ION GNSS+2024

GNSS + Other Sensors in Today's Marketplace

SEPTEMBER 16-20, 2024

TECHNICAL COMMITTEE

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Plenary Session Chair
Dr. Dorota Grejner-Brzezinska, *The Ohio State University*

ABSTRACT SUBMISSION REQUIREMENTS

To submit an abstract, sign into the ION Abstract Management Portal (AMP) at ion.org/abstracts. If you have not used AMP before, click "Create My Account." Once signed in, click on "ION GNSS+" and complete the form.

Authors will be given the option at the point of abstract submission to submit for either :

1) In-person presentation in Baltimore, with pre-recorded video presentation for on-demand viewers; or
2) On-demand, pre-recorded presentation video only. **No live-stream remote presentation option will be offered.**

A technical paper will be required for all abstracts submitted to the Research Tracks, regardless of in-person/on-demand only presentation status. Technical papers are optional for abstracts submitted to the Commercial Tracks.

All abstracts should be submitted electronically via AMP no later than March 1.

Content: Acceptance to the ION GNSS+ conference is competitive. Extended abstracts (500-2500 words) are required. Abstracts should describe objectives, anticipated or actual results, conclusions, key innovative steps, and the significance of your work.

Acceptance: Speakers will be notified of acceptance after April 24 and will be provided with an electronic presentation kit with presentation and publication guidelines.

Peer Review Option/Research Track Only: Authors whose abstracts are accepted in sessions in the Research Tracks (either as a primary, an alternate, or as an on-demand pre-recorded presentation) will have the option to have their paper peer reviewed. Peer reviews will be accomplished by a minimum of two qualified reviewers, and supervised by a committee. To be designated as peer reviewed the completed manuscript must be uploaded to AMP by June 30; the manuscript must pass the initial peer review (there will be no secondary reviews); and one of the authors must be present at the conference and prepared to present the paper if accepted to the in-person program, or the author must be registered for the on-demand conference if presenting on-demand. While final manuscripts are required for peer-review by June 30, corrected/updated manuscripts will be accepted through September 27.

Author Presentation Requirements:
1) **A pre-recorded video presentation will be required of all presenters.** The pre-recorded video presentation and Media Authorization License Form, must be submitted to AMP by September 6 to be eligible for ION Best Presentation Awards.
2) All authors, whether presenting in-person or via on-demand pre-recorded video presentation **must** pay registration fees.
3) Authors presenting as part of the in-person program (both primary and alternate) are required to attend the Speakers' Breakfast the morning of their presentation. Failure to meet any of these requirements may result in the cancellation of your paper from the program.

Proceedings Publication: Papers meeting all the peer review requirements will be designated as "peer reviewed" in the technical conference proceedings. Papers not meeting the peer review requirements will be published in the conference proceedings without the peer reviewed designation. Manuscripts not representative of the original abstract submitted, or manuscripts not presented for any reason, will NOT be included in the conference proceedings. Presentations (typically the slides used for presentation) submitted through AMP by September 27 will be included in the supplemental material that accompanies the conference proceedings provided to registrants (optional for Research Tracks when full papers are provided; required for the Commercial Tracks when a paper has not been provided). All manuscripts must be uploaded to AMP by September 27 to be included in the conference proceedings and/or supplemental material provided to conference participants.

CONFERENCE INFORMATION

September 16-20, 2024
Short Courses: Sept. 16 • Tutorials: Sept. 17 • Exhibit Hall: Sept. 18-19

CONFERENCE LOCATION

All ION GNSS+ conference functions will take place at the Hilton Baltimore Inner Harbor, located at 401 W Pratt St, Baltimore, Maryland 21201

REGISTRATION INFORMATION

Full registration includes access to technical sessions, the exhibit hall, conference meal functions and events, on-demand conference content, and conference proceedings. Individual registration benefits are non-transferable. **Register online at ion.org/gnss begining in Summer 2024**.

REGISTRATION RATES	In-Person*		On-Demand Access Only	
	On/Before Aug. 16	After Aug. 16	On/Before Aug. 16	After Aug. 16
Full, ION Member	$1,100	$1,300	$699	$899
Full, Non-Member	$1,180	$1,380	$779	$979
Single Day	$600	$700	N/A	N/A
Student	$700	$800	$499	$699

***For attendees staying at an official conference hotel, and claiming hotel discount. If not staying in at the Hilton Baltimore Inner Harbor, add $300 to the above regsitrarion fees.**

HOTEL RESERVATIONS

For hotel rates and reservations, go to ion.org/gnss/hotel.cfm. Click the "reserve now" button and follow the directions to reserve your room. You will receive an immediate online confirmation. **Remember to make your hotel reservation (and provide your hotel confirmation number when registering) by August 16 to get the discounted ION GNSS+ conference rates!**

EXHIBITOR INFORMATION

The ION GNSS+ conference is the largest GNSS-related trade show in the world! For exhibit information, email mandrews@ion.org. You can also visit ion.org/gnss.

INTERNATIONAL PARTICIPANTS

We recommend that you apply for a visa at least three months in advance. Travelers from all visa waiver program countries must present either a machine-readable passport or a U.S. visa. For general information about visas go to http://www.nationalacademies.org/visas/
Conference attendees requesting a visa letter to attend a conference must:
1) Submit the visa letter request form located at ion.org/gnss; and
2) Register and pay the conference registration fees before a letter of invitation will be sent.
Exemptions to this policy apply only to those authors whose papers have been accepted for presentation, company personnel working in the exhibit area or trade associated press.

STUDENT PAPER AWARDS

Student paper awards will be awarded on a competitive basis. Papers submitted by February 1 will be reviewed for technical content, clarity, and presentation by a selection committee. The primary student author of each paper selected for presentation will receive a travel expense stipend (payable by check, in U.S. dollars, drawn on a U.S. bank), conference registration and publication of the selected paper in the ION GNSS+ proceedings. For information on eligibility and deadlines, please visit ion.org/governance/student-paper-awards.cfm

JOURNAL PUBLICATION

Outstanding technical papers are reviewed for possible publication in the ION's open access archival journal, *NAVIGATION: Journal of the Institute of Navigation*. *NAVIGATION* is indexed and abstracted in the Advanced Technologies & Aerospace Database (ProQuest), COMPENDEX (Elsevier), Current Contents: Engineering, Computing & Technology (Clarivate Analytics), Earth, Atmospheric & Aquatic Science Database (ProQuest), Electrical & Electronics Abstracts (IET), Google Scholar, Inspec (IET), Materials Science & Engineering Database (ProQuest), Natural Science Collection (ProQuest), Science Citation Index Expanded (Clarivate Analytics), SciTech Premium Collection (ProQuest), SCOPUS (Elsevier), Technology Collection (ProQuest), and Web of Science (Clarivate Analytics). As of 2021, it has a 2.472 Journal Impact Factor (JIF). For more information, visit www.ion.org/publications/arc.cfm.

For updated conference information, see ion.org/gnss

THE INSTITUTE OF NAVIGATION
8551 Rixlew Lane, Suite 360
Manassas, Virginia 20109

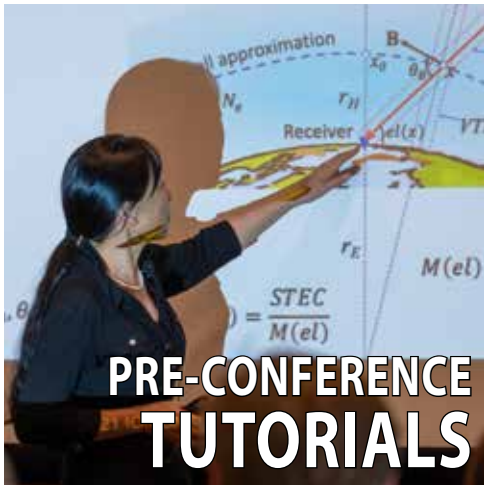
ION GNSS+ 2024

GNSS + Other Sensors in Today's Marketplace

Abstracts Due March 1

ION GNSS+ 2024

The 37th International Technical Meeting of the Satellite Division of the Institute of Navigation



IN-PERSON and ON-DEMAND


ION
INSTITUTE OF NAVIGATION
ION GNSS+
September 16-20, 2024
Exhibit Hall: September 18 and 19
Hilton Baltimore Inner Harbor
Baltimore, Maryland
2024
ION GNSS+
CALL FOR ABSTRACTS
Abstracts Due March 1, 2024
ion.org/gnss

COMMERCIAL AND POLICY TRACKS: Program Co-chair: Dr. Daniele Borio, Euro

Track A: Navigation for Mass Market

Track Chair: Dr. Melania Susi, Topcon Positioning Systems, Inc.

Advances in High Accuracy Positioning

Advancements in algorithms for high accuracy positioning, such as Precise Point Positioning (PPP), Real Time Kinematic (RTK) and PPP-RTK. Methods for reducing the convergence time using multi-frequency GNSS measurements, the design of algorithms tuned for measurements from mass-market devices, and robust techniques for high accuracy under challenging signal reception conditions. The characterization of both satellite-based and internet-based open correction services and the exploitation of signals from new satellite constellations for high accuracy solutions.
Chairs: Dr. Simon Banville, XONA and Dr. Ignacio Fernandez Hernandez, European Commission

Applications of GNSS Measurements from Smartphones

Many smartphones provide multi-constellation dual and multi-frequency raw GNSS measurements. Measurements from a variety of sensors, including inertial sensors, are also available and can be used in combination with GNSS measurements to improve the positioning solutions in complex environments. We invite contributions that look at enhanced positioning techniques in smartphones, e.g., based on Real Time Kinematic (RTK) and Precise Point Positioning (PPP) algorithms; improved stochastic modelling for GNSS smartphone observables; and algorithms and multi-sensor fusion for better indoor, outdoor, and urban-canyon positioning. Other topics of interest include: the integration with applications requiring reliable positioning solutions; jamming, spoofing detection and mitigation; use of smartphone raw GNSS measurements for scientific applications, such as geosciences; and smartphone GNSS antenna quality assessment.
Chairs: Dr. Mohammed Khider, Google Inc. and Dr. Robert Odolinski, University of Otago

Harsh Urban and Indoor GNSS

Methods for improving the accuracy and reliability of GNSS receivers in dense urban areas and inside buildings, including advanced signal processing techniques, NLOS and multipath detection and mitigation techniques, resilient multi-epoch positioning algorithms with outlier detection, aiding from 3D and 2D mapping, safe and reliable navigation with integrity position bound and fault detection and exclusion, aiding from inertial and other sensors, Real Time Kinematic (RTK) and Precise Point Positioning techniques (PPP). Methods for enhancing urban and indoor positioning accuracy and reliability using GNSS, machine learning, signals of opportunity, beacons, and combinations of these technologies.
Chairs: Dr. Terry Moore, University of Nottingham and Dr. Ilaria Martini, u-blox

Latest Advancement from GNSS Receiver and Localization Algorithm Manufacturers (Special Session: 10-Minute Presentations)

GNSS receivers and localization algorithms are experiencing a steady evolution of market differentiating KPIs, such as - performance, size, cost, new services, lower power consumption, interference resilience and new features. Several GNSS receivers, including mass-market products, are multi-constellation and multi-frequency with the support of Real-Time Kinematic (RTK) or Precise Point Positioning (PPP) services such as the Galileo High Accuracy Service (HAS), Beidou B2b correction service and augmentation with LEO and 5G based positioning services. Authentication and anti-jamming capabilities are supported as well. In this special session, the latest advancements, services and future products from GNSS receiver manufacturers, localization software experts and service providers are explored and presented. The session is organized in short ten-minute presentations providing an overview of the current and future developments in the complex and always evolving GNSS landscape.
Chairs: Steve Malkos, Google Inc. and Dr. Paul McBurney, OneNav Inc.

Navigation and Positioning

Navigation and positioning methods and algorithms for the mass-market sector. Techniques for improving the robustness of the algorithms under challenging conditions, including interference events, such as jamming or ionospheric scintillation. Navigation and localization through map building, collaborative pedestrian and robot navigation, pose estimation for humans and robots, and perception of the environment for autonomous operations. The use of a variety of sensors, including but not limited to LiDAR, cameras, INS, UWB, BLE, Wi-Fi, mmWave, magnetometers, and ultrasound, in various scenarios, including indoor environments.
Chairs: Dr. João Francisco Galera Monico, São Paulo State University (UNESP) and Dr. Heidi Kuusniemi, University of Vaasa

Positioning Technologies and Machine Learning

The exponential development of machine learning techniques, such as deep neural networks, has impacted many fields, including navigation. This session explores the application of modern machine learning techniques to open new applications in navigation and related fields. Topics include signal improvement, filtering and selection, online and offline multi-sensor algorithms, detection and mitigation of spoofing and jamming, use of novel sensors and observables, clock modeling and characterization, and scientific applications including ionospheric and atmospheric analyses. On the machine learning side, techniques not traditionally applied to navigation are of interest, including deep neural networks, boosting, graphical models, interpretable machine learning, semi- and unsupervised learning. Reproducible results and public datasets are of particular interest.
Chairs: Kinga Wezka, Warsaw University of Technology and Dr. Tara Mina, Stanford University

PANEL: Digital Reality and PNT

Digital reality, including augmented, virtual and mixed reality, is becoming widespread in different fields such as entertainment, sports, health, first responder, autonomous driving, indoor/urban navigation, and space applications. This technology can assist in enhancing perception skills, offering immersive visualization experiences, acquiring visual information from the environment, and identifying obstacles in challenging and dynamic scenarios. Digital information can also be overlayed to a live image enhancing the user operation capabilities and decision-making. This panel explores the advancements, opportunities, and challenges of digital reality in relationship to positioning and navigation.
Moderators: Dr. Charles Toth, The Ohio State University and Dr. Valérie Renaudin, Université Gustave Eiffel

Track B: Autonomous and Safety Critical Applications

Track Chair: Steffen Thölert, German Aerospace Center (DLR)

Augmentation Services, Integrity, and Authentication

The provision of new products, services, and techniques enhancing precision, integrity, robustness, and trust for safety critical and autonomous needs. Submissions on state-space-representation (SSR)-based techniques, integer ambiguity resolution, bandwidth efficient communication, multi-GNSS/frequency solutions, message/spreading code authentication and integrity. High performance and safety critical applications using SBAS, GBAS and ARAIM, including use cases and applications highlighting the benefits and challenges from a user's perspective.
Chairs: Dr. Rui Hirokawa, Mitsubishi Electric Corporation and Dr. Thomas Pany, University of the Bundeswehr, Munich

Autonomous Applications

Advances in navigation and mapping for assisted and autonomous vehicle or mobile platforms applications. Navigation cybersecurity, emerging cyber threats, and mitigations. Guided vehicle systems and pilot assistance with enhanced safety, availability, and efficiency in challenging environments. Safety, integrity, and certification requirements for autonomous navigation and guidance. Evolution of machine learning and other artificial intelligence technologies employed in autonomous navigation. Assistance and cloud-based technologies for robust and trusted autonomous systems.
Chairs: Dr. Li-Ta Hsu, The Hong Kong Polytechnic University and Laura Norman, Hexagon

Aviation and Aeronautics

Technologies to enhance safety, robustness, assurance, and efficiency of airborne operations and space missions. Integration of GNSS technologies for aviation, rockets, and autonomous flight termination systems (AFTS). Airborne GNSS and sensor integration for current and novel applications. Adoption and impact assessment of modernized GNSS, SBAS, GBAS and ARAIM. Robustness of augmentation systems to signal degradation, including ionospheric scintillation, multipath, jamming, and spoofing. Uses of new signals, services and multi-constellation systems, including LEO constellations. Requirements for performance monitoring and alerting. Advancing integrity, availability, accuracy, continuity, and security requirements and mitigation.
Chairs: Dr. Maria Caamano Albuerne, German Aerospace Center (DLR) and Dr. Sam Pullen, Stanford University

Land-Based Applications

Technologies and methodologies to address critical requirements and threats for land-based vehicles (on road or rails) particularly related to accuracy, safety or cyber security. Systems and algorithms developed for enhanced performance in accuracy, availability, reliability, integrity, robustness: GNSS jamming and spoofing detection and mitigation, sensor fusion, new algorithms, applications of artificial intelligence and machine learning, integration of radar, lidar, camera, 5G and LEO based positioning, applications of GNSS authentication services in the road and railway segments, advances in GNSS augmentation and MCMF GNSS for land-based applications, use of digital maps. Technology and performance demonstration, validation and certification.
Chairs: Dr. Ali Hassani, Sierra Space and Dr. Juliette Marais, Université Gustave Eiffel

Marine Applications and Search and Rescue

Concepts, innovation, and emerging applications in maritime navigation, and search and rescue. Autonomous vessels, vessel traffic management, and maritime surveying. Aid to navigation placement via navigational hazard location and mapping. Fishing, oceanography, and oil and gas exploration. Maritime applications of GNSS, GNSS augmentations - MF beacons and SBAS, non-GNSS satellite systems, terrestrial backup systems, and integration with vessel sensors and systems. Maritime cybersecurity authentication mechanisms. Accuracy, integrity, continuity, and availability requirements to guarantee resilient PNT.
Chairs: Dr. Richard J. Hartnett, U.S. Coast Guard Academy and Dr. Pyo-Woong Son, KRISO

PANEL: Emerging Autonomous Application – Challenges and Prospects

Would you trust an autonomous car or uncrewed aerial vehicle to handle your daily commute, make critical decisions, and ensure the safety of you and your family? In this panel, industry and academic experts will discuss the latest developments in self-driving cars, drones, and AI-powered systems, shedding light on opportunities and challenges. They will delve into safety and security enhancements, the most recent technological advancements, and the complex landscape of regulations. Are the technology and regulations sufficiently advanced for the era of autonomous cars and aerial mobility? What is Digital Flight (DF) and what are the challenges and benefits of DF as a new flight operations capability? What about privacy and other ethical concerns in the age of autonomy? Whether you're a tech enthusiast, a forward-thinking entrepreneur, or a policymaker shaping the future, this panel guarantees an exciting exploration of autonomous applications. Don't miss this exhilarating opportunity to stay at the forefront of innovation!
Moderators: Dr. Dorota Grejner-Brzezinska, The Ohio State University and Dr. Allison Kealy, Environmental Land Water & Planning of Australia

ABSTRACTS DUE MARCH 1

Track C: Status and Future Trends in Navigation
Track Chair: Dr. Sudha Vana, Rx Networks

GNSS Applications in Space
Space service volume; space-grade GNSS receivers for re-entering vehicles; improving spacecraft positioning using inter-satellite links; satellite laser ranging; innovative solutions for constellation build-up and maintenance; use of GNSS for orbit and attitude determination as well as precise orbit determination; moon navigation; and emerging space positioning applications. Advanced positioning techniques in space, such as snapshot-based positioning on the ground and in space, and interplanetary navigation.
Chairs: Dr. Sampad Kumar Panda, KL University and Florian Kunzi, German Aerospace Center (DLR)

Spectrum: Protection and Optimization
Protection and optimization of the RNSS spectrum against the effects of interference, jamming and spoofing in safety-critical applications, automation, autonomous vehicles and civilian use cases. Effects of interference, jamming, meaconing and spoofing on GNSS receivers, signal-to-noise ratio, data authenticity and authentication, ranging and position authentication, navigation system integrity, and denial of service. Interference detection, characterization, geolocation. Hardware and/or software-based mitigation techniques. Civilian anti-jam and/or anti-spoofing methods and algorithms. Civilian incidences of modern threats and challenges to GNSS applications. Optimization of GNSS spectrum usage for future navigation solutions, including optimum exploitation and sharing of the available bandwidth. Use of new frequency bands and signals of opportunity (such as LEO-based broadband signals, alternative RF signal sources, 5G/6G) for navigation. Regulatory and legal aspects of spectrum management.
Chairs: Stefan Wallner, ESA and Dr. Zeynep Andreotti, Hexagon

Technologies for Scientific and Sectorial Applications
Technologies for scientific and sectorial applications such as the smart/digital tachograph, road tolling systems, geo-tagging of photos, emergency location, remote sensing applications and climate change. Advances in PNT technologies, rules and policies for scientific and industrial applications such as advanced air mobility, road safety systems, railway signaling, maritime and rail traffic monitoring, wildlife tracking, emergency location services, augmented reality, personal navigation, and timing for critical infrastructures. Solutions improving positioning using GNSS, inertial navigation, signals of opportunity, image-based localization, and multi-sensor fusion in the context of challenging environments, constrained platform resources and limited infrastructure availability. Alternative PNT technologies, synergies of unconventional sensors used for positioning, and innovative methods for state estimation.
Chairs: Dr. Omar García Crespillo, German Aerospace Center (DLR) and Dr. Elisa Gallon, Airbus

Trends in GNSS Augmentation Systems
Evolving multi-GNSS and GNSS augmentation system integrity designs (ARAIM), monitoring, fault exclusion, protection level algorithms, testing, and results. Upcoming trends in automated navigation for aviation, automotive, rail, maritime, and other transportation applications. GNSS faults including satellite and constellation failure modes, external threats including spoofing, and the detection of various anomalies, which are critical to the safe and effective use of GNSS now and for emerging market needs. Correction services that can be used as augmentation for PPP, PPP-AR, PPP-RTK (SSR and OSR corrections). Dissemination of integrity support information via high and low-capacity data channels. Status and evolution of existing GBAS and SBAS (WAAS, MSAS, EGNOS, GAGAN, SDCM, AGNOS, KASS).
Chairs: Dr. Nacer Naciri, JPL and Dr. Anurag Raghuvanshi, York University

Trends in Future Satellite Navigation Technology, System Design and Development
Innovations in satellite constellation design for navigation and integrated communication/navigation. Proposals for interoperability of GNSS constellations. Optimization of GNSS signal structure via codes and data messages. The latest technologies such as extremely stable frequency standards on-board navigation satellites. Future GNSS open and authorized services such as search and rescue, authentication, or commercial services. New civil, military, commercial and governmental systems, and user capabilities. Optimization and integration of satellite navigation with other systems, sensors and/or signals of opportunity. Analysis of GNSS performance standards for new services and functionality.
Chairs: Dr. Vijaykumar Bellad, Rx Networks and Tim Murphy, Boeing

PANEL: Status of GPS, Galileo, BDS, QZSS, KPS, and NavIC
This panel session provides an update on the world's satellite-based navigation systems. A representative for each system will provide a system overview, summarize current or planned characteristics and performance, report recent programmatic events, update schedule and plans, and summarize ongoing interactions with other service providers. Questions from the audience are encouraged.
Moderators: Dr. Todd Walter, Stanford University and Dr. José Ángel Ávila Rodríguez, ESA

Track D: Multisensor and Autonomous Navigation
Track Chair: Dr. Safoora Zaminpardaz, RMIT University

Alternative Technologies for GNSS-Denied Environments
New methods, systems, and results from navigation systems that do not rely on GNSS. These systems may be based on LiDAR, camera and other optical sensors; non-GNSS RF signals; interferometric measurements; LTE cellular networks; IMUs; or other low-cost sensors that are applicable to ground and airborne autonomous vehicles. Topics include integration of multiple sensors, solutions and data sources; calibration and synchronization techniques for single- and multi-sensor systems, including cooperative or networked sensors; and innovative solutions and applications, such as direct georeferencing, precision agriculture, guidance and control of vehicles, deformation monitoring, directional drilling, pedestrian navigation systems, rapid mobile mapping, and crowd sourced mapping.
Chairs: Dr. Amir Khodabandeh, The University of Melbourne and Dr. Joshua Morales, StarNav

GNSS Augmentation and Robustness for Autonomous Navigation (GNSS Integrity Augmentation)
Augmentation of GNSS in aviation, maritime, rail, automotive, and other transportation applications (stand alone or with additional ground infrastructure). Applications of augmentation systems to support autonomous navigation; integrity of augmentation systems in the presence of signal degradation (ionospheric scintillation, multipath, jamming, spoofing, etc.); fault mode definition and fault detection; monitoring and exclusion techniques; integrity analysis for multi-frequency and/or multi-constellation GNSS; evaluation of continuity and availability. Dissemination of integrity support information via high and low-capacity data channels from SBAS, GBAS, ABAS, PPP and other systems.
Chairs: Dr. Thomas Dautermann, German Aerospace Center (DLR) and Dr. Yiping Jiang, The Hong Kong Polytechnic University

Indoor and Urban Navigation and Mapping
Opportunities to optimize existing heavy localization algorithms and to steer the research to multi-sensor, multi-fusion real-time capable applications. Innovative solutions for position, orientation, velocity, timing and/or mapping indoor and urban applications. Dealing with the synchronization delays and other relevant application limitations. Minimum sensor configuration to reach targeted key performance indicator. Opportunistic navigational updates, integration with virtual, augmented or mixed reality systems, use of semantics, high-precision indoor localization and orientation for industrial applications, mapping of vehicles and targets in warehouses, robust estimation techniques to handle these challenging environments. Multipath and non-line-of-sight mitigation by modeling or external resources aiding, including 3D city map and environment context. Minimum sensor setup using e.g., parking sensors and standard position solution to enable automatic parking in indoor and outdoor scenarios.
Chairs: Dr. Guohao Zhang, The Hong Kong Polytechnic Univ. and Dr. Chi-Shih (Chico) Jao, Apple

Navigation Using Environmental Features
New navigation theories, algorithms, sensors and ultimately systems using natural and artificial features of the surrounding environment that can be used for position, velocity, and attitude updates, or all the above. This includes visual interest/key-point features, terrain height, magnetic and gravitational fields, celestial objects, microclimate, acoustic features, odors, and particulates. We encourage using new natural-based feature classes, feature extraction and matching methods, and new algorithms for feature processing. Topics can expand beyond new AI algorithms for feature signature abstraction, recognition, tracking, and filter updates; collaborative and relative navigation using data distribution across users; perception of environment and mapping; managing ambiguity; new sensors and algorithms for real-time position, velocity, and attitude solution determination using environmental features; and navigation using multiple classes of environmental features.
Chairs: Dr. Sabrina Ugazio, Ohio University and Dr. Shahram Moafipoor, AEVEX Aerospace

Robust Navigation Using Alternative Navigation Sensors and Solutions
New navigation sensors and systems that improve robustness and reliability of navigation solutions in GNSS-challenged environments, for pedestrian users, watercraft, as well as ground and airborne vehicles. How to define performance requirements for position, orientation, and velocity for these applications? How to quantify the robustness and reliability of a multi-sensor system? How to model, estimate and monitor the integrity of these navigation solutions? How to improve the robustness for systems of or incorporating LiDAR and vision-aided navigation sensors, low-cost IMUs, and signals of opportunity? How can new radionavigation systems, such as signals from LEO satellites or terrestrial sources or signals of opportunity, complement GNSS for improved performance? How to address the new challenges in system robustness of using these new signals?
Chairs: Dr. Samer Khanafseh, Illinois Institute of Technology and Dr. Jason N. Gross, West Virginia University

PANEL: Autonomous Navigation for Ground, Seaborne, and Airborne Vehicles
How will automated vehicles transform our lives in the future? What are the remaining challenges that hold back autonomous vehicles, from self-driving cars to uncrewed aerial vehicles to autonomous transit, from the mass market? How much can we trust the autonomous navigation and guidance of these cyber-physical systems? What sensors/signals should we use that provide continuous, trustworthy, and secure flow of information needed for autonomous navigation? How is the robustness and integrity addressed by different stakeholders and industries? Seek answers to these questions, and ask more, in this panel on ground, seaborne, and airborne vehicles.
Moderators: Dr. Roberto Sabatini, Khalifa University and Dr. Grace Gao, Stanford University

RACKS: Program Co-chair: Dr. Jihye Park, Oregon State University

Track E: Algorithms and Methods
Track Chair: Dr. Byungwoon Park, Sejong University

Accurate GNSS Navigation in Challenging Environments
Developments and technologies improving the performance and efficiency of receivers and sensors in challenging environments: in urban or indoor areas with multipath interferences; or in the presence of ionospheric/tropospheric scintillations, for ground-based or satellite-based platforms. Receiver behavior under deep amplitude fading or fast phase fluctuations in signals, jamming, spoofing, highly dynamic conditions, signal anomalies, etc. Fusion algorithms, signal processing and receiver designs, machine learning and neural network approaches, and potential improvements to the signals themselves, with an emphasis on robustness, adaptation, multi-signal/multi-sensor capabilities, and sensor aiding. Vision-based modelling, 3D city map assistance, ray tracing, non-line-of-sight ranging for multipath detection, or simulation and mitigation in urban environments. Experimental tests and new models in real environments.
Chairs: Dr. Nobuaki Kubo, Tokyo University of Marine Science and Technology and Dr. Jungbeom Kim, Samsung Inc.

Advanced Processing of Terrestrial Signals of Opportunity
Developments in the use of signals of opportunity for PNT. Fusion of new-generation communication system signals with GNSS. Alternative location methods based on received signal strength estimation, ToA, TDoA, DoA, or advanced RF propagation models. Signal processing techniques to improve receiver synchronization to terrestrial signals; hybrid positioning techniques; and fine synchronization of terrestrial networks. The signals of interest include but are not limited to: Wi-Fi, cellular (3G, 4G, 5G), RFID, Bluetooth, NFC, HD Radio/DAB, Digital TV, LEO satellites, etc.
Chairs: Tucker Haydon, Sandia National Labs and Dr. David W.A. Taylor, Setter Research, Inc.

Advanced Technologies in High Precision GNSS Positioning
High-precision and high-integrity navigation algorithms for safety-critical applications of GNSS and other sensors. High-integrity measurement error modeling and uncertainty quantification methods; Precise Point Positioning (PPP), Real-Time Kinematic (RTK) and other precise positioning techniques; end-user fault detection and exclusion algorithms for high-precision GNSS or multi-sensor navigation systems; integrity monitoring and performance evaluation of multi-GNSS PPP/RTK/PPP-RTK correction services; satellite- and ground-based integrity augmentation techniques and their performance evaluation.
Chairs: Dr. Mathieu Joerger Virginia Tech and Dr. Junesol Song, University of Suwon

All-Source Intelligent PNT Method
Intelligent PNT with new techniques for sensing, measurement, data processing, and fusion. Participating PNT sources: GNSS, RNSS, UWB, Wi-Fi, acoustic waves, and opportunistic radio signals. Intelligent PNT systems make use of diverse sensors, including inertial sensors, odometers, magnetometers, altimeters, radar, LiDAR, cameras, etc. in order to provide reliable measurements under challenging or variable conditions. Topics include intelligent PNT data filtering and integration, stochastic model optimization, advances in uncertainty representation, real-time critical information perception, interpretation and smart fusion, reinforcement learning, cloud-based computing, trustworthy navigation in urban and smart urban areas, etc. Innovative ideas about close integration between machine learning and Bayesian inference.
Chairs: Dr. Francesco Basile, u-blox and Dr. YuXiang (Phillip) Peng, Qualcomm Technologies Inc.

LEO for Positioning, Navigation, and Timing
Low Earth Orbit has emerged as a game-changing arena for enhancing, complementing and back up GNSS services, pushing the boundaries of precision, accuracy, and resilience for global PNT capabilities. The development and integration of LEO-based PNT technologies is poised to revolutionize multiple industries and applications. Topics include large and mega LEO-based constellations to provide PNT capabilities; signal design and characteristics for LEO PNT service; LEO augmentation systems designed to enhance GNSS accuracy, reliability, availability, and integrity; resilience and security challenges and solutions associated with LEO-based PNT; novel algorithmic and modeling developments to enable precision LEO orbit determination; and user localization.
Chairs: Dr. Ryan Watson, Xona Space Systems and Dr. Rui Zuo, OneWeb

Sensor Network and Cooperative Navigation
Cooperative navigation applies techniques from the field of multi-agent systems to improve navigation performance and reduce hardware costs by exploiting network connectivity. Modeling of sensor network topologies, data transfer and sharing, multi-node collaborative information processing, non-linear optimization, relative navigation, centralized and distributed estimation, and fault detection and exclusion in cooperative navigation. Other techniques helping to achieve highly accurate, efficient, and reliable cooperative and networked positioning in dynamic and uncertain environments such as methods enabled by connected vehicles and infrastructure aiding.
Chairs: Dr. Ramsey Faragher, Focal Point Positioning and Dr. Gregor Möller, TU Wien

Smartphone Decimeter Challenge (Co-sponsored by Google)
Teams compete using a pool of GNSS datasets from smartphones along with high accuracy ground truth: 196 different drives over tens of different routes, with raw GNSS measurements including carrier phase and IMU data. Prize money of $15,000, plus sponsored attendance of ION GNSS+ 2024. Competition details at g.co/gnssTools. Anyone may submit abstracts for this conference session. Abstracts should highlight the algorithmic approaches, particularly AI, factor graph optimization, Batch and Kalman filters, and RTK techniques.
Chairs: Dr. Michael Fu, Google Inc. and Dr. Frank van Diggelen, Google Inc.

PANEL: Algorithms and Methods for GNSS Cyber Physical Security
Networked or cooperative applications of GNSS have become pervasive in low-cost devices such as smartphones, wearables, and geolocated Internet of Things (IoT) devices, and similar uses are rapidly being adopted in aerial and automotive settings. There are security opportunities that can come with the use of PNT with networked connectivity and centralized large-network processing; in the development of cyber-physical institutions for sensor certification, fraud prevention, and cooperative use of network resources. It also can come with risks such as when used with heterogeneous and potentially untrustworthy sources of data for inference. What new security benefits and challenges will arise in networked deployments of PNT technology for IoT, aerial, and vehicular applications? And what are the right strategies or methods to ensure cyber physical security?
Moderators: Dr. Joe J. Rushanan, The MITRE Corporation and Dr. Sherman Lo, Stanford University

Track F: Advanced GNSS Technologies
Track Chair: Dr. Attila Komjathy, JPL

Advanced Software and Hardware Technologies for GNSS Receivers
Developments that improve the performance and efficiency of GNSS receiver technology. Wideband GNSS antennas, high-sensitivity/high-dynamic range RF front ends, robustness to multipath and interference, use of assistance data, multi-constellation receiver algorithms, innovative and efficient software for GNSS receivers and new/existing applications, machine learning and deep learning algorithms for signal processing, experimental tests in real environments, software-defined GNSS receivers and associated processing methods, low power-consumption techniques, open source projects, and the use of software radio standards and tools.
Chairs: Dr. Rodrigo Leandro, u-blox and Dr. Paulo Sergio de Oliveira Jr., UFPR

Atmospheric Effects on GNSS
Tropospheric and ionospheric modeling, measurements, and algorithms to compensate for atmospheric errors. Novel methods for data collection, processing and analysis. Characterization of propagation environments. Ionospheric scintillation studies and impacts on GNSS services and applications. GNSS signatures and impact of travelling ionospheric disturbances including applications. Space weather and terrestrial weather applications. New ground-based and space-based GNSS networks and experiments.
Chairs: Dr. Vincenzo Romano, Istituto Nazionale di Geofisica e Vulcanologia and Hyeyeon (Ann) Chang, University of Colorado Boulder

Beyond GNSS: Emerging Trends in LEO-Based and Terrestrial Signals of Opportunity for PNT
The rapid deployment of LEO-based mega constellations for broadband has given us a myriad of signals from space with unprecedented availability and frequency diversity. Early research has shown that these signals can be used opportunistically for navigation. Several entities are working on LEO-based constellations that are built for PNT. Other terrestrial signal sources offer promising navigation performance – in some cases potentially outperforming space-based sources. Together, these technologies represent the exciting future of radionavigation-based technologies for PNT that promise to augment the pros and overcome the cons of GNSS. This session addresses these technologies, their expected performance, technical and policy challenges yet to overcome, and when we can expect operational capabilities.
Chairs: Dr. Zak Kassas, The Ohio State University and Dr. Aurore Sibois, Xona Space Systems

GNSS Robustness to Vulnerabilities
Algorithms and techniques for improving the resilience of GNSS PNT. GNSS signal authentication, including approaches such as signal design, receiver based anti-spoofing techniques, and use of external infrastructure. Signal anomaly detection algorithms and metrics, GNSS threat modeling as well as intentional and unintentional sources of signal interference and spectrum issues. Characterization, detection, mitigation and localization of interference sources such as multipath, scintillation, and solar storms; jamming, repeaters and spoofers; impact analysis, trials and test results across a range of navigation application domains; and methods for authenticating map and data base information. Time certification technology and applications.
Chairs: Dr. Anna Jensen, Swedish Maritime Administration and Dr. Sophie Damy, European Commission

Lunar Positioning, Navigation, and Timing
A comprehensive look at lunar position, navigation, and timing (PNT) methods and technologies vital for the exploration of the Moon. Topics include lunar PNT service-providing satellites' orbit and constellation designs, precise orbit determination, and time synchronization for lunar missions. Discussions on modulation techniques, and specifics of navigation messaging systems in support of lunar radionavigation services. Participants will elaborate on fault-tolerant sensor fusion methods, associated analysis of end-user performance, PNT algorithms suitable for different lunar contexts, the application of GNSS to lunar missions, emerging navigation technologies, and the role of lunar surface PNT augmentation systems. The focus is on practical insights and advancements in the field of lunar PNT.
Chairs: Juan Crenshaw, NASA GSFC and Danielle Mortensen, JHU Applied Physics Lab

Remote Sensing, Timing, Space and Scientific Applications
Scientific and engineering uses of GNSS, including terrestrial and space applications. GNSS Earth observation techniques; reflectometry for environmental remote sensing of land, ocean and ice; and GNSS remote sensing for detecting geophysical events such as earthquakes, tsunamis, volcanic eruptions, and man-made events. GNSS metrology and its applications. Advances in precision timing, and time and frequency transfer; multi-GNSS for timing applications. Space applications, including high sensitivity signal processing algorithms; integration solutions with sensors and orbital filters; antenna technologies for space; multi-GNSS receivers, technical advances of both COTS and specialized systems for space applications. Orbit determination, including precise orbit determination algorithms, constellation navigation, and spacecraft attitude determination.
Chairs: Dr. Andria Bilich, National Geodetic Survey/NOS/NOAA and Fiona Luhrmann, Oregon State University

PANEL: International Civilian Agency Lunar PNT Systems
Systems, techniques, and algorithms for navigation to the Moon and on the Moon: Lunar navigation satellite orbit design and trade-offs; satellite constellation design; end-to-end system architectures and performance analysis; precise orbit determination and timing synchronization techniques for Moon navigation; reference frames suitable for precise lunar radionavigation; signal modulations techniques for one-way and two-way one-service; lunar radio navigation message definition; sensor fusion techniques and PNT algorithms for low lunar orbits, landing, navigation on the surface of the Moon GNSS use for lunar navigation; enabling lunar navigation technologies; and lunar beacons. Our panel of experts will describe these technologies, emerging trends, international collaborations and expected outcomes.
Chairs: Dr. Masaya Murata, Japan Aerospace Exploration Agency and Dr. Cosimo Stallo, Thales Alenia Space Italia S.p.A.