo expo highlighting important moments in the history of European satellite navigation in Noordwijk, the Netherlands.

Fraunhofer IIS in Erlangen, Germany

*The **ION Dayton Section** Celebrated International GNSS Day by organizing a trivia game social in lieu of their usual monthly meetings. Approximately 50 people attended this event – mainly from the Dayton area.*
The event started with the cutting of the International GNSS Day cake by Prof. Frank Van Graas (AFIT/ANT Center) at precisely 10:23:00. Immediately afterwards the group transitioned to the International GNSS Day Trivia Game. The gathering was split into two teams of 15 people each. One team named themselves "0x3ff" (the hexadecimal representation of the number 1023) and the other team named themselves "Gold Codes" (the family of pseudorandom noise sequences used in legacy GPS C/A and P signal structures). Each team had to form a list of individuals that will face off with the other team with the knowledge that the trivia questions got progressively more difficult. Team Gold Codes was ultimately presented with the International GNSS Day Trophy. Attendees enjoyed the commemorating International GNSS Day with friends and colleagues. The Dayton Section is planning to make this a recurring annual event.

Unveiling Starlink for PNT

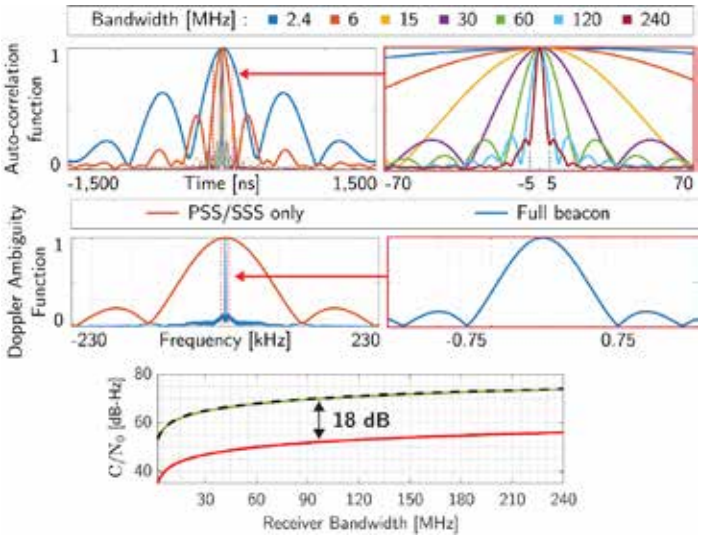
Sharbel Kozhaya, Joe Saroufim, and Zaher (Zak) M. Kassas

The Autonomous Systems Perception, Intelligence, & Navigation (ASPIN) Laboratory, led by Prof. Zak Kassas, at The Ohio State University is building a new PNT receiver utilizing Starlink. The new tech utilizes orthogonal frequency-division multiplexing (OFDM) beacon technology (similar to GPS pseudorandom noise (PRN) sequences) in Starlink's Ku-band downlink signals to:

- achieve enhanced pseudorange estimation resolution (down to nanosecond-level precision);
- improve Doppler estimation resolution (down to Hertz-level precision); and
- increase processing gain (up to 18 dB compared to current state-of-the-art methods for exploiting Starlink downlink signals).

These advantages enable receivers equipped with commercial-off-the-shelf (COTS) low-gain reception setups to acquire and track multiple overhead Starlink satellites simultaneously, unlocking the potential to use the Starlink internet mega constellation for positioning, navigation, and timing (PNT) purposes.

The *NAVIGATION* paper, Unveiling Starlink for PNT, revealed the full Starlink OFDM beacon and showed that the so-called primary synchronization sequence (PSS) and secondary synchronization sequence (SSS) for Starlink that has been published in the literature comprise less than 1% of the full Starlink OFDM beacon. The paper presented extensive experimental datasets, collected from 2021 through 2024 across multiple locations (Irvine, CA and Columbus, OH, USA). The *NAVIGATION* paper's most recent experiment in July 2024 (in Columbus, OH) involved a stationary receiver configured to capture 8 Ku-band downlink channels using a low-noise block downconverter with feedhorn (LNBF) antenna. The data were collected over a 10-minute duration at a recording bandwidth of 2.5 MHz. The receiver successfully acquired and tracked 63 unique overhead Starlink satellites, with an average of 3 satellites tracked simultaneously at any given time. The receiver's generated Doppler frequency shift, pseudorange, and carrier phase observables from these satellites showed that:



Achieved performance with published PSS/SSS vs. the NAVIGATION paper full Starlink OFDM beacon. Top – Left: Autocorrelation function of Starlink OFDM beacon vs. bandwidth. Right: Zoom on the center segment of the autocorrelation function. Middle – Left: Doppler ambiguity function of the PSS/SSS vs. full OFDM beacon. Right: Zoom on the center segment of the Doppler ambiguity function. Bottom – Maximum achievable carrier-to-noise ratio (C/N0) vs. receiver bandwidth when correlating against received OFDM signals from a Starlink satellite using a typical LNBF. Dashed black: theoretical maximum. Solid green: using the full OFDM beacon. Solid red: using the PSS/SSS.

Clockwise: Joe Saroufim, Samer Hayek, Paul El-Kouba, and Prof. Zak Kassas at the rooftop of the ASPIN Laboratory at The Ohio State University testing the setup for stationary receiver localization with multi-constellation LEO signals.

a. Pseudorange measurements from Starlink are affected by artifacts due to their communication-focused system design, rendering standalone pseudorange-based PNT with Starlink unachievable without additional processing.
b. The Doppler shift measurements are sufficiently adequate to yield an accurate positioning solution.

3. Having an average of three trackable overhead satellites promise the ability to obtain a snapshot positioning solution. A positioning solution with a 3D position estimation error of 2 m can be achieved in 20 s, starting from a rather poor initial position estimate (initial error on the order of hundreds of kilometers).

After the *NAVIGATION* paper was published, the approach was tested in several locations around the U.S. and on a variety of size, weight, power, and cost

(SWaP-C)-constrained platforms: St. Louis, MO (stationary localization) [1]; Pittsburgh, PA (ground vehicle navigation) [2]; Albuquerque, NM (extremely high-altitude balloon navigation) [3]; and Columbus, OH (uncrewed aerial vehicle (UAV) navigation) [4]. The approach was also used to navigate a vessel in the Arctic, the results of which were recently presented at the 43rd IEEE Military Communications Conference, receiving the IEEE Frederick W. Ellersick Award for the Best Paper in the Unclassified Program [5].

The results in the *NAVIGATION* paper were achieved in an "organic" fashion; the researchers did not collaborate with SpaceX nor had prior knowledge of the Starlink system. To achieve the *NAVIGATION* paper's results, the researchers developed a cognitive receiver that unveiled Starlink's downlink signals on-the-fly without reverse-engineering the signals [6], [7]. The researchers also developed algorithms that compensated for Starlink's ephemeris and timing errors [1], [8].

Utilizing the full OFDM beacon can turn Starlink into a promising alternative PNT source, offering near GPS-like performance. Starlink's communications signals can be a promising alternative PNT source in GNSS-denied environments.

The Starlink receiver received considerable commercialization interest. Patent disclosures for the developed receiver have been filed and the receiver has been licensed and is being transitioned to sponsors.

For the full article and accompanying figures and data, please see: Kozhaya, S., Saroufim, J., & Kassas, Z. M. (2025). Unveiling Starlink for PNT. *NAVIGATION, Journal of the Institute of Navigation,* 72(1). https://doi.org/10.33012/navi.685

[1] Saroufim, J., & Kassas, Z. "Ephemeris and timing error disambiguation enabling precise LEO PNT," *IEEE Transactions on Aerospace and Electronic Systems,* 2025, Vol. 61, no. 3, 6138-6153.

[2] Kassas, Z., Kozhaya, S., & Saroufim, J."Exploiting Starlink LEO for PNT: signal structure and ephemeris

Sharbel Kozhaya and Joe Saroufim building the payload to test the developed approach to navigate a ground vehicle with Starlink LEO signals.

and timing error correction," *Inside GNSS Magazine,* Vol. 20, Issue 4, Aug. 2025, 30-41 (cover article).

[3] Barrett, W., Sanderson, J., Kozhaya, S., Saroufim, J., & Kassas, Z. "Evaluation of Starlink LEO satellite signals for high-altitude platform station opportunistic navigation," *Proc. of IEEE International Conference on Wireless for Space and Extreme Environments,* Dec. 16-18, 2024, Daytona Beach, FL, 100-105.

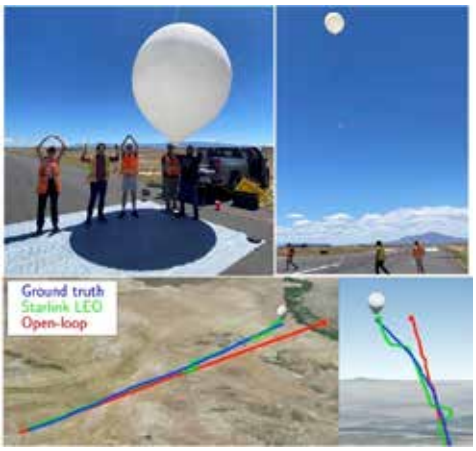
[4] Hayek, S. Saroufim, J., Kozhaya, S., & Kassas, Z."UAV navigation with Starlink," *submitted to the 2026 International Technical Meeting of the Institute of Navigation,* Anaheim, CA.

[5] Barrett, W., Kozhaya, S., Kassas, Z., & Marsh, D."Navigating the Arctic Circle with LEO Satellites," *Proc. of IEEE Military Communications Conference,* Oct. 6-10, 2025, Los Angeles, CA, 919-924.

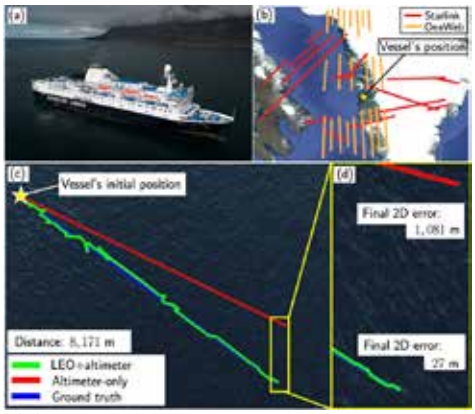
[6] Kozhaya, S. Kanj, H., & Kassas, Z."Multi-constellation blind beacon estimation, Doppler tracking, and opportunistic positioning with OneWeb, Starlink, Iridium NEXT, and Orbcomm LEO satellites," *Proc. of the 2023 IEEE/ION Position, Location, and Navigation Symposium,* Monterey, 1184-1195 (Best student paper award).

[7] Kozhaya, S., Hayek, S., & Kassas, Z."Cognitive beacon estimation of unknown LEO satellites signals of opportunity for PNT," *IEEE Journal on Selected Areas in Communications,* 2025, in press.

[8] Hayek, S., & Kassas, Z. "Modeling and compensation of timing and spatial



Top Left: OHIO and New Mexico! Jennifer Sanderson, Prof. Kassas, Will Barrett, and the ICARUS balloon prior to launch. Right: balloon launched carrying the SWaP-C-constrained payload designed based on the NAVIGATION paper's methodology. Bottom: high-altitude balloon navigation results in New Mexico at an elevation of 82,177 ft. The balloon navigated for 948 m in 50 s. With Doppler observables from five Starlink satellites fused with altimeter data, the position root mean-squared error (RMSE) was 12.3 m compared to 83.3 m with an unaided open-loop [3].



(a) The vessel that navigated in the Arctic. (b) Trajectories of tracked 12 Starlink and 9 OneWeb satellites during the 20-minute-long data collection interval. (c) Vessel's ground truth trajectory (blue), estimated trajectory with the vessel's dynamical model fused with altimeter data (red), and estimated trajectory by fusing measurements from LEO+altimeter (green) over the vessel's 8.17 km trajectory. (d) Zoom on the final errors by altimeter-only (1,081 m) and LEO+altimeter (27 m) [5].

ephemeris errors of non-cooperative LEO satellites with application to PNT," *IEEE Transactions on Aerospace and Electronic Systems,* 2025, Vol. 61, no. 3, pp. 5579-5593.

Navigation: Art or Science?

Marvin B. May

As my readers are aware, I have often disagreed with some of the answers obtained using artificial intelligence apps (for example, see the Historian newsletter article in the Winter 2024 issue). However, most recently I queried the Google artificial intelligence app with the following question: "Is navigation an art, a science, or something else?"

The app's answer was:

"Navigation is widely considered to be both an art and a science, in addition to being a practical skill. The balance between these elements varies depending on the context, such as using ancient celestial techniques versus modern GPS. The artistic element of navigation involves skill, intuition, and creative problem-solving, which are often honed through experience."

In this instance, I agree with the AI app. The beauty associated with navigation, and its history can be seen in many related quotations, often attributed to famous, or infamous, people. Below are some of my favorite quotations:

"Do not go where the path may lead. Go instead where there is no path and leave a trail." Anonymous

"That's among the most important lessons of history–and of life. There is so much around us that might never have happened were it not for a host of qualities called imagination, commitment, courage, creativity, and determination in the face of obstacles–that maybe most of all." David McCullough

"History, Stephen said, is a nightmare from which I am trying to awake." James Joyce, Ulysses

"The woods are lovely, dark and deep. But I have promises to keep. And miles to go before I sleep. And miles to go before I sleep." Robert Frost

"The farther backward you can look, the farther forward you will see." Anonymous

"Navigation is an extremely important aspect of behavior because we navigate to find food, to find shelter, and to escape predators." Ronen Segev (a neuroscientist at Ben-Gurion University of Negev)

"There are no shortcuts to any place worth going." Beverly Sills

"If you don't know where you're going, any road will take you there." Anthony Sepsis and Associates

"If God had been satisfied with inertial systems, he would not have created gravitation." Albert Einstein said to Abraham Pais, *A Tale of Two Continents*

"We are forlorn like children, and experienced like old men, we are crude and sorrowful and superficial—I believe we are lost." Erich Maria Remarque, *All Quiet on the Western Front*

"You can lose your way anywhere." Christine Heppermann, *Poisoned Apples: Poems for You, My Pretty*

"History may not repeat itself, but it sure rhymes closely." Mark Twain

"We need to stop letting history repeat itself over and over." Donald Trump

"And if Amsterdam was hell, and if hell was a memory, then he realized that perhaps there was some purpose to his being lost. Cut off from everything that was familiar to him, unable to discover even a single point of reference, he saw that his steps, by taking him nowhere, were taking him nowhere but himself. He was wandering inside himself, and he was lost. Far from troubling him, this state of being lost became a source of happiness, of exhilaration. He breathed it into his very bones. As if on the brink of some previously hidden knowledge, he breathed it into his very bones and said to himself, almost triumphantly: I am lost." Paul Auster, *The Invention of Solitude*

"You can't depend on your eyes when your imagination is out of focus." Mark Twain

"We are products of our past, but we don't have to be prisoners of it." Rick Warren, *The Purpose Driven Life*

"This issue is clear. It is between light and darkness, and everyone must choose his side" G. K. Chesterton quoted in Dean Koontz's *Relentless*

"Some things were better lost than found." Stephen King, *The Dead Zone*

"I've never been lost, but I was mighty turned around for three days once." Daniel Boone

"How would it be," said Pooh slowly, "if, as soon as we're out of sight of this Pit, we try to find it again?"
"What's the good of that?" said Rabbit.
"Well," said Pooh, "we keep looking for Home and not finding it, so I thought that if we looked for this Pit, we'd be sure not to find it, which would be a Good Thing, because then we might find something that we weren't looking for, which might be just what we were looking for, really."
"I don't see much sense in that," said Rabbit.
"No," said Pooh humbly, "there isn't. But there was going to be when I began it. It's just that something happened to it on the way." A. A. Milne

"If you go looking for love you won't find it because love is never lost; only we are lost." Shannon L. Alder

"Sometimes when you lose your way in the fog, you end up in a beautiful place! Don't be afraid of getting lost!" Mehmet Murat Ildan

"Yesterday, I got lost.
You did too.
So what?
People get lost all the time.
It's just a matter of finding yourself and treasuring that." Maddie Hamplie

"If a man knows not to which port he sails, no wind is favorable." Cicero

"Not all who wander are lost." J.R.R. Tolkien

"We shall not cease from exploration and the end of all our exploring will be to arrive where we started and know the place for the first time." T.S. Eliot

Man cannot discover new oceans unless he has the courage to lose sight of the shore." Andre Gide

"Just because you're lost doesn't mean you can't explore." Clara Bensen

"Travel makes one modest; you see what a tiny place you occupy in the world." Gustave Flaubert

"An explorer cannot stay at home reading maps other men have made." Susanna Clarke

"Exploration is really the essence of the human spirit." Frank Borman

"So much of who we are is where we have been." William Langewiesche

"Half the fun of travel is the aesthetic of lostness." Ray Bradbury

"One's destination is never a place but a new way of seeing things." Henry Miller

"I don't know where I'm going but I'm on my way." Cyclist Magazine

"The principles of inertial navigation, which have been well understood for many years, possess a simplicity and elegance that border on the sublime." Kenneth Britting

Postscript: You may also want to express your appreciation of the beauty of navigation and its history. I have created a Visual Basic app that will add a navigation history quotation to the signature line of your Outlook email. Just write an email to me requesting this app and I will respond with the code, instructions and a compatible file of sample navigation history quotations. You may then also add your own navigation history quotations, and the app will randomly choose from among all the quotations in the file.

Writing of history and navigation, I was requested (or rather coerced) to be the ION Historian in 1996. Previously, I was a technical nerd who rarely saw beyond the horizon of my last equation. I greatly appreciate the opportunity afforded to me over these last 29 years as the ION's first, (and only) to expand my intellectual horizons and hopefully also those of the readers.

"Fair winds and following seas."

Marvin B. May is a Professor Emeritus of navigation, ION Fellow, and ION Historian. His email address is Marvin.may@mayvenengineering.com. or mayven4@comcast.net.

National Security Matters

National Defense Authorization Act for Fiscal Year 2026

Congressional Inaction Continues

Doug Taggart
President
Overlook Systems Technologies, Inc.
and ION Fellow
with
Jules McNeff
VP Strategy and Program

To meet the ION's deadline for this column, I'm drafting this in late October, as Congress continues to neglect its primary responsibility, passing appropriations to keep government functions and programs running.

As of this writing, there is no end in sight.

Regardless of what unfolds in the coming days or weeks, it is nearly certain that any measure to reopen the government will be a short-term continuing resolution (CR), likely composed of one or more omnibus bills, rather than specific appropriations for any of the 12 annual bills that Congress is supposed to enact.

When that future CR expires, we could very well be right back where we are now, at an impasse for funding government operations.

Since the current Congressional budgeting and spending process was established nearly five decades ago, Congress has completed appropriations before the start of the fiscal year (FY) only four times: FY1977 (the first year of the current system), FY1989, FY1995, and FY1997. Given this poor on-time record, it's difficult to have much confidence that appropriations for FY2026 will be in place anytime soon.

FY26 Budgeting Irregularities

Preparing for the FY26 congressional budgeting process began with an unusual twist. On May 2, 2025, the administration released a "skinny" discretionary budget request rather than the traditional full submission typically delivered in early February. This abbreviated request outlined topline discretionary spending levels, including a proposed $163 billion cut to non-defense discretionary spending, but omitted detailed account-level justifications and any proposed changes to mandatory spending or tax policy.

The administration did not release the fuller budget materials, including an appendix with appropriation-level detail, until the end of May, with additional information following later. This delayed and piecemeal approach marked a significant departure from the standard process and made it more difficult for lawmakers, analysts, and the public to fully assess the administration's budget priorities.

National Defense Authorization Act (NDAA)

When compared to the appropriations process, Congress has a somewhat better track record with passing annual authorization bills through the NDAA process.

However, even here, deadlines are rarely met. Since 1977, the NDAA has been delayed by an average of 44 days past the start of the fiscal year.

Thirty days into FY2026, both the House and Senate have passed their respective versions of the NDAA. In early July, the Senate Armed Services Committee completed its markup of the FY2026 NDAA. Shortly thereafter, the House Armed Services Committee (HASC) finalized its own version.

The full House passed its bill, H.R. 3838, titled the *Streamlining Procurement for Effective Execution and Delivery and National Defense Authorization Act for Fiscal Year 2026*, on September 10th. On October 9th, the Senate passed its version, S. 2296, by a bipartisan vote of 77–20. The accompanying report is Senate Report 119-39.

Both chambers must now reconcile their differences in a conference committee. Against that backdrop, the following is a summary of the GPS/PNT-related funding authorizations and reporting requirements included in both bills prior to conference.

GPS/PNT References in the Two Bills

Under the topic of *Precision Artillery Munitions Modernization,* the HASC seeks a briefing from the Secretary of the Army by December 30, 2025, on an assessment to enhance the performance of *Excalibur increment 1b* in GPS-denied environments to include the feasibility of a home-on-jam capability.

Under the topic of *Electronic Warfare Testing and*

Requirements for Group 1-3 Unmanned Aerial Systems and Loitering Munitions, the HASC seeks a briefing from the Secretary of Defense not later than December 1, 2025, on the Department's ability to employ Group 1-3 Unmanned Aerial System (UAS) against adversary Electronic Warfare (EW) systems. The briefing should also include how the Department tests Group 1-3 UAS in realistic EW environments, and what requirements exist for Group 1-3 UAS to enable operations in RF and GPS denied environments.

Under the topic of *Integration of Terrestrial-Based Positioning, Navigation, and Timing Systems for Global Positioning System Denied Environments,* the HASC directs the Secretary of Defense in coordination with the Secretaries of the Army, Navy, and Air Force to provide a brief on the feasibility, operational impact, and cost-effectiveness of integrating terrestrial-based APNT solutions into the Department's PNT architecture.

Under the topic of *Commercial Low Earth Orbit Resilient Positioning, Navigation, and Timing,* the HASC directs the Secretary of the Air Force to provide a report not later than March 1, 2026, on commercial LEO PNT services to operate in the absence of GPS, ability to resist jamming and spoofing in comparison to GPS, the ability to provide timing accuracy less than 10 nanoseconds, and positioning accuracy of less than 30 centimeters.

Under the topic of *Comprehensive Strategy for GPS Capabilities*, the HASC has expressed concern over the lack of a strategic, comprehensive plan from the U.S. Space Force regarding PNT capabilities. In the bill, the committee noted that in 2024 the U.S. Air Force realigned appropriated funds to support an urgent operational development effort known as Resilient GPS (R-GPS). However, the FY2026 budget request did not include funding for R-GPS, nor did it allocate resources for the procurement of any GPS III Follow-On (GPS IIIF) satellites within the program of record. In response, the HASC directed the Secretary of the Air Force to provide a briefing by February 1, 2026, assessing current and future threats to the existing GPS architecture.

In the Senate's NDAA markup, under Section 1544. *Improving United State Missile Defense Capabilities*, there is a requirement to assess the funding needs to accelerate the development and fielding of resilient PNT solutions capable of operating effectively in GPS denied environments. Such solutions may include quantum-enhanced inertial and atomic clock technologies, terrestrial-based systems, radar-based tracking, vision aid navigation, LEO signals, and commercially available PNT systems that leverage advanced sensor fusion, and artificial intelligence-driven error correction.

With respect to authorization recommendations in both the House and Senate NDAAs, the only deviation from the President's Budget Request related to GPS/PNT appears in the House bill, which includes a $15 million plus-up for GPS IIIF.

In total across all DoD appropriations, the House markup recommends $354 million in additional funds compared to the President's budget and the Senate version of the NDAA, bringing the total authorization to $1.085 trillion.

Critical PNT Decisions

The broad range of resource-driven issues, about which the Congress is seeking GPS/PNT information, highlights the many uncertainties facing the national PNT Enterprise as GPS modernization lags while foreign GNSS challenges mount.

The uncertainties affect not only GPS capabilities for the military, but also the development and use of diverse additional sources of PNT information to complement and backup GPS for all national security applications.

Both the Congress and the new administration must come to closure rapidly on continuing modernization of GPS, the fielding of integrated PNT applications to ensure PNT resilience for the Joint Force, and resilient PNT for domestic critical infrastructure operations.

These resourcing activities must go forward for both military and civil users as the Defense Department adopts a posture more directly focused on its warfighting responsibilities.

Marching Forward as the Department of War

A memorandum from the Secretary of War, dated October 10, 2025, and titled *Department of War Secondary Titles,* directs that, effective immediately, designated officials and organizations within the Department of Defense "will use the secondary title, e.g., Under Secretary of War (Policy), etc., for all official actions … where it does not create confusion with respect to legal, statutory, or international obligations."

The memo concludes with a forecast of an action plan to be developed within 45 days, including a legislative proposal to officially rename the Department of Defense as the Department of War in law.

With these developments underway, it is now up to the Congress to determine how future National *Defense* Authorization Acts will be titled. Time will tell.

Ending Comment

For more than 15 years, this column has carried the title Defense Matters based upon the significant influence DoD activities have had on the evolution of the national PNT Enterprise. My contributions consistently reflect that focus and will continue to do so, though it is neither necessary nor appropriate to carry forward the new Department of War naming convention.

For that reason, the column will now be titled ***National Security Matters.*** This new title continues to reflect the influence of GPS and related PNT systems on national military effectiveness, while also recognizing their vital role in our economy and the resilient operation of critical domestic infrastructure.

It underscores the reality that ensuring PNT resilience is not solely a responsibility of the DoD, but a shared imperative across civil departments and agencies as well as from the legislative and, potentially, even judicial branches of our government.

ION's JOURNAL NAVIGATION Spotlights

High Citation *NAVIGATION* Manuscripts Recognized

ION would like to recognize the following papers published in the ION's journal, *NAVIGATION,* that received the greatest number of citations in 2022 and 2023 as calculated as part of the Web of Sciences 2024 Journal Impact Factor report that was published this past summer.

MOST CITATIONS: Published in 2023, Hong Kong UrbanNav: An Open-Source Multisensory Dataset for Benchmarking Urban Navigation Algorithms, authored by Li-Ta Hsu, Feng Huang, Hoi-Fung Ng, Guohao Zhang, Yihan Zhong, Xiwei Bai, and Weisong Wen from The Hong Kong Polytechnic University

Li-Ta Hsu Feng Huang Hoi-Fung Ng Guohao Zhang Yihan Zhong Xiwei Bai, and Weisong Wen

NAVIGATION: Journal of the Institute of Navigation December 2023, 70 (4) navi.602; DOI: https://doi.org/10.33012/navi.602

CLOSE SECOND: Published in 2022, Improving GNSS Positioning Using Neural-Network-Based Corrections, authored by Ashwin V. Kanhere, Shubh Gupta, Akshay Shetty, and Grace Gao from Stanford University

Ashwin V. Kanhere Shubh Gupta Akshay Shetty, and Grace Gao

NAVIGATION: Journal of the Institute of Navigation December 2022, 69 (4) navi.548; DOI: https://doi.org/10.33012/navi.548

The authors of these manuscripts were recognized with a certificate at ION GNSS+ 2025 in Baltimore, Maryland and some ION swag.

Geodetic Altitude from Barometer and Weather Data for GNSS Integrity Monitoring in Aviation

Maximilian Simonetti and Omar García Crespillo

This work proposes a derivation of geodetic altitude from real airborne barometric pressure measurements coupled with global weather data. Second, it proposes an augmentation of GNSS ARAIM with this geodetic altitude, which is referred to as *barometric geodetic altitude.*

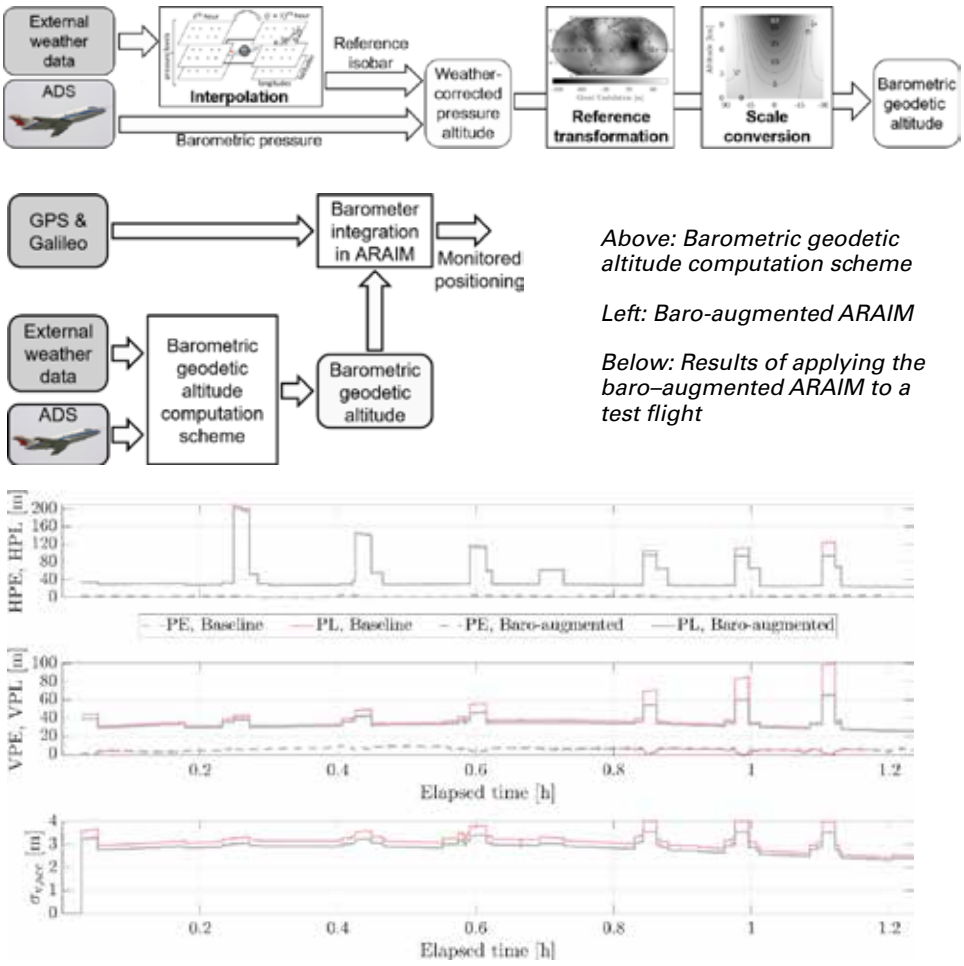
The uniqueness of the solution mainly relies on the unprecedented accuracy of geodetic altitude estimation based on pressure measurements. This is achieved by considering several factors that are not typically considered in the determination of flight levels or barometric altitude determination in the literature. One of these factors is the use of external weather data within our pressure altitude derivation algorithm. We propose an interpolation of existing 4D weather information to the user's location to obtain local estimates of temperature, pressure, and humidity. This defines a local reference surface within the pressure altitude (or hypsometric) equation.

Our solution greatly improves the accuracy of the geometric altitude estimation when compared to traditional pressure altitude computation methods, which employ constant reference surfaces for the sole purpose of enabling vertical separation between aircraft. A second relevant factor is our rigorous conversion of altitude scale and altitude reference, from those of pressure altitude to those of geodetic altitude. A final factor is a model we have derived to mitigate the effects of aircraft dynamics on the airborne pressure measurements.

This work is based on the airborne data gathered during several flight tests performed with the German Aerospace Center's (DLR) Dassault Falcon 20–E5 research jet aircraft. The analyses demonstrate that accurate geodetic altitude can be estimated based on airborne pressure measurements and external weather data. Results also show that the augmentation of GNSS ARAIM with the derived barometric geodetic altitude can enhance integrity, availability and continuity, especially during aircraft maneuvers. Ultimately, the proposed solution may support air traffic management (ATM) or urban air mobility (UAM) applications requiring robust vertical navigation and of significantly improving aircraft-based augmentation systems (ABAS) performances, in particular during maneuvers and final approach.

The methodology is being considered to improve the vertical navigation and relative vertical separation of aircrafts.

Mission preparation of the DLR flight experiments facility in Oberpfaffenhofen.
DLR (CC BY-NC-ND 3.0)



Above: Barometric geodetic altitude computation scheme

Left: Baro-augmented ARAIM

Below: Results of applying the baro–augmented ARAIM to a test flight

The altitude conversions in our method can also support the implementation of a vertical conversion service for U-Space to reach a common reference altitude system in a mixed air-space. Furthermore, in the case of GNSS interruption, the vertical information of our method can support alternative positioning, navigation, and timing (APNT) solutions in combination with terrestrial signals.

The methodology represents a promising concept for future aircraft vertical navigation. The barometric geodetic altitude computation scheme and our derived empirical error models may be employed within stand–alone vertical navigation architectures or within integrated architectures, as our proposed *baro-augmented* GNSS ARAIM, or in further systems featuring also additional technologies, such as APNT systems and/or inertial reference systems.

For the full article and accompanying data and figures, please see: Simonetti, M., & García Crespillo, O. (2024). Geodetic altitude from barometer and weather data for GNSS integrity monitoring in aviation. *NAVIGATION,* 71(2). https://doi.org/10.33012/navi.637

Performance Evaluation of DFMC SBAS Messages Broadcast by the Japanese Quasi-Zenith Satellite System (QZSS) in Oslo, Norway

Toru Takahashi, Susumu Saito, Mitsunori Kitamura, and Takeyasu Sakai

At latitudes above 72 degrees, it is not possible to receive signals from satellite-based augmentation systems (SBAS) deployed in geostationary orbit. This unique study conducted a performance evaluation of dual-frequency multi-constellation (DFMC) SBAS signals broadcast by Japanese Quasi-Zenith Satellite System (QZSS) in Oslo, a high-latitude location, to assess the feasibility of their use in the Arctic region.

The key experiment was the receiving test of DFMC SBAS signals broadcast by QZSS, conducted in Oslo, which lies in a high-latitude region and represents the visibility limit of QZSS. The results of the performance evaluations are significant in that they demonstrate the feasibility of using DFMC SBAS broadcast by QZSS for LPV operations in the Arctic region.

As Arctic sea ice cover continues to decline, aviation, and maritime activities in the Arctic are increasing. Because of the poor infrastructure in the Arctic, the global navigation satellite system (GNSS), which operates with augmentation systems such as the SBAS, provides an efficient solution for navigation in Arctic regions for aviation, maritime, and drilling.

Performance evaluation currently being conducted in Ny-Ålesund, located in the Arctic region where signals from SBAS satellites are completely unavailable. In addition, a DFMC SBAS receiver has been installed on the oceanographic research vessel Mirai, which is operating in the Arctic Ocean, enabling performance evaluations under actual maritime conditions. These efforts allow for both statistical performance evaluation in the Arctic region and assessment of DFMC SBAS performance in a shipboard environment.

In the future, it is expected that equipping aircraft and ships with DFMC SBAS receivers will enable applications such as Arctic sea route exploration, navigation, resource exploration, and drilling—without the need to build new infrastructure.

For the full article and accompanying data and figures, please see: Takahashi, T., Saito, S., Kitamura, M., & Sakai, T. (2025). Performance evaluation of DFMC SBAS messages broadcast by the Japanese Quasi-Zenith Satellite System (QZSS) and received in Oslo, Norway. *NAVIGATION,* 72(2). https://doi.org/10.33012/navi.692

GNSS Program Updates
News from Systems Around the World

Kevin Dennehy

Galileo

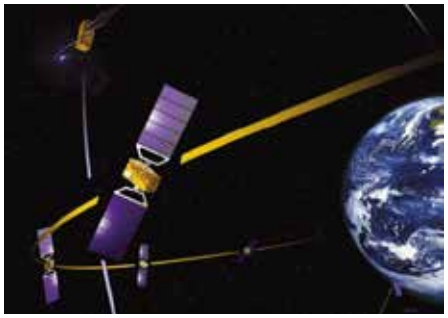
Europe's Galileo constellation, now at 31 satellites with 27 usable, continues expanding services while tackling spoofing and interference, one official said at ION GNSS+ 2025. Eric Chatre, Head of the European Union's GNSS exploitation and evolution, emphasized user focus in the constellation's 30th anniversary year.

"We are broadening the scope of applications for users. User satisfaction hit 86.2 percent in 2024, which is up from 83.8 percent in 2023," he said.

ESA is planning the next Galileo launch in late December 2025 aboard the Ariane 6 rocket. The mission, VA266, will carry a pair of Galileo L14 satellites into medium-Earth orbit.

Chatre praised the constellation's Open Service Navigation Message Authentication (OSNMA), saying it enables GNSS receivers on the market and is the "gold standard."

Chatre mentioned that the Public Regulated Service (PRS), for governmental strategic use, passed resilience tests in May. He said that the EU is close to signing the first PRS agreement with Norway.



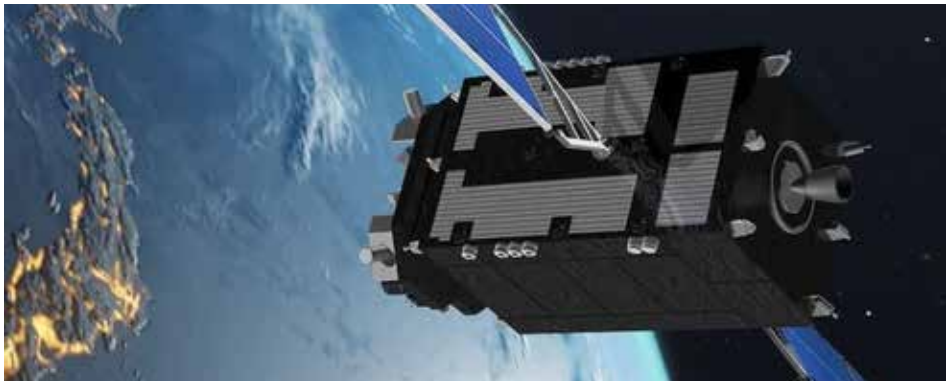
Galileo plans a launch in December 2025.
ESA

GPS

The U.S. GPS constellation remains robust with 31 operational satellites, but one official warned of thinning reserves as older blocks age, prompting accelerated replenishment and ground system upgrades. Dr. Christopher Erickson, Chief of PNT and Spectrum in the Air Force Assistant Secretary for Space Acquisition and Integration office, said while the current status exceeds the baseline of 24 satellites, the system "operators are younger than average age of our satellites."

Block IIR satellites average 23.6 to 27.9 years old, with five remaining; IIR-M units, seven in orbit, clock in at 17.7 to 19.8 years; 11 GPS IIF satellites average 11.5 to 15.1 years; and eight GPS III units are just 3.7 to 6.5 years old.

Erickson said that the troubled GPS OCX ground control program, while delivered in July by contractor RTX to the U.S. Space Force's Mission Delta 31, still will go through a series of stringent tests that will run through 2026. "We are in the process of vetting all of the work the contractors have done. We are going line-by-line, page-by-page," he said. "Once the whole system has been transferred to the ground system—we will have one final round of tests. Expect next year to hear from us about the timelines for the process."



Japan is planning for an 11-satellite QZSS constellation.
Cabinet Office, Government of Japan

QZSS

Japan's Quasi-Zenith Satellite System (QZSS) now operates five satellites plus one, with seven expected by 2026—and plans for 11 next-generation units, said Motohisa Kishimoto, Senior Coordinator, QZSS strategy office, National Space Policy Secretariat.

Kishimoto reported that QZS-6, launched February 2025 via an H3 rocket, has been healthy since July 18. The remaining satellites, QZS-5 and -7, are near system-level testing completion, launching in fiscal 2025, he said.

The constellation features one GEO (QZS-3) and three QZO IGSO satellites for Asia-Pacific. The constellation's ground system was completed in August 2023 for seven satellites, including master controls at Hitachi-Ota and Kobe, 10 tracking stations in southwestern (Japanese) islands, and 30 worldwide monitors.

KPS

South Korea's Korean Positioning System (KPS) is progressing to preliminary design review by year-end, targeting a first satellite launch in 2029 and initial operations in 2030, said Dr. Byoung-Sun Lee, KPS Program Director at Korea AeroSpace Administration (KASA), who noted the 14-year Phase 1 development since 2022.

"It's a long time. Galileo took 30 years," he said. "Phase 1 has one satellite in 2029 (launched), a ground segment by 2030—and Phase 2 adds seven more."

Kevin Dennehy has been writing about GNSS for 30 years. He is editor of Location Business News, https://locationbusinessnews.com. If your company has an idea for a business story, please contact: kdennehy@locationbusinessnews.com.

The Business of GNSS

Kevin Dennehy

In the biggest GNSS news since our last update, ION members **Leonardo, Airbus** and **Thales** have signed a memorandum of understanding (MoU) to merge their space activities. According to the companies, and after clearing regulatory hurdles, the merged business would be operational by 2027, employ 25,000 people and generate revenue of $7.53 billion.

The planned unnamed entity would combine assets in satellite infrastructure, navigation and space-based services — a move directly tied to efforts around systems such as the Galileo and Europe's broader positioning, navigation, and timing (PNT) goals.

In other business news, ION member **Topcon Positioning Systems** has launched a dedicated Geomatics Sales Unit to deliver high-precision hardware, software, and services under a unified business structure focused on geospatial and surveying workflows. The new unit will be headed by industry veteran Neil Vancans.

The **U.S. Department of Transportation** has awarded a contract to ION member **Iridium Communications** through its Complementary Positioning, Navigation, and Timing (CPNT) Action Plan to deploy PNT services nationwide.

ION members **Septentrio** and **Xona Space Systems** have signed an MoU to deepen their collaboration on next-generation positioning and timing solutions. Septentrio also announced it has begun volume production and shipment of its mosaic-G5 GNSS receiver modules.

Advanced Navigation's new Boreas D50.
Advanced Navigation

ION member **Advanced Navigation** has launched a new line of inertial navigation systems (INS) designed to safeguard missions against GNSS jamming and spoofing. The new EP range includes the Boreas D Series — with D50, D70, and D90 models and Certus Evo, which are tailored to defense markets, the company said.

ION member **u-blox** has launched the UBX-M10150-KB chip and the MAX-M10N module, the first entries in its M10 platform designed for firmware upgrades and ultra-low power consumption, the company said. The company also launched the ANN-MB3, a triple-band (L1/L2/L5) RTK antenna optimized for its F20 platform and compatible with F9 receivers.

U-blox's UBX-M10150-KB chip and the MAX-M10N module.
U-blox

The **Defense Advanced Research Projects Agency** announced that it awarded ION Member **Safran Federal Systems** a contract to develop "robust and reliable" quantum sensors to improve the US military's PNT architecture in multiple domains, including space. In other company news, and displayed at ION GNSS+ 2025, Safran's Skydel GNSS simulation software, which supports Xona's **Pulsar** signals, allows developers to test low-Earth orbit (LEO) PNT.

Another company, **StarNav,** displayed its SNDR-X multi-channel receiver that demonstrates real-time acquisition and tracking in a PNT solution.

ION member **NextNav** said it has closed its agreement to acquire 128 active M-LMS A-block licenses from Telesaurus Holdings and Skybridge Spectrum Foundation, bolstering its spectrum holdings in the lower 900 MHz band.

StarNav's Joshua Morales and Kathryn Hammar display the company's SNDR-X receiver at the Safran booth at ION GNSS+ 2025.
Kevin Dennehy

ION members **JAVAD GNSS** and **ProStar** have announced a bundled utility mapping solution combining JAVAD's GNSS receivers with ProStar's PointMan for utility, construction, and surveying applications.

Kevin Dennehy has been writing about GNSS for 30 years. He is editor of Location Business News, https://locationbusinessnews.com. If your company has an idea for a business story, please contact: kdennehy@locationbusinessnews.com.

ION Fellow Wins RIN's Harold Spencer-Jones Medal

RIN President, Professor Washington Yotto Ochieng, presenting the Harold Spencer-Jones Medal to ION Fellow, Professor Todd Humphreys

ION Fellow, Professor Todd Humphreys, was awarded the Royal Institute of Navigation's (RIN) Harold Spencer-Jones Medal on June 19, 2025 at the RIN's Annual General Meeting, held at the Royal Geographical Society, London. The award was presented by RIN President, Professor Washington Yotto Ochieng in recognition of world-leading research into global GNSS threats, and pioneering improvements to the resilience of positioning, navigation, and timing systems. The Harold Spencer-Jones Medal is the highest honor awarded by RIN.

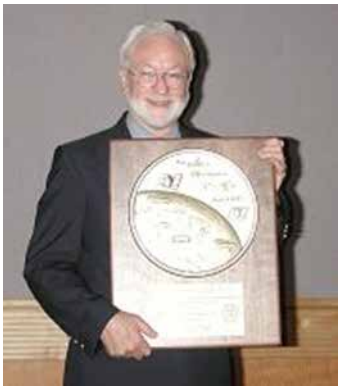
Professor Humphreys presenting at the Royal Geographical Society, London (June 2025).

"The first time I was invited to the UK for a Royal Institute of Navigation event back in 2012, I was struck by the technical caliber and camaraderie among RIN members. Since then, I've forged strong ties and friendships with RIN members, whom I hold in high regard. It was thus a special honor to be awarded the RIN's highest accolade this year and to be named among Harold Spencer-Jones Gold Medalists," said Professor Humphreys.

In Memoriam

Thomas A. Stansell, ION Fellow and past Kepler, and Weems Award winner, passed away on September 17, 2025 in Rancho Palos Verdes, California. He was 90 years old.

Mr. Stansell was a pioneer of satellite navigation, recognized for development and commercialization of Transit and GPS User Equipment. Tom began his career in 1960 when he joined the Johns Hopkins University Applied Physics Laboratory where he was assigned to the Navy Navigation Satellite System development program. In the 1980's he led the transition of Magnavox's commercial satellite navigation and positioning technologies and products from Transit to GPS. Among others, this included the first truly portable GPS survey products, the first semi-codeless tracking of L2, and the first all-digital GPS receiver architecture. He led Magnavox (and later Leica's) development of miniature GPS survey receivers, pioneered precise and real time GPS control of earthmoving machinery, and received patents for multipath mitigation techniques. He was a designer of satnav receivers; and the first to deliver the first fully functional, multichannel GLONASS receivers. He played a key role



and contributed crucial ideas to the design of L5, L2C and M-code signals.

Tom was well known in the ION leadership and technical community. He served as a former ION GPS Meeting Program and General Chair, was an ION Fellow (1999), Weems Award (1995), a Kepler Award winner (2003), winner a USAF GPS Navstar Award (2002), and received numerous other industry awards. He is remembered for his positivity and energy.

Calendar of Upcoming Events

JANUARY 2026

26-29: ION International Technical Meeting (ITM) & ION Precise Time and Time Interval (PTTI) Meeting 2026, Hyatt Regency Orange County, Anaheim, California
ion.org

FEBRUARY 2026

4-6: PNT2026, Royal Randwick Racecourse, Sydney NSW, Australia
ignss.org.au/pnt-2026

MARCH 2026

23-27: Munich Space Summit, Alte Kongresshalle, Munich, Germany
The Munich Space Summit – launching March 23–27, 2026 – merges two of Munich's most recognized space events into one powerful platform: the Munich Satellite Navigation Summit and the Munich New Space Summit.
https://www.munich-space-summit.org/

APRIL 2026

13-16: ION Pacific PNT Meeting, Hilton Waikiki Beach, Honolulu, Oahu, Hawaii
ion.org

20-21: Civil GPS Service Interface Committee (CGSIC), DOT Headquarters, Washington, DC
GPS.gov

28-30: European Navigation Conference (ENC) 2026, Vienna, Austria
enc-series.org

JUNE 2026

1-4: ION Joint Navigation Conference (JNC) 2026, Northern Kentucky Convention Center, Greater Cincinnati Ohio Area
ion.org

SEPTEMBER 2026

14-18: ION GNSS+ 2026, Hyatt Regency Grand Cypress, Orlando, Florida
ion.org

JANUARY 2027

25-28: ION International Technical Meeting (ITM) & ION Precise Time and Time Interval (PTTI) Systems and Applications Meeting 2027, Hyatt Regency Orange County, Anaheim, California
ion.org

ION
INSTITUTE OF NAVIGATION
8551 Rixlew Lane, Suite 360
Manassas, VA 20109-3701

Nonprofit Org.
U.S. Postage
PAID
Permit No. 425
Southern, MD