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**Mobile App:** To access the ION GNSS+ program and other conference information on your mobile device point your browser to m.ion.org

**Wi-Fi:** Complimentary Wi-Fi Access (limited to lobby areas and technical session rooms, will not work in the exhibit hall). Network Name is IONGNSS; password is ion2019.

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MEDIA PARTNERS
8:15 a.m.  CGSIC Registration Desk–Brickell Ballroom Foyer

**Morning Session (Brickell Ballroom)**

**TIMING SESSION**

Chair: Dr. Stefania Römisch, National Institute of Standards and Technology (NIST)
Deputy Chair: Dr. Lin Yi, NASA Jet Propulsion Laboratory (JPL)

9:00  Introduction, Dr. Stefania Römisch, NIST
9:10  USNO Laboratory Update, Mr. Stephen Mitchell, U.S. Naval Observatory (USNO)
9:30  NRL Time and Frequency Activities, Ms. Francine Vannicola, Naval Research Laboratory
9:50  Report from JPL, Dr. Lin Yi, Jet Propulsion Laboratory (JPL)/Caltech
10:00 Controlling Clocks, Dr. Demetrios Matsakis, Master Clock Inc.
10:10 Development of a Satellite-Based Cold Atom Clock, Dr. Liang Liu, Chinese Academy of Sciences
10:30  Break
10:50  Kepler: Optical Technologies for Global Satellite Navigation and Time Metrology, Dr. Christopher Guenter, German Aerospace Center (DLR)
11:10  Current and Future Atomic Clocks – Roadmap and Applications, Dr. David Scherer, MITRE
11:30  Impact of GGTO Determination and Accuracy on Positioning and Timing, Dr. Pascale Defraigne, Royal Observatory of Belgium
11:50  Resilient PNT for the Civilian Sector, Dr. Arthur Schulz, MITRE
12:10  Discussion
12:30  Session End

**Afternoon Concurrent Sessions**

**INTERNATIONAL INFORMATION SESSION  (BRICKELL BALLROOM)**

Chair: Mr. John Wilde, SPACEKEYS

2:00  Introduction, Mr. John Wilde, SPACEKEYS
2:10  Commercialization & Corporatization of GNSS Service Providers, Dr. Dejian Kong, Assistant Professor, China University of Political Science and Law
2:40  Characterization of Radio Frequency Interference for GNSS Maritime Applications, Mr. Emilio Pérez-Marcos, Research Fellow, German Aerospace Center: Institute of Communications and Navigation
3:10  Activities of the UN International Committee on Global Navigation Satellite Systems (ICG), Ms. Sharafat Gadimova, ICG Executive Secretariat, United Nations Office of Outer Space Affairs
3:30  Update on BeiDou Navigation Satellite System (BDS), Dr. Jun Shen, Deputy Director, International Cooperation Center, China Satellite Navigation Office
4:00  Progress Towards a Regional SBAS Service for Australia and New Zealand, Mr. Simon Reynolds, Senior SBAS Engineer, Geoscience Australia and Mr. Dave Collett, Senior Positioning Advisor, Land Information New Zealand
4:30  Korea PNT Update, Dr. Jong Uk (James) Park, Korean COSPAR Committee, Space Science Division, Korea Astronomy and Space Science Institute
5:00  Discussion
5:30  Session End

**SURVEYING, MAPPING, AND GEOSCIENCES SESSION (ORCHID BALLROOM)**

Chair: Ms. Francine Coloma, NOAA National Geodetic Survey

Co-Chair: Mr. Neil Winn, U.S. National Park Service

2:00  Current Status and the Future of CORS Network, Ms. Francine Coloma, CORS Team Geodesist, NOAA National Geodetic Survey
2:20  Determining Positions After 2022, Mr. Denis Riordan, NGS Regional Advisor of South East, NOAA National Geodetic Survey
2:40  InSAR, Dr. Falk Amelung, Professor, University of Miami
3:00  FPRN Moving Forward, Mr. Ron Hanson, FPRN Manager, Florida Department of Transportation
3:20  Break
4:00  GNSS Positioning Accuracy in the NPS/DOI, Mr. Neil Winn, GIS Specialist, National Park Service
4:20  The Status of Geologic and Geomorphic Mapping in Florida, Mr. Guy “Harley” Means, Assistant State Geologist, Florida Geological Survey, Florida Department of Environmental Protection
4:40  GPS and InSAR Monitoring of Coastal Subsidence in Florida: Implications to Coastal Flooding Hazard Assessments, Dr. Shimon Wdowinski, Associate Professor, Florida International University, Department of Earth and Environment
5:00  Ionospheric Product Developments at the Space Weather Prediction Center, Mr. Rob Steenburgh, Space Scientist, NOAA Space Weather Prediction Center
5:30  Session End
8:00 a.m.  CGSIC Registration Desk–Jasmine Ballroom Foyer

Morning Plenary Session (Jasmine Ballroom)
9:00  Welcome/Opening, Ms. Karen Van Dyke, Director, PNT and Spectrum Management, U.S. Department of Transportation, Chair, CGSIC
9:05  Meeting Overview, Captain Michael Glander, Commanding Officer, U.S. Coast Guard Navigation Center (NAVCEN), Deputy Chair, CGSIC
9:10  Keynote Address, Ms. Diana Furchtgott-Roth, Deputy Assistant Secretary, Office of the Assistant Secretary for Research and Technology, U.S. Department of Transportation
9:30  U.S. National Space-Based PNT Update, Mr. Harold “Stormy” Martin, Director, National Coordination Office for Space-Based Positioning, Navigation, and Timing
9:50  GPS Program Update, Lieutenant Colonel Ken McDougall, Chief, GPS Integration Branch, U.S. Air Force GPS Directorate
10:10 GPS Constellation Status and Performance, Lieutenant Colonel Ken McDougall, Chief, GPS Integration Branch, U.S. Air Force GPS Directorate
10:30 Break
10:45 GPS International Activities, Mr. Jeff Auerbach, U.S. Department of State, Office of Space and Advanced Technology
11:10 Update on DHS PNT Actions, Mr. James Platt, PNT Program Management Office, U.S. Department of Homeland Security
11:35 Q/A, Panel Presenters
12:00 Lunch (on your own)

Afternoon Plenary Session (Jasmine Ballroom)
1:30 Subcommittee Reports:
   • International Information Subcommittee, Mr. John Wilde, SPACEKEYS
   • Timing Subcommittee, Dr. Stefania Römisch, NIST
   • Surveying, Mapping, and Geosciences Subcommittee, Ms. Francine Coloma, NOAA National Geodetic Survey
2:10 WAAS Program Status, Ms. Deborah Lawrence, Federal Aviation Administration, U.S. Department of Transportation
2:30 Civil Signal Operational Capability IPT, Dr. Andrew Hansen, Principal, Aviation Modeling & System Design, Volpe Center, U.S. Department of Transportation
2:50 Automated Flight Termination System, Ms. Lisa Hansen, AFTS Program Manager, NASA Kennedy Space Center
3:10 Report: Economic Benefits of GPS (Sponsored by Commerce Department), Mr. Alan O’Connor, RTI International
3:30 Break
4:10 User Support Forum
   • NAVCEN User Update
   • Public Interface Control Working Group, Mr. Daniel Godwin, Section Chief, GPS Requirements, U.S. Air Force GPS Directorate and 2nd Lt Benjamin Ratner, GPS Requirements, U.S. Air Force GPS Directorate
4:30 GPS User Perspectives:
   • The Role of Civil Signal Authentication in Trustable Systems, Mr. Logan Scott, President, LS Consulting
5:00 Q/A, Panel Presenters
5:30 Adjourn
ION GNSS+ 2019 SHORT COURSES – TAUGHT BY ION MASTERS

Pre-Conference Short Course Information

Monday’s short courses are provided on a complimentary basis to all paid ION GNSS+ attendees with the compliments of the Satellite Division and the ION Master Instructors. ION Master Instructors are internationally recognized GNSS experts and educators. All of the ION Masters have generously donated their time and talents to this effort, as a service to the GNSS community, with the ION’s gratitude. Short courses are presented lecture style. Electronic course notes are the intellectual property of the ION Master Instructor and are provided to registered attendees at the discretion of the instructor via the meeting website.

SHORT COURSE SCHEDULE

Included with all Paid ION GNSS+ Registrations

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<tr>
<th>Time</th>
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<tr>
<td>1:30 p.m.–3:00 p.m.</td>
<td>Select from:</td>
<td>Dr. Pratap Misra</td>
</tr>
<tr>
<td>Room: Flagler</td>
<td>GNSS 101: An Introduction</td>
<td>Patricia H. Doherty</td>
</tr>
<tr>
<td>Room: Monroe</td>
<td>Introduction to Space Weather</td>
<td>Dr. Dorota A. Grejner-Brzezinska</td>
</tr>
<tr>
<td>Room: Tuttle</td>
<td>Sensor Integration for Personal Navigation</td>
<td>Dr. Richard J. Hartnett</td>
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<tr>
<td>3:30 p.m.–5:00 p.m.</td>
<td>Select from:</td>
<td>Dr. Frank van Diggelen</td>
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<tr>
<td>Room: Flagler</td>
<td>GNSS 102: Measurements from Phones, L1, L5 and Carrier Phase</td>
<td>Logan Scott</td>
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<tr>
<td>Room: Monroe</td>
<td>Approaches for Resilient and Robust Positioning, Navigation and Timing (PNT)</td>
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<tr>
<td>Room: Tuttle</td>
<td>Using a Sextant: Celestial Navigation</td>
<td>Dr. Richard J. Hartnett</td>
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SHORT COURSE DESCRIPTIONS

Monday Afternoon 1:30 p.m.–3:00 p.m.

GNSS 101: An Introduction

An overview of the principles of satellite navigation and the requisite technologies that matured in the second-half of the 20th century leading to the development of Transit, which became operational in 1964, followed by GPS in 1995. The principal technologies required for a Global Navigation Satellite System (GNSS) are stable space platforms in predictable orbits, global coordinate frames, spread spectrum signals and ultra-stable clocks. These technologies made GNSS possible, but it’s the revolution in integrated circuits that led to a receiver chip, which adds about $1 to the cost of a smartphone and can determine, virtually instantaneously, your position within a couple of meters, velocity within 5 cm/s, and time within 50 ns. These innovations have transformed the way we move about, transact commerce and fight wars. As a preview to GNSS 102, this class will also introduce L5, group-delay, intersystem biases and the basics of carrier phase.

Dr. Pratap Misra, an ION Fellow and Kepler Award recipient, has been active in the GNSS field for 30 years, starting with a project at MIT Lincoln Laboratory aimed at combining measurements from GPS and GLONASS to improve navigation for civil aviation.

Introduction to Space Weather

Space Weather is an emerging field of space science that studies how the Sun influences the Earth’s space environment, and the impacts of those interactions on technological and society. Some of the most intense interactions can damage our Earth-orbiting commercial and scientific satellites; threaten astronaut safety; introduce high levels of radiation for crew and passengers in flights crossing over the poles; disrupt electric power grids, oil pipelines and the reliability and accuracy of global communications and navigation systems, including GNSS. With society’s ever-increasing dependence on space-based technology it is important to be aware of Space Weather, its potential impacts and what governments are doing to enhance forecasting and mitigation of its most damaging effects.

This course will introduce the basic physical concepts of the source of Space Weather. This includes information on the Sun, solar wind, eruptive solar phenomena, magnetosphere, ionsphere and geomagnetic induction. The course will continue with a view of the impacts of Space Weather on technological systems in space and on the ground. Finally, we will introduce current government policy and plans to enhance forecasting capabilities and mitigation of Space Weather.

Dr. Pratap Misra

Patricia H. Doherty

Sensor Integration for Personal Navigation

A review of the state-of-the-art navigation sensors and techniques suitable for personal and pedestrian navigation, with an extension to the Unmanned Aerial Systems (UAS) navigation. Personal Navigation (PN) is defined as navigation for military and emergency personnel, while pedestrian navigation refers to location/navigation/tracking of all other types of mobile users. An emphasis will be on navigation sensors and techniques in GNSS-challenged environments, such as inertial measurement unit (IMU), wireless local area network, IR and RF transponders, and ultra-wideband (UWB) networks, as well as 2D and 3D active and passive imaging sensors. Following the technology overview, sample implementations and performance assessment of selected navigation system prototypes will be presented. System design, as well as a summary of the performance analysis in the mixed indoor-outdoor environments, with special emphasis on dead-reckoning (DR) performance, will be discussed.

Dr. Dorota A. Grejner-Brzezinska

Dr. Richard J. Hartnett
**Monday Afternoon**

3:30 p.m.–5:00 p.m.

**GNSS 102: Measurements from Phones, L1, L5 and Carrier Phase**

NEW! Version 3.0.3.0 of the Google GNSS Analysis App for desktops released; get it at https://g.co/gnssTools. If you enjoyed the “Measurements from Phones” class last year–come back! We have a whole new set of data and tools for you. After a brief overview of GNSS raw measurements in phones, we will spend most of the course on the new signals available from smartphones, L5 and Carrier Phase, and the new tools and features available to you (free) including the new release of the Google GNSS Analysis Tools for desktops (see http://g.co/GNSSTools). In this course we will use these tools to analyze: L1 vs L5 sensitivity, L1-L5 group delay, Inter-system biases, and carrier-phase residuals (from which you can see things like phase-drift, and cycle slips). We will also show you custom filters on the raw measurement fields. Example: Do you want to analyze only those signals with C/No > 20 dBHz? Just specify ‘Cn0DbHz>20’ and the Analysis Tool takes care of it for you. Similarily, for any other Boolean operations on any of the twenty-six fields reported through the raw measurements API.

This class is a follow-on to “GNSS 101–An Introduction”. In GNSS 101 you will be introduced to the fundamentals of GNSS, including L5, group-delay, inter-system biases, and the basics of carrier phase. In GNSS 102, you will learn how to make actual measurements of these values from actual phones.

**Approaches for Resilient and Robust Positioning, Navigation and Timing (PNT)**

Diverse elements of international infrastructure are critically reliant on GNSS for precise location and time, often in ways that are not obvious. This tutorial provides a high-level perspective on the effects of interference on GNSS receivers and offers some possible threat mitigation approaches and policy recommendations. The tutorial starts with a discussion of potential GNSS threats and vulnerabilities. Then, after a quick review of how receivers determine position, the focus is on the effects of various interference types on select signals. The effects of ground mobile propagation in limiting effective jammer range are examined. Mitigations, such as adaptive arrays and IMU aiding, are discussed.

Civil jamming examples and incidents are covered, along with methods to detect, identify and mitigate against their effects. In particular, the importance of maintaining situational awareness for establishing environmental context is examined. Techniques for detecting civil spoofing and authenticating signals will be discussed.

**Logan Scott** has over 40 years of military and civil GPS systems engineering experience. He specializes in radio frequency signal processing and waveform design. He has pioneered approaches for building jamming-resistant digital receivers and has long advocated for hardening civil infrastructure. Logan is an ION Fellow and holds 42 patents.

**Using a Sextant: Celestial Navigation**

How do modern navigators use a sextant, chronometer, stars, and almanac information to solve for ship or aircraft position? The fundamentals are likely more straightforward than you realize! Today’s mariner typically uses six tools to solve for vessel position:

- An almanac (or computer) that predicts precise location of celestial bodies as a function of time;
- A reasonably accurate timepiece;
- A device to measure elevation angle of a celestial body (e.g., sextant);
- A “star finder”;
- A navigational chart; and
- A mathematical or tabular method to convert observations to contours (lines) of position.

This short course will cover some theory; however, the primary focus will be on the practice of using these six tools to solve for vessel position. Final discussions will focus on experiences with celestial navigation, with topics to include best times to shoot stars, horizon challenges, sources of error, and typical accuracy.

**Logan Scott** has over 40 years of military and civil GPS systems engineering experience. He specializes in radio frequency signal processing and waveform design. He has pioneered approaches for building jamming-resistant digital receivers and has long advocated for hardening civil infrastructure. Logan is an ION Fellow and holds 42 patents.

**Dr. Richard J. Hartnett** is a professor of Electrical Engineering at the U.S. Coast Guard Academy in New London, CT, having retired in 2009 from the USCG as a Captain (O-6). His current research interests include the mathematics of positioning, statistical signal processing methods in electronic navigation, and autonomous vehicle design.
Pre-Conference Tutorial Information

The ION GNSS+ pre-conference tutorials have been organized to provide in-depth learning of specific GNSS related disciplines prior to the start of the technical program. All courses will be taught in a classroom setting by some of the world’s leading GNSS educators.

Electronic course notes will be provided to attendees via the meeting website. Note that power will NOT be made available to course attendees for individual laptop computers; please come prepared with adequate battery power if required. It is also recommended that attendees dress in layers to accommodate varying temperatures in the facility.

Tutorial Registration: Registration for the ION GNSS+ tutorials is accomplished through the regular conference registration process, at a cost of $450 per tutorial. ION reserves the right to cancel a tutorial if adequate registration is not obtained. If a course is cancelled the full cost of the course will be refunded via the original payment method.

TUTORIAL SCHEDULE

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<td>Multi-constellation GNSS Signals and Systems</td>
<td>Dr. Chris G. Bartone</td>
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<td>Fundamentals of Inertial Navigation Systems and Aiding</td>
<td>Dr. Michael Braasch</td>
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<td></td>
<td>Kalman Filter Applications to Integrated Navigation 1</td>
<td>Dr. James L. Farrell / Dr. Frank van Graas</td>
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<tr>
<td>1:30 p.m.–5:00 p.m.</td>
<td>Introduction to Multiband and Multi-constellation SatNav Receivers using Python</td>
<td>Dr. Sanjeev Gunawardena</td>
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<tr>
<td></td>
<td>Autonomous System Navigation and Machine Learning</td>
<td>Dr. Mike Veth / Dr. Don Venable</td>
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<td></td>
<td>Kalman Filter Applications to Integrated Navigation 2</td>
<td>Dr. James L. Farrell / Dr. Frank van Graas</td>
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TUTORIAL DESCRIPTIONS

Tutorials: Tuesday Morning
9:00 a.m.–12:30 p.m.

Multi-constellation GNSS Signals and Systems
Course Level: Beginner
This course emphasizes the fundamentals of multi-constellation GNSS. The course begins with an overview of GNSS followed by presentation on each of the GNSS in operation and/or development today. The course will highlight common features of the various GNSSs and point out key differences between them. Topics to be covered include:

- GNSS Segments; space, ground, user segments
- GNSS Link Budget
- Fundamental concept of GNSS position and time determination
- GNSS Coordinate frames, datum’s and time
- GNSS antenna & receiver technologies—overview
- GNSS signal structure formats: Carrier, Code, Data
- Direct Sequence Spread Spectrum; auto and cross correlation
- GPS legacy and modernized signals:
  - GPS SV Blocks
  - Legacy GPS: C/A, P(Y) code and NAV formats
- Modernized GPS: L2C, L5, L1C, CNAV and CNAV-2 formats
- GLONASS
- GLONASS SV versions
- Legacy C/A, P codes and FDMA signals
- Modernized CDMA codes and frequencies
- Galileo, E1, E6/E6P, E5a, E5b, AlBOC, SAR Codes, frequencies and data formats
- BeiDou, BDS I, BDS II, BDS III, B1, B2, B3 signals and formats
- SBAS used throughout the Globe
- QZSS, L1, L2, L5, L6 signals, codes and services
- NAVIC: L5, S band signals, message types
- GNSS corrections for clock, code, atmospheric, transit time, etc.
- GNSS User Solutions

Fundamentals of Inertial Navigation Systems and Aiding
Course Level: Beginner
This tutorial will start by highlighting the basic principles of operation of an inertial navigation system. The course will focus initially on the concepts underlying the algorithms used to determine position, velocity and attitude from inertial sensor measurements. Key error characteristics will be described as well such as Schuler oscillation and vertical channel instability. We will also consider the impact of various sensor errors on system performance. The tutorial will continue by covering the basics of Kalman filtering and aided-inertial systems. The daunting matrix mathematics involved in the full algorithm can be extremely intimidating to the newcomer. The basic concepts of estimation theory will be briefly reviewed, and the Kalman Filter will be described first in terms of simple one-dimensional problems for which the full algorithm reduces to an approachable set of scalar equations. We will look at the performance of the filter in some simple case studies and by the end will have an intuitive feel for how the full filter operates. We will apply the Kalman filter to the aiding of inertial systems. We will see how external sources of position and velocity (such as GPS) can be used first to measure inertial system error and then, with the aid of the Kalman filter, to estimate and correct inertial sensor error as well as system error.

Dr. Chris G. Bartone, P.E.
is a professor at Ohio University with over 35 years of professional experience and is an ION Fellow. He received his PhD EE from Ohio University, a MSEE from the Naval Postgraduate School and BSEE from Penn State. Dr. Bartone has developed, and teaches, a number of GPS, radar, wave propagation and antenna classes. His research concentrates on all aspects of navigation.

[Dr. Chris G. Bartone Image]
Dr. Michael Braasch is the Thomas Professor of Electrical Engineering and a principal investigator with the Ohio University Avionics Engineering Center. Mike has over 30 years of experience in navigation research; and has taught graduate-level courses in inertial navigation, Kalman filtering and integrated navigation for the past 20 years. Dr. Braasch has also taught short courses on these subjects at all of the major inertial navigation system manufacturers in the United States. Dr. Braasch is an ION Fellow, a Senior Member of the IEEE and is an instrument-rated commercial pilot.

Kalman Filter Applications to Integrated Navigation 1

Course Level: The course is at the beginner-level and will enhance understanding of the principles of filtering at the beginner and intermediate levels.

The focus of this course is on the basic theory, an intuitive understanding as well as practical considerations, for the design and implementation of Kalman filters. Although many new types of filters are published in the literature, the Kalman filter is still the optimal and most efficient solution for the majority of integrated navigation systems. The course starts with a review of statistics and detailed insights into the most important noise processes, including random walk and Gauss-Markov processes. This is followed by a review of state variables and an overview of Kalman filters, including linear, linearized and extended filters. Matlab®-based examples are provided to facilitate hands-on experience with Kalman filters for integrated navigation applications.

For those having no previous experience with modern estimation, a review of fundamentals is included. Linear systems are characterized in terms of (1) a vector containing the minimum number of independent quantities required to define its state at any instant of time and (2) a matrix expression capable of propagating that state from one time to another. In combination with expressions relating measurements to states, a standard cycle is formed whereby a system’s entire time history is continuously produced, with the best accuracies achievable from any combination of sensors, extravagant or austere, providing any sequence of measurements that can be incomplete, intermittent and indirect, as well as imprecise. That already wide versatility is broadened further by straightforward extension to systems with nonlinearities (Extended Kalman Filter; EKF) which has proved adequate for a host of applications (including some to be discussed in this tutorial). The relation between Kalman (sequential) and block (weighted least squares) estimation is illustrated, and a number of important subtleties that often go unrecognized will be uncovered.
Autonomous System Navigation and Machine Learning

Course Level: Beginner to Intermediate

The revolution in autonomous vehicle development is providing novel solutions in an ever-growing range of applications. A critical component of autonomous vehicle design is the navigation system, which is required to provide a robust, accurate, navigation solution in a wide-range of operating environments. In this short course, we explore the concepts and technology associated with developing and testing navigation systems for autonomous vehicles, both using traditional multi-sensor fusion techniques and via artificial neural networks (i.e., deep learning).

The course begins with an overview of sensors commonly used for autonomous systems including inertial sensors, GNSS, laser scanners, and image-based sensors. The associated error models are developed for each sensor and examples are presented regarding performance using experimental data. Next, sensor integration approaches are developed including traditional Kalman filtering and proceeding to nonlinear filtering techniques. Comparisons are made regarding performance trade-offs for the various approaches. Finally, an overview of deep learning artificial neural network frameworks (CNN) and recurrent neural networks (RNN). The development will include both a theoretical and algorithmic perspective along with a review of hardware requirements for real-time implementation. Emphasis will be placed on designing a deep learning-based approach for navigation using a monocular camera sensor using open-source data.

Dr. Mike Veth is the co-founder of Veth Research Associates. His research focus is applying nonlinear estimation theory to optimally combine a wide variety of navigation and non-navigation sensors to enable robust autonomous applications. He received his BS in Electrical Engineering from Purdue University and a PhD in Electrical Engineering from the Air Force Institute of Technology. He has served the ION as Eastern Region Vice President, Dayton Section chair, session chair, track chair and program chair. Dr. Veth has authored over 40 technical articles and book chapters in areas relating to computer vision, navigation and control theory. He is a member of the ION, a Senior Member of the IEEE and a graduate of the US Air Force Test Pilot School.

Kalman Filter Applications to Integrated Navigation 2

Course Level: The course is designed to follow Kalman Filter Applications to Integrated Navigation 1 and Inertial Navigation, and will also be of benefit to intermediate-level attendees who are familiar with filtering concepts and inertial navigation principles.

Integration of GPS with an Inertial Measurement Unit (GPS/IMU) is used to illustrate the application of Kalman Filtering integrated navigation. The course starts with a brief summary of the Kalman Filter followed by the steps required to implement the filter, including the selection of the state variables, observability, error sources, sensor bandwidth, update rate, time synchronization, lever arm, and identification of the noise processes. At the conclusion of the course, participants should be able to understand the underlying principles that lead to the successful design and implementation of Kalman filters for integrated navigation applications.

The approach presented offers a major benefit of departure from other IMU/satnav integrations. Precise carrier phase observations one second apart provide streaming velocity for dead reckoning, yielding huge improvement in multiple aspects of performance (robustness, integrity, interoperability, immunity to low-precision carrier phase (LP-CM), radial Doppler shifts, multipath effects, tropospheric refraction, etc.). Flight-verified cm/sec velocity performance, including an instance of zero elevation above horizon, is shown. Of crucial significance, integration with a low-cost IMU is shown to be sufficiently dramatic to conclude that there is little reason not to use it.


Dr. Don Venable is currently a principal researcher at Veth Research Associates. Previously, he was a senior electronics engineer at the Navigation and Communications Branch of the Air Force Research Laboratory (AFRL), Sensors Directorate. His research focus is combining probabilistic deep learning with traditional Bayesian estimation theory for non-GPS navigation and object tracking applications. He received his PhD from the Air Force Institute of Technology and both his MS and BS in Electrical Engineering from Ohio University. For his dissertation research, he designed and built a novel optical navigation system for airborne applications. Dr. Venable is active in the Institute of Navigation.

Dr. Frank van Graas is a Fritz J. and Dolores H. Russ Professor of Electrical Engineering at Ohio University, where he has been on the faculty since 1988. He is the ION Past president (1998–99) and currently serves as the ION treasurer. He served as the ION’s Executive Branch Science and Technology Policy Fellow at NASA (2008-2009 academic year). At Ohio University his research includes GNSS, low-frequency signals, LADAR/EO/IR, surveillance and flight test. He is an ION Fellow and has received the ION’s Kepler (1996), Distinguished Service (1999), Thurlow (2002), and Burka (2010) awards.
ION GNSS+ Plenary Session
Tuesday, September 17, 2019 • 6:30 p.m.–8:30 p.m. • Jasmine Ballroom

Welcome, Meeting Highlights and Introduction of Technical Committee
Satellite Division Chair
Dr. Chris Hegarty
The MITRE Corporation

Opening of the Plenary Session
Satellite Division Vice Chair
Patricia Doherty
Boston College

Keynote Addresses

A Day Without Satellites
Dr. Pål Brekke
Norwegian Space Agency, Norway

It’s easy to overlook the central role satellites play today, simply because of how seamlessly they integrate into our daily lives. From tens of thousands of kilometers away, navigation satellites help us navigate with incredible precision. Our global communications systems would not work without satellites. Satellites also enable remote regions, ships and aircraft to communicate with the rest of the world. We use satellites for TV feeds, tracking ships, oil spill detection as well as providing accurate weather forecasts. But what if a superstorm from the Sun disrupts all satellites? What would be the impact on our technology-based society? This presentation will outline how it would be to wake up one morning to a day without satellites.

Dr. Brekke is a solar physicist and senior advisor at the Norwegian Space Agency. He worked for six years at NASA Goddard Space Flight Center as the Deputy Project Scientist for SOHO. He is a Norwegian delegate to several ESA Programme Boards and also a Professor at the University of Svalbard. Dr. Brekke is also an author of several international popular science books about the Sun and the Northern Lights translated into seven languages. He has recently produced the award-winning documentary "The Northern Lights – a Magic Experience." He is also a member of the exclusive Explorers Club in New York.

Journey to the Sun
Dr. Nicola Fox
Director, Heliophysics Division, NASA

NASA Heliophysics research studies a vast system stretching from the Sun to the Earth, to far beyond the edge of the planets. Studying this system - much of it driven by the Sun's constant outpouring of solar wind - not only helps us understand fundamental information about how the universe works, but also helps protect our technology and astronauts in space. NASA seeks knowledge of near-Earth space, because, when extreme space weather can interfere with our communications, satellites and power grids. The study of the Sun and space can also teach us more about how stars contribute to the habitability of planets throughout the universe.

Mapping out this interconnected system requires a holistic study of the Sun's influence on space, Earth and other planets. NASA has a fleet of spacecraft strategically placed throughout our heliosphere - from Parker Solar Probe at the Sun observing the very start of the solar wind, to satellites around Earth, to the farthest human-made object, Voyager, which is sending back observations on interstellar space. Each mission is positioned at a critical, well-thought-out vantage point to observe and understand the flow of energy and particles throughout the solar system - all helping us untangle the effects of the star we live with.

Dr. Fox is Heliophysics Division Director in the Science Mission Directorate at NASA Headquarters in Washington, D.C. Until August 2018, Dr. Fox worked at the Applied Physics Lab at the Johns Hopkins University where she was the chief scientist for Heliophysics and the project scientist for NASA’s Parker Solar Probe. Dr. Fox served as the deputy project scientist for the Van Allen Probes, and the operations scientist for the International Solar Terrestrial Physics program. Dr. Fox received her BS in Physics and PhD in Space and Atmospheric Physics from the Imperial College of Science, Technology and Medicine in London. She received an MD in Telematics and Satellite Communications from the University of Surrey.
Wednesday Morning, September 18, 8:30 a.m.–12:15 p.m.

Room: Brickell
8:30 a.m.–12:15 p.m.
Session A1: Applications of Raw GNSS Measurements from Smartphones

Dr. Mohammed
Khider Google

Dr. Wouter Pelgrum
NextNav

Dr. Mohamad Elnyany
HONGKONG UNIVERSITY, South Korea

Room: Flagler
8:30 a.m.–12:15 p.m.
Session B1: GNSS Augmentation Systems and Integrity 1

Dr. Eulho Kim
Hongik University, South Korea

Dr. Sam Pullen
Stanford University

Room: Monroe
8:30 a.m.–12:15 p.m.
Session C1: Land-Based Applications

Livio Marradi
Thales Alenia Space, Italy

Lionel Ries
European Space Agency, The Netherlands

8:35 The Performance of GNSS-IMU Integration of Smartphone Based on In-flight Calibration of IMU Using Android GNSS Raw Measurements: D. Shin, T. Lee, Korea Institute of Science and Technology, South Korea; B. Park, Sejong University, South Korea; E. Kim, Hongik University, South Korea

8:57 Assessment of GNSS Performance on Dual-Frequency Smartphones: M. Navarro-Gallardo, Airbus GmbH, Germany; J. Redelkiewicz, F. Dian, M. Sunkevicius, European GNSS Agency, Czech Republic; S. Damy, J. Fortuny-Guasch, Joint Research Centre of European Commission, Italy

9:20 PPP with External Antenna Addition on Smartphones: A. Blot, D. Laurichesse, C. Rouch, Centre National d’Etudes Spatiales, France; C. Granger, ALTRAN, France


10:04 Achieving Resilient 3D-Mapping-Aided GNSS through New Approaches to Outlier Detection: P. Groves and M. Adjrad, University College London, UK

11:03 GNSS NLOS Pseudorange Correction based on Skymask for Smartphone Applications: H-F. Ng, G. Zhang, L-T. Hsu, The Hong Kong Polytechnic University, Hong Kong

11:26 An Integrated GNSS/PPDR Fusion Navigation System with Raw Measurements from Smartphone: L. Guo, Wuhan University, China; J. Wang, Beijing UniStrong Science & Technology Co., Ltd., China; F. Wang, J. Sang, W. Liu, Wuhan University, China

11:48 GNSS POWER: An Innovative Stand-Alone Approach for Real-time Navigation: M. Fortunato and A. Mazzonni, Sapienza University of Rome, DICEA, Italy

Alternate
1. High Accuracy Application of Mobile GNSS Chipset Based on MediaTek Solution: P. H. Jau, H. Chen, CT Weng, MediaTek Inc., Taiwan

8:35 Fault-Free Integrity Analysis of Mega-Constellation-Augmented GNSS: D. Racelis, Virginia Tech; B. Pervan, Illinois Institute of Technology; M. Joerger, Virginia Tech


9:20 Assessment of Dual-frequency Signal Quality Monitor to Support CAT II/III GBAS: J. Song, C. Milner, I. Selmi, ENAC, Université de Toulouse, France; O. Julien, u-Blox AG, Switzerland

9:43 Ionospheric Delay Gradient Threat Model for GBAS based on GPS Data in China: Z. Wang, T. Li, Q. Li, Y. Zhu, Beijing University, China

10:40 Analysis of Test Statistic and Position Error Cross-Correlation Effect on Integrity Risk: E. Bang, C. Milner, C. Macabiau, ENAC, Université de Toulouse, France; E. Gallon, B. Pervan, Illinois Institute of Technology; P. Estival, DSNA, France

11:03 Advanced RAIM Demonstrator and Integrity Support Message Prototyping: I. Martin, European Commission, Belgium; M. Squammini, European Commission, Joint Research Center (JRC), Italy

11:26 Mass Market Lane Accuracy Positioning with High Integrity: R. Bryant, O. Julien, C. Hide, u-Blox, Switzerland; I. Shret, Polymath Insight Limited, UK

11:48 Integrity Algorithm of Kalman-Filter Based Multi-Sensor Navigation System for Sensor Fault in the Filter Prediction Step: J. Lee, M. Kim, D. Min, J. Lee, Korea Advanced Institute of Science and Technology, South Korea

Alternates
1. Quantifying Integrity Risk over Exposure Time Intervals: X. Zhu, Z. Hu, S. Wang, Shanghai Jiao Tong University, China; B. Pervan, Illinois Institute of Technology

2. A Dual-frequency Ground Based Augmentation System Prototype for GPS and BDS: Y-T. Sung, Y-W. Lin, S-J. Yeh, S-S. Jan, National Cheng Kung University, Taiwan

3. Tighter GDOP Bounds and Their Use in Satellite Subset Selection: F. Swaszek, University of Rhode Island; R.J. Hartnett, K.C. Seals, U.S. Coast Guard Academy; R.M.A. Swaszek, Boston University


9:20 Autonomous Vehicle High-Accuracy Position and Integrity Engine Performance Results: E. Dominguez-Tilero, A. Chamorro Moreno, M.T. Fernandez Calzon, GMW, Spain; J. Garcia, FICOSA, Spain; J. Ibanez-Guzman, E. Stawiarski, RENAULT, France; P. Xu, University of Technology of Compiègne, France; G. Avellone, F. Pisoni, STMicroelectronics, Italy; E. Falletti, LINKS Foundation, Italy; M. Ortiz, IFSTTAR, France

9:43 Assessing the Performances of Hybridized GNSS Receivers in Railway Environment: G. Carrie, C. Gernot, Syntony GNSS, France; A. Barre, SNCF, France; J. Korsakissok, Syntony GNSS, France

10:40 A New GNSS-PPP/INS Data Fusion for Global Infrastructureless Safe Train Positioning: M. Cunha, S. Meyer, JXblue, France; F. R. Legros, GEOFLX, France; D. Laurichesse, N. Karouche, CNES, France; A. Barre, SNCF, France

11:03 A Tightly-Coupled GNSS/INS/MM Integration System Based on Binary Search Algorithm for Train Localization Applications: D. Liu, Beijing Jiaotong University (BITU), China; W. Jiang, BITU, Beijing Engineering Research Center of EMC and GNSS Technology for Rail Transportation, China; B. Cai, State Key Laboratory of Rail Traffic Control and Safety, BITU, EMC and GNSS Technology for Rail Transportation, China; J. Wang, W. Shangguan, BITU, EMC and GNSS Technology for Rail Transportation, China

11:26 Galileo and EGNS Adoption in Automotive Emergency Call System (eCall): K. Boniface, C. Gioia, M. Suss, J. Fortuny-Guasch, European Commission, Joint Research Centre, Italy; F. Shardelli, European GNSS Agency, Czech Republic

11:48 Hybridizing GNSS with Sensors and Terrestrial Technologies for Positioning in 5G: G. Cueto-Felgueroso, GMW, Spain; F. Grec, ESA; J.A. del Peral-Rosado, G. Seco-Granados, UAB, Spain; C. Gentner, E. Staudinger, German Aerospace Center (DLR), Germany; D. Bartlett, u-blox; E. Serna, Telefónica I+D, M. Azaola, A. Fernández, F. Blázquez, F. Mata, GMW, Spain; R. Prieto–Cerdeira, L. Ries, ESA

Alternates
1. Interference Detection and Position Improvement Using Android Smartphone, raw Measurements, SNR and NLOS Detection: S. Roberts, L. Bonenberg, C. Hancock, O. Ogundipe, F. Basile, X. Meng, R. Qu, J. Jing, University of Nottingham, UK

2. GNSS/Inertial Vehicular Engine (GIVE) for Automotive Navigation: A. Soloviev, A. Vadlamani, J.D. Sharon, C. Yang, QuNav

3. Filtering and Sensor Augmentation for GPS Measurements in WildLife Tags: M. Lichtenstein and G.H. Elkaim, UC Santa Cruz
10:05 a.m. - 10:35 a.m. Morning Refreshments in the Exhibit Hall, sponsored by:

SYSTRON DONNER INERTIAL
An EMCORE Company

Room: Tuttle
8:30 a.m.–12:15 p.m.
Session D1: Connected and Collaborative Autonomy

Dr. Nadezda Sokolova
Sintef, Norway

Dr. Steffen Schön
Leibniz Universität Hannover

Experts from academia, government and industry will discuss the different security threats to GNSS signal reception including jamming, spoofing and data forgery. Several strategies to strengthen GNSS signal reception and improve PNT security will be analyzed along with the different national and international initiatives currently under development for the protection of the GNSS ecosystem. New opportunities opened by technological advancements, such as the availability of raw measurements from smartphones and the possibility of multisensor PNT verification, will be discussed from the GNSS security perspective.

Panel Members:
1. An Assessment of the Effect of RFI Threats on GNSS-based Downstream Applications: Dr. Fabio Dovis, Politecnico di Torino, Italy
2. Roadmap to Delivering U.S. Civil Complementary PNT Capabilities: Ms. Karen Van Dyke, U.S. Department of Transportation
3. European Contributions to Protect GNSS: Dr. Ignacio Fernández-Hernández, European Commission, Belgium
4. Embracing Diversity: How to Achieve Robust and Secure PNT: Dr. Zak Kassas, University of California, Irvine
5. Robustness Through Sensor Fusion: Dr. John Raquet, JHU
6. Insights from two Years of GNSS Interference Observations from Space: Dr. Todd Humphreys, University of Texas at Austin

Room: Jasmine
8:30 a.m.–12:15 p.m.
Session E1: PANEL: PNT Security and Robustness

Dr. Oscar Pozzobon
Qascom, Italy

Logan Scott
LS Consulting

8:35 Quantitative Scintillation Diagnostics Using Total Electron Content from Commercial Off-The-Shelf GNSS Receivers: C.S. Carrano, K.M. Groves, C.L. Rino, P.H. Doherty, Boston College
8:57 Simulating Realistic Ionospheric Scintillation of GPS Signals for Robust PNT Testing: T. Pinto Jayawardena, Sprent Communications and University of Bath, UK; C. Mitchell, University of Bath, UK; R. Boyles, Sprent Communications, UK; J. Bravo, K. Bolm gren, A.M. Ali, University of Bath, UK; G. Buesnel, Sprent Communications, UK; B. Forte, R. Watson, University of Bath, UK
10:40 A New Method to Estimate Ionospheric Irregularity Drift Velocity Using ROT and Spared GNSS Reference Stations: B. Park, C. Lim, Sejong University, South Korea; J. Wang, National Oceanic and Atmospheric Administration; Y.J. Morton, University of Colorado Boulder
11:03 New Space Weather Measurements from MACAWS: Monitors for Alaskan and Canadian Auroral Weather in Space (MACAWS): A.J. Foster, MIT Haystack Observatory, S. Skone, University of Calgary, Canada; D. Hampton, University of Alaska, Fairbanks; E. Donovan, E. Spanswick, University of Calgary, Canada
11:26 Design and Development of an Improved Sensitivity Reconﬁgurable GNSS Receiver for Space-based Reflectometry: S. Guruprasad, York University, Canada
11:48 Impact of Tropospheric Anomalies on Ground-to-Air Radio Navigation Systems: S. Narayanan, C. Günther, O. Oeschas, German Aerospace Center (DLR), Germany

Alternates:
1. A Comparative Study of Amplitude Scintillation (S4-index) on Different GNSS L-band Frequencies in Association of Sporadic-E over Northern Crest of Magnetic Dip Equator near Arabian Peninsula: M.M. Shaikh, G. Gopakumar, A. Maxoudi Dany, United Arab Emirates
2. Assimilation Experiments of GNSS-derived T2D and Sentinel Satellite-derived Products into the WRF Numerical Model to Improve Forecasts of Severe Rain Events: E. Realini, Geomatics Research & Development srl, Italy; M. Lagasso, L. Pulvirenti, A. Parodi, CIMR Research Foundation, Italy; A. Gatti, C. Tagliaferro, Geomatics Research & Development srl, Italy; G. Venuti, S. Barndell, Politecnico di Milano, Italy; E. Passera, A. Rucci, TREL Altamura srl, Italy; N. Pierdicca, Sapienza University of Rome, Italy; B. Rommen, European Space Agency, ESA-ESTEC, The Netherlands
3. Investigation of Important Aspects of GNSS/InSAR Techniques Integration for Atmospheric Water Vapor Retrieval: E. Shejai, K. Wilgan, A. Geiger, Institute of Geodesy and Photogrammetry, Switzerland
4. Forecasting Ionospheric Delays using GPS Observations with Deep Neural Networks: A Bi-directional Long Short-Term Memory: D. Venkata Ratnam, I. Sivirani, P. Sree Harsha, KLEF Deemed to be University, India

Room: Orchid
8:30 a.m.–12:15 p.m.
Session F1: Atmospheric Science and Space Applications with GNSS

Dr. Attila Komjathy
NASA JPL, Italy

Dr. Lucia Alfonsi
INGV, Italy

8:57 Multi-Epoch Multi-Agent Collaborative Localization Using Grid-based 3DMA GNSS and Inter-Agent Ranging: S. Tanwar, G.X. Gao, Stanford University
9:20 Cooperate Localized of Networked Multi-agent System: J. Lin, J.J. Gehrt, R. Zweigel and D. Abel, RWTH Aachen University, Germany
10:40 Analysis of Rank-1 Updating in Decentralized Estimation for Collaborative Navigation: C. Yang, A. Soloviev, QuNav; A. Rutkowsky, Air Force Research Laboratory
11:03 Integrity Monitoring Algorithm for GNSS-based Cooperative Positioning Applications: C. Zhuang, H. Zhao, S. Hu, C. Sun, W. Feng, Beihang University, China
11:13 Distributed Cooperative Inter-Agent Ranging Via a Network of Receivers: S. Bhamidipati, University of Illinois

Alternates:
1. Optimizing Sensor Combinations and Processing Parameters in Dynamic Sensor Networks: N. Garcia Fernandez and S. Schön, Leibniz Universität Hannover, Germany
2. Range-only Collaborative Localization for Ground Vehicles: Q. Shi, X. Cui, S. Zhao, M. Lu, Tsinghua University, China
4. Sliding Mode Control for Vehicular Platoon Based on V2V Communication: H. Li, J. Yin, H. Li, V. Pickert, S. Dlay, Newcastle University, UK; R. Tiwari, Nottingham Scientific Ltd., UK
Wednesday Afternoon, September 18, 1:45 p.m.–5:30 p.m.

Room: Brickell
1:45 p.m.–5:30 p.m.
Session A2: Navigation in Urban Environments

1:50 A Precise Vehicle Localization Based on LTE Surface Correlation in Tunnel using Smartphone Only: B. Shin, J. Lee, Korea Institute of Science and Technology, South Korea (KIST); S. Jeon, J. Kim, Kakao Mobility, South Korea; T. Lee, KIST, South Korea


2:35 CoDRIVE – Delivering High Accuracy, Ubiquitous Positioning through Combined Radio Navigation and Inertial Sensing Technologies: S. Roberts, X. Meng, J. Jing, C. Xu, Y. Cui, University of Nottingham, UK; G. Ye, UbipOS UK Ltd., UK; L. Bonenborg, University of Nottingham, UK

2:58 Predicting Collision Probability for GNSS-based UAV Path Planning Using Stochastic Reachability: A. Shetty, University of Illinois Urbana-Champaign; G.X. Gao, Stanford University

4:00 Localizing in Urban Canyons using Joint Doppler and Rangeing and the Law of Cosines Method: W. Jun, Georgia Institute of Technology; K.-M. Cheung, Jet Propulsion Laboratory (JPL); E.G. Lightsey, Georgia Institute of Technology; C. Lee, JPL


5:08 Traffic Light Control for Emergency Vehicles Using Robust and Continuous Galileo PRS Positioning in Urban Environments: C. Strobel, Fraunhofer IIS, Germany; J. Wendel, A. Waelkens, D. Pfaffelhuber, Airbus, Germany; M. Overbeck, A. Rügamer, W. Felber, Fraunhofer IIS, Germany

Alternates


4. Ambiguity Resolution by Mixture Kalman Filter for High-Precision GNSS: K. Berntorp, A. Weiss, S. Di Cairano, Y. Sato, Mitsubishi Electric Corporation

This session provides an update on the world’s satellite-based navigation system. 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.

Panel Members:
1. GPS: Col John Claxton, U.S. Air Force Space and Missile Systems Center
2. GLONASS: Dr. Sergey Karutin, Deputy Director General, Central Research Institute for Machine Building, Russia (Invited)
3. Galileo: Mr. Eric Chatre, European Commission, Belgium; Mr. Francisco Javier Benedico Ruiz, Galileo Project Manager, European Space Agency, Belgium
5. QZSS: Mr. Satoshi Kogure, Executive Director for QZSS Development, National Space Policy Secretariat, Japan
6. NavIC: Representatives from NavIC (Invited)

Room: Jasmine
1:45 p.m.–5:30 p.m.
Session B2: PANEL: Status of GPS, GLONASS, Galileo, BDS, QZSS and NavIC

1:50 Putting “Performance” Into Aircraft Approach Navigation: A. Lipp, EUROCONTROL, France

2:12 Development of Advanced RAIM Minimum Operational Performance Standards: J. Blanch, T. Walter, Stanford University; G. Berz, EUROCONTROL, Belgium; J. Burns, B. Clark, Federal Aviation Administration; M. Joerger, Virginia Tech; M. Mabiléau, European GNSS Agency; I. Martini, European Commission, Belgium; C. Milner, ENAC, France; B. Pervan, Illinois Institute of Technology; Y. Lee, The MITRE Corporation


2:58 Initial Results for Dual Constellation Dual-frequency Multipath Models: M.-S. Ciruelo, M. Felux, S. Caizzone, C. Enneking, F. Fohlmeister, M. Riipi, German Aerospace Center (DLR), Germany; I. Gulie, D. Rueegg, Airbus Defence and Space, Germany; J. Griggs, Collins Aerospace; R. Lazzerini, F. Hagemann, F. Tranchet, Airbus Operation SAS; P. Bouniol, Thales Avionics, France

4:00 GNSS Multipath Error Model for Aircraft Surface Navigation Based on Canonical Scenarios for Class F Airport: C. Amielh, A. Chabory, C. Macabiau, ENAC, France; L. Azoulai, Airbus, France


4:46 Airborne Antenna and Multipath Error Characterization for DFI-DR Error Standardization: S. Caizzone, M.-S. Ciruelo, W. Elmarissi, C. Enneking, A. Winterstein, German Aerospace Center (DLR), Germany

5:08 Optimized Low Level Trajectories for Instrument Flight Rules in Alpine Areas: R. Pott, Institute of Geodesy and Photogrammetry, ETH, Switzerland; S. Guillaume, Institute of Geodesy and Photogrammetry, ETH, and Institut d’ingénierie du territoire, heig-vd, Switzerland; A. Geiger, Institute of Geodesy and Photogrammetry, ETH, Switzerland; H. Wipf, Airnav Consulting, Switzerland

Alternate
1. Improvement of Positioning Accuracy with GNSS using User Range Accuracy and Posterior Variance Model: J. Wang, Q. Li, R. Liu, Civil Aviation University of China, China

Room: Orchid
1:45 p.m.–5:30 p.m.
Session C2: Aviation and Aeronautics

1:50 STREAMING GNSS and Space-Time Applications: I. Blasone, European GNSS Agency, France

2:12 Development of Advanced RAIM Minimum Operational Performance Standards: J. Blanch, T. Walter, Stanford University; G. Berz, EUROCONTROL, Belgium; J. Burns, B. Clark, Federal Aviation Administration; M. Joerger, Virginia Tech; M. Mabiléau, European GNSS Agency; I. Martini, European Commission, Belgium; C. Milner, ENAC, France; B. Pervan, Illinois Institute of Technology; Y. Lee, The MITRE Corporation


2:58 Initial Results for Dual Constellation Dual-frequency Multipath Models: M.-S. Ciruelo, M. Felux, S. Caizzone, C. Enneking, F. Fohlmeister, M. Riipi, German Aerospace Center (DLR), Germany; I. Gulie, D. Rueegg, Airbus Defence and Space, Germany; J. Griggs, Collins Aerospace; R. Lazzerini, F. Hagemann, F. Tranchet, Airbus Operation SAS; P. Bouniol, Thales Avionics, France

4:00 GNSS Multipath Error Model for Aircraft Surface Navigation Based on Canonical Scenarios for Class F Airport: C. Amielh, A. Chabory, C. Macabiau, ENAC, France; L. Azoulai, Airbus, France


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5:08 Optimized Low Level Trajectories for Instrument Flight Rules in Alpine Areas: R. Pott, Institute of Geodesy and Photogrammetry, ETH, Switzerland; S. Guillaume, Institute of Geodesy and Photogrammetry, ETH, and Institut d’ingénierie du territoire, heig-vd, Switzerland; A. Geiger, Institute of Geodesy and Photogrammetry, ETH, Switzerland; H. Wipf, Airnav Consulting, Switzerland

Alternate
1. Improvement of Positioning Accuracy with GNSS using User Range Accuracy and Posterior Variance Model: J. Wang, Q. Li, R. Liu, Civil Aviation University of China, China

3:25 p.m. - 3:55 p.m. - Afternoon Refreshments in the Exhibit Hall, sponsored by: Trimble

5:30 p.m.–7:30 p.m., Reception in Exhibit Hall
Wednesday, September 18, 1:45 p.m.–5:30 p.m.

**Room: Tuttle**
1:45 p.m.–5:30 p.m.  
Session D2: Innovations for Robotic Vehicle Applications

**Room: Flagler**
1:45 p.m.–5:30 p.m.  
Session E2: GNSS Augmentation Systems and Integrity 2

**Room: Monroe**
1:45 p.m.–5:30 p.m.  
Session F2: GNSS Signal Processing in Degraded Environments 1

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1:50 Carrier Phase Error Characterization under Scintillation for Future Aviation Standards using PPP Corrections: M. Sgammini, European Commission, Joint Research Centre, Italy; I. Martini, European Commission, Belgium

1:55 Extended Short Multopath Insensitive Code Loop: X. Weng, Beihang University and Keysight Technologies (China) Co., Ltd., China; Y. Kou, Beihang University, China

2:00 Characterizing the Carrier Phase Distortions for Different Interference Mitigation Approaches using an Uncalibrated Antenna Array: T. Bamberg, M. Meurer, German Aerospace Center (DLR), RWTH Aachen University, Germany

2:05 GNSS Multipath Detection and Mitigation Using Multi-Frequency Signals: S. Zhang, S. Lo, J.D. Powell, Stanford University

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2:15 Vertical Protection Level Estimation for Direct Constellation: J. Gehrnt, M. Nitsch, D. Abel, R. Zweigel, RWTH Aachen University, Germany

2:20 Interference and Spoofing Resilient Attitude Estimation Using Observations from Distributed Linear Subarrays Separated by Long Baselines: M. Brachvogel, M. Niestroj, S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany; S.N. Hasnain, R. Stephan, M.A. Hein, Technische Universität Ilmenau, Germany

2:25 GNSS Multipath Detection and Mitigation Using Multiple Signal Quality Monitoring (SQM) Metrics Jointly: C. Sun, Beihang University, China; J.W. Cheong, A.G. Dempster, University of New South Wales, Australia; H. Zhao, C. Zhuang, Beihang University, China

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2:40 Network-Based Ionospheric Gradient Monitoring to Support GBAS: M. Caamaño, M. Felix, D. Gerbeth, German Aerospace Center (DLR), Germany; J.M. Juan, G. Gonzalez-Casado, J. Sanz, Polytechnic University of Catalonia, UPC, Spain

2:45 GNSS Multipath Detection by Ionospheric Scintillation: S. Saio, and T. Yoshihara, National Institute of Maritime, Port, and Aviation Technology, Japan

2:50 Vertical Protection Level Estimation for Direct Positioning Using a Bayesian Approach: S.V. Singh Chauhan, University of Illinois at Urbana Champaign; G.X. Gao, Stanford University

Alternates

1. GNSS Multipath Detection by Using Multiple Signal Quality Monitoring (SQM) Metrics Jointly: C. Sun, Beihang University, China; J.W. Cheong, A.G. Dempster, University of New South Wales, Australia; H. Zhao, C. Zhuang, Beihang University, China

2. Interference and Spoofing Resilient Attitude Estimation Using Observations from Distributed Linear Subarrays Separated by Long Baselines: M. Brachvogel, M. Niestroj, S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany; S.N. Hasnain, R. Stephan, M.A. Hein, Technische Universität Ilmenau, Germany


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2:55 Propagation of the Aurora Ecosystem: M. Kirkko-Jaakkola, Finnish Geospatial Research Institute, Finland

3:00 Low-Cost GNSS Aiding by Visual Odometry, Radar and 3D Maps: R. Lesjak, A. R. Koller, M. Klöpschitz, U. Kleb, G. Djuras, R. Ladstädt, S. Ladstätter, M. Rüther, Joanneum Research, Austria


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3:10 GNSS Multipath Detection by Using Multiple Signal Quality Monitoring (SQM) Metrics Jointly: C. Sun, Beihang University, China; J.W. Cheong, A.G. Dempster, University of New South Wales, Australia; H. Zhao, C. Zhuang, Beihang University, China

3:15 Interference and Spoofing Resilient Attitude Estimation Using Observations from Distributed Linear Subarrays Separated by Long Baselines: M. Brachvogel, M. Niestroj, S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany; S.N. Hasnain, R. Stephan, M.A. Hein, Technische Universität Ilmenau, Germany


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3:25 Hybridization of GNSS and On-Board Sensors for Validating the Aurora Ecosystem: M. Kirkko-Jaakkola, Finnish Geospatial Research Institute, Finland


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3:40 GNSS Multipath Detection by Using Multiple Signal Quality Monitoring (SQM) Metrics Jointly: C. Sun, Beihang University, China; J.W. Cheong, A.G. Dempster, University of New South Wales, Australia; H. Zhao, C. Zhuang, Beihang University, China

3:45 Interference and Spoofing Resilient Attitude Estimation Using Observations from Distributed Linear Subarrays Separated by Long Baselines: M. Brachvogel, M. Niestroj, S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany; S.N. Hasnain, R. Stephan, M.A. Hein, Technische Universität Ilmenau, Germany


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3:55 Propagation of the Aurora Ecosystem: M. Kirkko-Jaakkola, Finnish Geospatial Research Institute, Finland

4:00 Low-Cost GNSS Aiding by Visual Odometry, Radar and 3D Maps: R. Lesjak, A. R. Koller, M. Klöpschitz, U. Kleb, G. Djuras, R. Ladstädt, S. Ladstätter, M. Rüther, Joanneum Research, Austria


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4:10 GNSS Multipath Detection by Using Multiple Signal Quality Monitoring (SQM) Metrics Jointly: C. Sun, Beihang University, China; J.W. Cheong, A.G. Dempster, University of New South Wales, Australia; H. Zhao, C. Zhuang, Beihang University, China

4:15 Interference and Spoofing Resilient Attitude Estimation Using Observations from Distributed Linear Subarrays Separated by Long Baselines: M. Brachvogel, M. Niestroj, S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany; S.N. Hasnain, R. Stephan, M.A. Hein, Technische Universität Ilmenau, Germany


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4:25 Hybridization of GNSS and On-Board Sensors for Validating the Aurora Ecosystem: M. Kirkko-Jaakkola, Finnish Geospatial Research Institute, Finland


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4:40 GNSS Multipath Detection by Using Multiple Signal Quality Monitoring (SQM) Metrics Jointly: C. Sun, Beihang University, China; J.W. Cheong, A.G. Dempster, University of New South Wales, Australia; H. Zhao, C. Zhuang, Beihang University, China

4:45 Interference and Spoofing Resilient Attitude Estimation Using Observations from Distributed Linear Subarrays Separated by Long Baselines: M. Brachvogel, M. Niestroj, S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany; S.N. Hasnain, R. Stephan, M.A. Hein, Technische Universität Ilmenau, Germany

Within today’s transportation systems, there exists a wide spectrum of automation as it applies to navigation; from systems involving no aspects of automation to those that are fully automated, even autonomous. There is a clear trend widening the scope of automation that is enabled by robust navigation. Cars, ships, trains, and aircraft are all poised to integrate these functions in an effort to improve transportation safety, capacity, and efficiency. In the case of today’s aircraft, which still assume the on-board presence of a trained pilot to serve as the ultimate mitigation against risk and unforeseen contingency events, this increase in automation will necessarily change the role of the pilot, as well as the automation. Considerations must be made to determine the appropriate level of automation for an application and how to balance that with human and other system interaction. Representatives from academia, government, and industry will discuss their thoughts on the spectrum of automation and the challenges associated with integrating automation into commercial and mass market applications.

Panel Members:
1. Nunzio Gambale, CEO, Locata Corp., Australia
2. Jim Barrett, Manager, Technology Services, BNSF Railway Co
3. Doug Harrington, Dep. Director, DOT/MARAD
4. Jonathan Koopmann, Chief, Technology, Innovation, & Policy Division, Volpe Center

ROOM: JASMINE
8:30 a.m.–12:15 p.m.
Session A3: PANEL: The Spectrum of Automation in Navigation

- Dr. Andrew Hansen, US Department of Transportation
- Dr. Fabrice Kunzi, General Atomicis AIS
- Mitch Harinis, Strategic Synergies, LLC
- Dr. Jiwon Seo, Yonsei University, South Korea

8:57 Multi Gaussian Distribution for ARAIM SISRE Overbound: S. Pereira, Airbus Defence and Space GmbH, and RWTH Aachen University, Germany; M. Meurer, German Aerospace Center (DLR) and RWTH Aachen University, Germany; B. Pervan, Illinois Institute of Technology, South Korea
9:20 Particle RAIM for Integrity Monitoring: S. Gupta and G.X. Gao, Stanford University
9:43 Definition of a European GNSS Timing Service: R. Piriz, J. Figado, A. Cezón, A. Fernández, GMV, Spain; M. Bolchi, VVA; A. Bauch, PTB; P. Defraigne, ORB, Belgium; A. Danesi, M. Jeannot; J.P. Boyero, European Commission, Belgium
10:40 A Kinematic Campaign to Evaluate EGNOS 1046 Maritime Service: D. Ibáñez Segura, A. Rovira García, J. Sanz, J.M. Juan, G. González Casado, M.T. Alonso, Universitat Politècnica de Catalunya, Spain; J.A. López Salcedo, Universitat Autònoma de Barcelona, Spain; H. Jia, Cranfield University, UK; F.J. Pancorbo García, C. García Daroca, I. Martín Calle, S.R. Abadía Heredia, EVERIS, Spain; M. López Martínez, European GNSS Agency, Czech Republic

Alternates
1. Entering the LEO Navigation Augmentation era—the Development and Progress of Luojia-1A Satellite in Wuhan University: L. Wang, R. Chen, Wuhan University, China; B. Yu, C. Wu, State Key Laboratory of Satellite Navigation System and Equipment Technology, China
2. A Global Navigation Augmentation System Based on LEO Communication Constellation: Y. Meng, L. Bian, L. Han, W. Lei, T. Yan, CAST Xi’an, China
3. LEO-based Navigation Augmentation Technology Test: R. Luo, Y. Xu, H. Yuan, Y. Tang, Chinese Academy of Science, China

ROOM: FLAGLER
8:30 a.m.–12:15 p.m.
Session B3: GNSS Augmentation Systems and Integrity

- Dr. Mitch Harinis, Strategic Synergies, LLC
- Dr. Jiwon Seo, Yonsei University, South Korea
- Mitch Harinis, Strategic Synergies, LLC
- Dr. Jiwon Seo, Yonsei University, South Korea

8:35 Considering SBAS and Marine Radiobeacon Corrections to Support Safe Maritime Operations: A. Grant and G. Shaw, The General Lighthouse Authorities of the UK and Ireland
8:57 A Measurement Based Accuracy Prediction of Terrestrial Radio Navigation System for Maritime Backup in South Korea: Y. Han, P-W. Son, S. Lee, S.G. Park, T.H. Fang, S. Park, Korea Research Institute of Ships and Ocean Engineering (KRODO), South Korea
9:20 Bridging Maritime GNSS Jamming Attacks by GNSS IMU-DVL Multi-Sensor-Fusion: R. Ziebeld, German Aerospace Center (DLR), Germany; M. Romanovas, BASELABS GmbH, Germany; D. Arias Medina, Ch. Lass, S. Giewies, DLR, Germany
9:43 The Implementation of an Autonomous Surface Vessel Prototype: X. Tang, Southeast University, China; C. Li, S. Yin, Shanghai Aerospace Control Technology Institute, China; Y. Wang, Z. Wu, Nanjing University of Science and Technology, China; Q. Meng, Hong Kong Polytechnic University, T. Zhang, Southeast University, China;
11:03 The SAR Galileo Return Link Service Operational Concept: S. Delattre, C. Scaleggi, M. Fontanier, French Space Agency CNES, France; J. Benoist, P. Novell, European GNSS Agency GSA, France
11:48 Sharing Ships’ Weather Data via AIS: B. Tetreault, USACE; G.W. Johnson, Alion Science and Technology

Alternates
1. Unscented Kalman Filter Based Carrier Tracking to Mitigate Ionospheric Scintillation Threat in High-latitude for Maritime PNT: R. Tiwari and J. Yin, Nottingham Scientific Ltd., UK; S.E. Christiansen, Kongsberg Seatecs AS, Norway
2. EGNOS Performance Navigation on Board of Oceanographic Hespérides Vessel: E. Lacarra, R. González, T. Seoane, ESSP, Spain; Manuel López, GSA
3. Transmission of EGNOS Corrections via IALA Beacons and AIS/VDES Stations: M. López, GSA; M. Cano, R. Martínez, ALG; C. Álvarez, L. Tavira, Indra, Spain; J. Morán, V. Antón, J. Vázquez, ESSP SAS, Spain

ROOM: ORCHID
8:30 a.m.–12:15 p.m.
Session C3: Marine Applications and Search and Rescue

- Dr. Fiammetta Diani, European GNSS Agency, Czech Republic
- Dr. Lisa Mazzuca, NASA Search and Rescue
- Fiammetta Diani, European GNSS Agency, Czech Republic
- Dr. Lisa Mazzuca, NASA Search and Rescue

10:05 a.m. - 10:35 a.m. - Morning Refreshments in the Exhibit Hall, sponsored by: Collins Aerospace

12:15 p.m. –1:15 p.m., Buffet Lunch, Exhibit Hall • 1:15 p.m.–1:45 p.m., Free Time in Exhibit Hall
Room: Monroe  
8:30 a.m.–12:15 p.m.  
Session D3: Navigation Using Environmental Features

Kimia Shamaei  
University of California, Irvine

Dr. Zhou Zhu  
East Carolina University

8:35  
LIDAR SLAM Using Normal Distribution Transform and Measurement Consensus: A.V. Kanhere and G.X. Gao, Stanford University

8:57  

9:20  
Feature Error Model for Integrity of Pattern-based Visual Positioning: C. Zhu, C. Steinmetz, B. Belabas, and M. Meurer, German Aerospace Center (DLR), Germany

9:43  
3D Mapping Aided GNSS-Based Cooperative Positioning Using Factor Graph Optimization: G. Zhang, The Hong Kong Polytechnic University, China

10:40  
5G-Microwave Tracking Performance Characterization: A. Pink Soderini, P. Thevenon, C. Macabiau, ENAC, France; L. Borgagni, Orolia/Spectracom, France; J. Fischer, Orolia/Spectracom, USA

11:03  
Image Aided Point-wise Autonomous Annotation for LIDAR Data: Y. Li, L. Pei, D. Zou, Y. Zhu, T. Li, X. Liang, Shanghai Jiao Tong University, China

11:26  
WiFi Fingerprinting and Tracking Using Neural Networks: P. Wu, Tales Imbiriba, G. LaMountain, Northeastern University, USA; J. Vilà-Valls, University of Toulouse, France; P. Closas, Northeastern University

11:48  

Alternates

1.  

2.  
New Passive Acoustic Monitoring System for Automotive Parking Guidance: K. Zheng, Y. Jiang, Dalian Maritime University, China

Blue Text Indicates Student Paper Award Winner

Room: Brickell  
8:30 a.m.–12:15 p.m.  
Session E3: Aided GNSS and Sensor Fusion in Challenging Environments 1

Dr. Melanie Sassi  
European Commission, IRC, Italy

Dr. Juan Blanch  
Stanford University

8:35  
DGNS/Vision Integration for Robust and Accurate Spacecraft Navigation: V. Capuano, A. Harvard, S-J. Chung, Aerospace Robotics and Control Laboratory, California Institute of Technology

8:57  
Combining Inertially-augmented Coherent Integration (Supercorrelation) with 3D-Mapping-Aided GNSS: P.D. Groves, M. Adjrad, University College London, UK; R. Faragher, M. Powe, P. Estevos, Focal Positioning, UK

9:20  
Evaluation of a Tight GNSS/INS Integration Based on Robust Estimators in Automotive Scenarios: O. Garcia Crespillo, German Aerospace Center (DLR), Germany; J. Skaloud, EPFL, Switzerland; M. Meurer, DLR, Germany

9:43  
Integrated Attitude Determination via GNSS Carrier Phase and Inertial Aiding: D. Medina, German Aerospace Center (DLR), Germany & Universidad Carlos III de Madrid, Spain; G. Giorgi, DLR, Germany; V. Centrone, DLR, Germany & Politecnico di Torino, Italy; R. Ziebold, DLR, Germany; J. Garcia, Universidad Carlos III de Madrid, Spain

10:40  
An Ambiguity-free Smoothing Algorithm for Multipath Mitigation in INS/RTK Tightly-Coupled Integration: W. Li, X. Cui, M. Lu, Tsinghua University, China

11:03  
On the use of an Ultra-tight Integration for Robust Navigation in Jammed Scenarios: C. Cristodaro, Politecnico di Torino, Italy; G. Falco, LINKS Foundation, Italy; L. Ruotsalainen, University of Helsinki and Finnish Geospatial Research Institute, Finland; F. Dovis, Politecnico di Torino, Italy

11:26  
Low-cost, Dual-frequency PPP GNSS and MEMS-IMU Integration Performance in Obstructed Environments: S. Vana and S. Bisnath, York University, Canada

11:48  
Performance Comparison of GNSS/INS Integrations Based on EKF and Factor Graph Optimization: W. Wen, Y.C. Kan, L.T. Hsu, The Hong Kong Polytechnic University, Hong Kong

Alternates

1.  
Open Source Software-defined-receiver Using Assisted GNSS Technique: B. Wang, University of Colorado Boulder, & Huazhong University of Science and Technology, China; L. Ruan, R. Blay, D.M. Akos, University of Colorado Boulder

2.  
The Performance Analysis of an Adaptive INS/ GNSS Tightly-coupled Integration System Aided by Odometer and Barometer: Y-C. Tien, Y-L. Chen, K-W. Chiang, National Cheng Kung University, Taiwan

3.  
Simplified GNSS Fusion-based Train Positioning System and its Diagnosis: H. No, J. Veznet, C. Milner, ENAC, Université de Toulouse, France

4.  

Room: Tuttle  
8:30 a.m.–12:15 p.m.  
Session F3: Low-Cost High Precision GNSS Positioning

Dr. Yang Gao  
University of Calgary, Canada

Dr. Janesong EMAC, France

8:35  
Galileo E5b Rover Receiving E5a Corrections? No Problem!: J-M. Steelegaens, W. De Wilde, Septentrio, Belgium

8:57  
Evaluation of Improvements to the Location Corrections Through Differential Networks (LORD-IN) System: R. Gilabert, E. Dill and S. Young, NASA Langley Research Center; M. Uijt de Haag, Ohio University

9:20  
Performance Analysis of an Improved GPS LNAV to Support the Development of Low-cost Real-time PPP Systems with High Scalability and Availability: P. Zhou, Z. Lu, Y. Gao, Y. Xiang, University of Calgary, Canada

9:43  
Accuracy Trend Analysis of Low-cost GNSS Chips: The Case of Multi-constellation GNSS PPP: J. Aggrey, S. Bisnath, N. Naciri, G. Shinghal & S. Yang, York University, Canada

10:40  
Automated PPP Processing of Low-Cost GNSS Receiver Data: S. Banville, Canadian Geodetic Survey (CGS), NRCan, Canada; G. Lachapelle, University of Calgary, Canada; R. Ghodousi-Fard, CGS, NRCan, Canada

11:03  
Low-cost Vehicle GNSS Positioning Algorithm Using SRR2OSR Method: D. Wang, S. Teng, H. Cui, Qianxun Spatial Intelligence Inc., China

11:26  
Kinematic PPP Errors Associated with Ionospheric Plasma Irregularities during the 2015 St. Patrick’s Day Storm: Z. Yang and Y.J. Morton, University of Colorado Boulder

11:48  
Inter-Receiver GNSS Pseudorange Biases and Their Effect on Clock and DCB Estimation: A. Hauschild, P. Steigenberger, and O. Montenbruck, German Aerospace Center (DLR), & Space Operations Center (GSOCC), Germany

Alternates

1.  
A Robust Approach to Mitigate Colored Noise for Low-cost High-precision Positioning: Y. Gao, Y. Gao, University of Calgary, Canada; B. Liu, University of Calgary, Canada & Jiao Tong University, China; Y. Du, J. Wang, University of Calgary, Canada & Chang’an University, China

2.  

3.  
Preliminary Test for Compact Wide-Area RTK: A New Centimeter-Level High-Precision Navigation System for Wide-Area Service: D. Kim, C. Kee, Seoul National University, South Korea

4.  
Service Strategy on GNSS Precise Positioning for 5G Applications Using Standardized Assistance: K. Asari, M. Saito, and I. Mikami, Satellite Positioning Research and Application Center (SPAC), Japan
Thursday, September 19, 1:45 p.m. –5:30 p.m.

Room: Brickell
1:45 p.m.–3:25 p.m.
Session A4a: GNSS Chipset Manufacturer Showcase

1:50 A NAVIC Enabled Multi-band Hardware Receiver: D. Di Grazia, STMicroelectronics, Italy; D. Cardineau, STMicroelectronics France; F. Pisoni, STMicroelectronics, Italy


Alternates
1. A Highly Integrated Dual-channel Configurable GNSS Receiver Front-end for Wideband Receivers: S. Unruqin, A. Rügamer, H. Milosiu, W. Felber, Fraunhofer IIS, Germany
2. CORDIC-FFT Architecture Implementation for Hardware Accelerator in SoC Low Cost SDR Hardware: C.C. Mishra, C.S. Kumar, Indian Institute of Technology, India

Room: Brickell
3:55 p.m.–5:30 p.m.
Session A4b: Interference Detection and Mitigation using Raw Measurements from Smartphones

4:00 Launching the Super-correlation Library for ARM-based GNSS chips: The Software Upgrade to Supercharge your GNSS Receiver is Here: R. Faragher, M. Powe, P. Esteves, N. Couronneau, M. Crockett, H. Martin, E. Ziglioli, C. W. Roberts, NSL, UK


4:46 GNSS Threat Monitoring and Reporting with the Android Raw GNSS Measurements and STRIKE3: D. Miralles, M. Moghadam, D.M. Akos, University of Colorado Boulder

5:08 Multi-GNSS Anti-Spoofing in Mobile Phones Using Wi-Fi Measurements: S. Kuismanen, S. Söderholm, J. Syrjärinne, HERE Technologies, Finland

Alternates
1. Authentication of GNSS Orbital and Clock Parameters at Android Application Layer: P. Crosta, T. Watterson, G. Galluzzo, R. Lucas, European Space Agency, Netherlands
2. Crowd Sourced GNSS Signal Interference Detection using Smartphone Devices: M. Siutkowska, E. Benedetti, W. Roberts, NSL, UK

4:56 Women in PNT: Roundtable Discussion Groups

Informal discussions on issues important to women at work in PNT
5:30 p.m.–7:00 p.m., Hibiscus Room

For more information, see page 26.

Women in PNT

COMMERCIAL AND POLICY SESSIONS

Room: Flagler
1:45 p.m.–5:30 p.m.
Session B4: Spectrum: Protection and Optimization

1:50 Interference Mitigation Method Based on Tensor Decomposition: L. Liu, W. Wang, Y. Wang, X. Jian, Northwestern Polytechnical University, China

2:35 Development of Array Receivers with Anti-Jamming and Anti-Spoofing Capabilities with Help of Multi-Antenna GNSS Signal Simulators: A. Konovaltsev, German Aerospace Center (DLR), Germany; E. Pérez Marcos, M. Meurer DLR & RWTH Aachen University, Germany; R. Wong, G. Buesnel, Spirent Communications, UK; W. Lange, Lange-Electronic GmbH, Germany

2:58 Experimental Results of an LMS-based GPS Interference Mitigation Method for a Single-element Dual-polarized Antenna: K. Park, J. Seo, Yonsei University, South Korea

4:00 Per-satellite Conﬁdence Estimation for Direction of Arrival Based Spooﬁng Detection: F. Rothmaier, Y-H. Chen, S. Lo, Stanford University

4:23 Interference Detection and Robust Mitigation Method Based on Tensor Decomposition: L. Liu, W. Wang, Y. Wang, X. Jian, Northwestern Polytechnical University, China

4:46 Dual-Domain Robust GNSS Interference Mitigation: H. Li, Northeastern University; D. Borio, European Commission, Joint Research Centre, Italy; P. Closas, Northeastern University


Room: Tuttle
1:45 p.m.–5:30 p.m.
Session C4: Autonomous Applications


2:12 An Efﬁcient Tuning Framework for Kalman Filter Parameter Optimization using Design of Experiments and Genetic Algorithms: A. Zhang and M.M. Atia, Carleton University, Canada

2:35 Integrity Performance for Precise Position in Automotive: L. Norman, B. Culling, L. de Groot, Hexagon Positioning Intelligence, Canada


4:00 The Post-broadcast Integrity System of Qianxun for SSR Service: Q. Zhao, H. Guo, S. Jing, J. Wu, P. Xin, M. Wei, J. Wang, Y. Feng, X. Hou, Y. Jiang, J. Chen, S. Li, S. Feng, Qianxun Spatial Intelligence Inc., China

4:23 A Low-cost Interferometric Fiber Optic Gyro for Autonomous Driving: T. Imamura, T. Matsui, Motion Control Lab, Tamagawa Seiki Co., Ltd., Japan; M. Yachi, Tamagawa Mobile Equipment Co., Ltd., Japan; H. Kumagai, Tamagawa Seiki Co., Ltd., Japan

4:50 GNSS Functional Safety for the Autonomous Vehicle: F. Pisoni, G. Avellone, D. Di Grazia, STMicroelectronics, Italy; J. Durand, STMicroelectronics, France; A. Silverio, STMicroelectronics, Italy; J. Garcia, FICOSA, Spain; E. Dominguez Tijero, GMV, Spain; E. Falletti, LINKS Foundation, Italy

5:08 Cutting-edge Technical Solutions for the Next Generation of Autonomous Vehicles: D. Calle, E. Carbonell, A. Chamorro, J. Durán, P. Navarro, I. Rodríguez, GMV, Spain

Room: Tuttle
1:45 p.m.–3:55 p.m. - Afternoon Refreshments in the Exhibit Hall

Women in PNT

Panel Members:
1. Importance of the Safety Band for Connected and Automated Vehicles: Mrs. Karen Van Dyke, Director, S. Department of Transportation.
2. Mr. Brett Roubinek, Transportation Research Center Inc.
3. Robust Positioning for Autonomous Systems in Cities: Dr. Ramsey Faragher, Focal Point Positioning.
5. Belt-and-suspenders PNT for Self-driving Cars and Air Taxis: Dr. Todd Humphreys, University of Texas at Austin.

Room: Jasmine
3:55 p.m.–5:30 p.m.
Session D4b: PANEL: GNSS Challenges and Unsolved Problems

As we enter an exciting phase with four operational GNSS systems (plus many regional and augmentation systems), satellite navigation is becoming an increasingly critical global capability. This panel will be looking at some of the large challenges that remain to be solved as we move into the future. Topics to be covered include tighter requirements on accuracy, integrity for autonomous vehicles, and protection against increasingly capable cyberattacks. We will also look at some bigger picture systems-level questions such as what the UK plans are for satellite navigation post-Brexit, and a look into the long-term future of satellite navigation post-GPS III.

Panel Members:
1. Antispoofing as a Critical Challenge for Critical Applications: Mr. Logan Scott, LS Consulting.
2. Integrity for Autonomous Systems: Dr. Mathieu Joerger, Virginia Tech.
3. Canadian Geodetic Survey, Canada: The Availability of Accuracy: Dr. Simon Banville, NRCan, Canada.
4. Satellite Navigation in the UK Post-Brexit: Dr. Terry Moore, University of Nottingham, UK.

Room: Monroe
1:45 p.m.–5:30 p.m.
Session E4: Advanced Integrity Algorithms for Multisensor Navigation

Panel Members:
1:50 UAV Integrity Monitoring Measure Improvement Using Terrestrial Signals of Opportunity: M. Maaref and Z.M. Kassas, University of California, Irvine.
2:12 Examining the Benefits of LiDAR Odometry Integrated with GNSS and INS in Urban Areas: A. Aboutaleb, H. Ragab, Queen's University, Canada; A. Nour ELdin, Royal Military College, College.
2:58 Bounding Sequential Estimation Errors Due to Gaussian-Markov Noise with Uncertain Time Constants: S. Langel, The MITRE Corporation; O. Garcia Crespiollo, German Aerospace Center (DLR), Germany.
4:00 Design of Decentralized Filter to Satisfy Per-Defined Integrity and Continuity Requirements: I. Lakshminarayan, D. Gebre-Egziabher, University of Minnesota, Twin Cities.
4:23 Integrity Analysis and Comparison of GNSS/INS Integrated Navigation System with/without NHC under GNSS Spoofing Attacks: Y. Wei and H. Li, Tsinghua University, China.
5:08 Simulation of Test Scenarios for Multi-sensor Mobile Mapping Systems: R. Borchert, B. Gundlisch, Bochum University of Applied Sciences, Germany; H. Kuhlmann, Bonn University, Germany.

Alternates:
1. Improving GNSS Availability for High Integrity Systems using GNSS/INS Over-bounding: J.D. Larson, University of Alabama; D. Gebre-Egziabher, University of Minnesota–Twin Cities; J.H. Rife, Tufts University.
2. Error Model Development for ARAIM Exploiting Satellite Motion: E. Gallon, IT, M. Joerger, VT; B. Pervan, IIT.
3. Six-Degrees-of-Freedom Dilution of Precision for Integrity of Camera-based Localization: C. Zhu, C. Steinmetz, B. Belabbas, M. Meurer, German Aerospace Center (DLR), Germany.

Women in PNT: Roundtable Discussion Groups
Informal discussions on issues important to women at work in PNT
5:30 p.m.–7:00 p.m., Hibiscus Room
For more information, see page 26.
Friday Morning, September 20, 8:30 a.m.–12:15 p.m.

**Room: Brickell**
8:30 a.m.—12:15 p.m.
Session A5: Development of Indoor Positioning

Steve Malkos
Google

**Room: Flagler**
8:30 a.m.—12:15 p.m.
Session B5: Trends in Future Satellite Navigation Technology, System Design and Development

Dr. Ramsey Faragher
Focal Point Positioning, OR

Dr. Takayasu Sakai
Electronic Navigation Research Institute, Japan

**Room: Jasmine**
8:30 a.m.—12:15 p.m.
Session C5: PANEL: Integrity and Cybersecurity: The Next Challenges for Safety Applications

Dr. Chris Wallens
Independent Consultant, Australia

Matt Harris
Boeing

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8:35 Crowd Sourced Pedestrian Dead Reckoning and Mapping of Indoor Environments using Smartphones: C. Gentner, M. Schmidhammer, German Aerospace Center (DLR), Germany
8:57 A Novel CSI-Based Ranging Model for Indoor Localization Using Kalman Filter: J.J. Wang, J.G. Hwang, J.G. Park, Kyungpook National University, South Korea; C. Kee, Seoul National University, South Korea
9:20 Indoor Positioning via WLAN Channel State Information and Machine Learning Classification Approaches: E. Schmidt; Y. Huang, D. Akopian, The University of Texas at San Antonio
9:43 Fusion of Attitude and Statistical Walking Direction Estimations with Time-Difference Carrier Phase Velocity Update for Pedestrian Dead Reckoning Method: J. Perul, V. Renaudin, Geoloc Laboratory, IFSTTAR, France
10:40 LTE Signal Based Vehicle Localization in Indoor Parking Lot Using Mobile Phone: B. Shin, J.H. Lee, Korea Institute of Science and Technology (KIST), South Korea; C. Kee, Seoul National University, South Korea; T. Lee, KIST, South Korea
11:03 A Multi-source Fusion Scheme for Real Time Indoor Positioning Based on Smartphone: Z. Zhang, J. Liu, F. Yang, S. Yang, X. Gong, Z. Li, P. Tong, X. Lei, Wuhan University, China
11:26 Visual Structure From Motion for UAV Indoor Localization: X. Xu, Harbin Engineering University, China; M. Yasser, H. Ragab, Queen’s University, Canada; Y. Gao, Harbin Engineering University, China; A. Noureldin, Royal Military College of Canada; K. He, Harbin Engineering University, China
11:48 The Simplified Localization Method of Near-field Interference Source Based on the Cyclotronarity: M. Kuang, L. Wang, J. Xie, Y. Wang, Northwestern Polytechnical University, China

Alternates
1. Surface Correlation Based Indoor Precise Localization System in Vulnerable Environment with Very Few RF Transmitters: J.H. Lee, B. Shin, Korea Institute of Science and Technology (KIST), South Korea; J. Park, Korea University, South Korea; T. Lee, KIST, South Korea
3. A Hybrid Indoor Localization Method Based on Smartphone: S. Yang, J. Liu, F. Yang, Z. Zhang, X. Gong, Z. Li, P. Tong, X. Lei, Wuhan University, China

8:35 Binary Root Protograph LDPC Codes for CSK Modulation to Increase the Data Rate and Reduce the TTD: L. Ortega Esplugà, C. Poulliat, M.L. Boucheret, M. Aubault-Roudier, H. Allibtar, TeSa, France
8:57 Validation of New Galileo Authentication and High Accuracy Services with the TGFV: T. Lewandowski, R. Jurado, F.J. Soberro, GMV, Spain; R. Swindon, S. Sinda, ESA, The Netherlands
9:43 Laboratory Characterization of Optical Inter-satellite Links for Future GNSS: J. Surof, J. Pollak, R. Mata Calvo, M. Richerzhagen, R. Wolf, T.D. Schmidt, German Aerospace Center (DLR), Germany
10:40 GPS III Arrived – An Initial Analysis of Signal Payload and Achieved User Performance: S. Theoerl, P. Steigenberger, O. Montenbruck, M. Meurer, German Aerospace Center (DLR), Germany
11:48 Feasibility Analysis of Different Airborne Architectures for DFM GNSS: A. Lipp, EUROCONTROL, France

Alternates
1. Status and Development of GNSS Satellite-ground Coordinated Operation: D. Wang, X. Chen, Beijing Satellite Navigation Center, China
2. Technology of BDS Real-time Precise Orbit Determination Enhanced by LEOs: L. Wang, G. Zhang, G. Huang, Chang’an University, China
4. Improving the Performance of Galileo E1-OS by Optimizing the I/NAV Navigation Message: M. Paonni, European Commission, Joint Research Centre (JRC), Italy; M. Anghileri, Airbus Defence and Space GmbH, Germany; T. Burger, L. Ries, European Space Agency, The Netherlands; S. Schlöter, B. Schotsch, M. Ouedraogo, Airbus Defence and Space GmbH, Germany; S. Damy, European Commission, JRC, Italy; E. Chatre, M. Jeannot, J. Godet, D. Hayes, European Commission, Belgium

Safety requirements and cybersecurity requirements to date are still considered separately. The panel discussion will focus on updates, practical scenarios and cases of integrity failures as well as spoofing, jamming and cyberattacks, impact that security requirements can have on safety and vice versa. Practical cases of non-intentional jamming and spoofing to safety critical applications, and considered results and mitigations. Impact of proposed GPS, Galileo and EGNOS authentication services to safety.

Panel Members:
1. Dr. Todd Walter, Stanford University
2. Mr. Jim Barrett, BSNF Railway
3. Mr. Michael Vanguardia, Boeing
4. Mr. Andreas Lipp, Eurocontrol, France
Room: Tuttle  
8:30 a.m.–12:15 p.m.  
Session D5: UAV Navigation Technology and Algorithms

Room: Monroe  
8:30 a.m.–12:15 p.m.  
Session E5: Interference Detection and Alternative PNT

Room: Orchard  
8:30 a.m.–12:15 p.m.  
Session F5: Scientific Uses of Raw GNSS Measurements from Smartphones

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**8:35**  An Algorithm for Finding the Direction of Arrival of Counterfeit GNSS Signals on a Civil Aircraft: G. Falco, M. Nicola, E. Falletti, M. Pini, LINKS Foundation, Italy

**8:57**  Direction-of-Arrival-Based Classification of Authentic and Spoofed GNSS Signals: M.C. Esswein and M.L. Psaki, Virginia Tech

**9:20**  GNSS Spoofing Detection and Mitigation Technique based on the Cyclic MUSIC Algorithm: J. Zhang, X. Cui, M. Lu, Tsinghua University, China

**9:43**  Joint Tracking of Multifrequency Signals Using a Beamforming Technique: S. Zorn, M. Niestroj, M. Brachvogel, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University & German Aerospace Center (DLR), Germany

**10:40**  Characterizing Terrestrial GNSS Interference from Low Earth Orbit: M. J. Murrian, L. Narula, and T. E. Humphreys, University of Texas at Austin

**11:03**  Feasibility Demonstration of RNP with Terrestrial Ranging: O. Oschas, G. Battista, R. Kumar, S. Narayanan, O. Garcia Crespillo, N. Schnneckenburger, B. Belababs, M. Meurer, German Aerospace Center (DLR), Germany

**11:26**  Sensitivity of Innovation Monitors to Uncertainty in Error Modeling: B. Kujur, C. Tanil, S. Khanafseh, B. Pervan, Illinois Institute of Technology

**11:48**  Effects of Optimized Mitigation Techniques for Swept-Frequency Jammers on Tracking Loops: W. Qin, Politecnico di Torino, Italy; M. Troglo Gamba, E. Falletti, LINKS Foundation, Italy; F. Dovis, Politecnico di Torino, Italy

Alternates:
1. Wavelet Based Adaptive Notch Filtering to Mitigate COTS PPDs: J. Rossouw van der Merwe, A. Rügamer, F. Garzia, W. Felber, Fraunhofer IFS, Germany
2. A GNSS Spoofing Generator Using Vector-Based Receiver: Q. Meng and L-T. Hsu, The Hong Kong Polytechnic University, China

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**8:35**  Sub-Meter Accurate UAV Navigation and Cycle Slip Detection with LTE Carrier Phase Measurements: K. Shamaei and Z.M. Kassas, University of California, Irvine

**8:57**  Comparison of Uncertainty Suppression Methods for Sparsely Sampled Fields: S. Yonan, R. Curry, and G.H. Elkaim, UC Santa Cruz

**9:20**  Robust Scene-Matching Algorithm Based on Relative Velocity Model for Aerial Images: S.H. Choi, Seoul National University, South Korea; C.G. Park, Seoul National University/Automation and Systems Research Institute, South Korea

**9:43**  Sensitivity Analysis of RADAR Altimeter-aided GPS for UAS Precision Approach: A. Videmsek, University of Bath, UK; A. Rügamer, F. Garzia, W. Felber, Fraunhofer IIS, Germany


**11:03**  Enhanced Fixed Wing UAV Navigation in Extended GNSS Outages Using a Vehicle Dynamics Model and Raw GNSS Observables: H.A. Mwenegotha, T. Moore, J. Pinchin, University of Nottingham, UK; M. Jabbal, University of Nottingham–Fluids and Thermal Engineering, UK

**11:26**  Optimal Stochastic Sensor Error Modeling Based on Actual Impact on Quality of GNSS-INS Integrated Navigation: M. Khaghani, S. Guerrier, University of Geneva (UNIGE), Switzerland; J. Skaloud, Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland; Y. Zhang, UNIGE, Switzerland

**11:48**  STAP Performance and Antenna Miniaturization in Multi-Antenna GNSS Receivers: E. Pérez Marcos, German Aerospace Center (DLR), RWTH Aachen University, Germany; S. Caizzone, DLR, Germany; M. Cuntz, DLR & RWTH Aachen University, Germany; A. Konovaltsev, DLR, Germany; M. Meurer, DLR, RWTH Aachen University, Germany

Alternates:
1. Antenna Baseline Impact on Attitude and Geolocation Error: P. Carter, Auburn University; J. Starling, Integrated Solutions for Systems (IS4S); S. Martín, D. Blevy, Auburn University
2. UWB-Based Indoor Navigation with Uncertain Anchor Nodes Positioning: G. Pagès and Jordi Vila-Valls, ISAE-Supélec, University of Toulouse, France
3. Precise and Extremely Fast Method of Ambiguity Resolution for a Single Epoch of GNSS Data: M. Bakula, University of Warmia and Mazury, Poland
1:50 A GNSS Payload with Low-cost Commercial-of-the-shelf Receivers: M. Meindl, M. Rothacher, K. Chen, ETH Zurich, Institute of Geodesy and Photogrammetry, Switzerland; F. Krelliger, E. Styerger, Lucerne University of Applied Sciences and Arts, Switzerland; S. De Florio, L. López Gilabert, Astrocot, Switzerland

2:12 The Joint ESA/NASA Galileo/GPS Receiver on-board the ISS-GARISS Project: W. Endler, E. Schoenemann, F. Gini, ESA/ESOC, Germany; J.J. Miller, NASA Headquarters, USA; O.S. Sands, D. Chelmins, NASA Glenn Research Center, USA; O. Pozzobon, S. Fantinato, A. Dalla Chiara, F. Bernardi, Qascom, Italy

2:35 DOVE GPS: An Unconventional Approach to CubeSat Orbit Determination: R.W. Kingsbury, M. Cullen Self, C. Foster, Planet Labs, Inc.

2:58 A Novel Centimeter-Level Real-Time Orbit Determination Method Using Space-Borne GPS/Beidou Measurements from FY-3C: W. Jun, Beijing UniStrong Science & Technology Co., Ltd., China; G. Lei, W. Fuhong, Wuhan University, China; W Lin, T Lzheng, Beijing UniStrong Science & Technology Co., Ltd., China

3:20 GPS-Based Attitude Determination of a Rotating Spacecraft Using Single Antenna Subject to Phase Wind-up: B. Weaver, Tufts University; T. Bogner, J. Arnold Soltz, Draper; J. Rife, Tufts University


4:04 Proba-3 Precise Orbit Determination Based on GNSS Observations: W. Endler, F. Gini, E. Schoenemann, V. Mayer, ESA/ESOC, Germany


1:50 A Message Authentication Proposal for Satellite Based Nation-wide PPP-RTK Correction Service: R. Hirokawa, S. Fujita, Mitsubishi Electric Corporation, Japan

2:12 Authentication Architectures for the WAAS L5 Signal: A. Neish, T. Walter, J.D. Powell, Stanford University

2:35 Field Testing of GNSS Users Protection Techniques: S. Cancela, J. Navarro, D. Calle, GMV, Spain; T. Reithmaier, Ifen, Germany; A. Dalla Chiara, Qascom, Italy; I. Fernández-Hernández, European Commission, Belgium; G. Seco-Granados, Universidad Autónoma de Barcelona, Spain; J. Simón, European GNSS Agency, The Netherlands

2:58 Testing of PPP Solution Aided with Enhanced Algorithms of Integer Ambiguity Resolution: L. de la Cruz, C. Mezzera, P. Navarro, P. Roldán, G. Tobias, GMV, Spain

3:20 Performance Analysis of Precise Point Positioning (PPP) with Rx Networks High Accuracy Assistance Service: V. Bellad, T. Marathe, B. Aminian, N. Valentine, S. Sarasidisdi, Z. Baji, M. Petryshyn, V. Chen, Rx Networks Inc. Canada

3:42 Investigation of PPP Convergence for Automotive Applications using Ionospheric Model Derived from Space-borne LEO and Ground CORS GNSS Networks: Y. Yi, M. Horton, Y. Li, X. Wang, D. Wang Aceinna Inc.


4:26 TerraStar X: Precise Point Positioning with Fast Convergence and Integrity: P. Alves, C. Ellum, A. Jokinen, Z. Lukes, S. Masterson, L. Mervart, K. Sheridan, P. Toor, Hexagon Positioning Intelligence, Canada; F. Takac, R. Martin, Leica Geosystems, Switzerland

Alternate


Room: Tuttle
1:45 p.m. – 4:50 p.m.
Session C6: Authentication and Augmentation Services

Dr. Ignacio Fernández Hernández European Commission, Belgium
Dr. Gustavo López Ríoserlo European Space Agency, The Netherlands

Room: Jasmine
1:45 p.m. – 4:50 p.m.
Session D6: Technologies for GNSS-Denied Environments

Dr. Allison Kealy RMIT University, Australia
Omar García Cereijo German Aerospace Centre (DLR), Germany

Room: Flagler
1:45 p.m. – 4:50 p.m.
Session B6: GNSS Applications in Space

Dr. Werner Endler European Space Agency, Germany
David Chelmins NASA
Room: Orchid  
1:45 p.m.–4:50 p.m.  
Session E6: Remote Sensing, Timing and Clock Technology

1:50  Ocean Vector Wind Retrieval from Delay-Doppler Maps Using Ambiguous State Processing: I. Collett, Y.J. Morton, University of Colorado Boulder
2:12  Coherent Components of GNSS-R Signal Observed from CYGNSS Raw IF Data: Y. Wang, Y.J. Morton, University of Colorado Boulder
2:35  Ground Testing of the GNSS II Engineering Model on FengYun-3E Satellite: P. Li, Beijing Key Laboratory of Space Environment Exploration, National Space Science Center (NSSC), Chinese Academy of Sciences (CAS), China; Y. Sun, NSSC/CAS, University of Chinese Academy of Sciences (UCAS), China; X. Wang, Q. Du, NSSC/CAS, China; D. Wang, Y. Cai, NSSC/CAS, China; C. Wu, NSSC/CAS, UCAS, China; Y. Tian, UCAS, China; C. Liu, X. Meng, J. Xua, W. Bai, C. Liu, NSSC/CAS, China; W. Li, NSSC/CAS, UCAS, China; D. Zhao, H. Qiao, NSSC/CAS, China
2:58  Innovative Toolbox for Reference Station Multipath and Interference Site Surveying: A. Emmanuele, M. Puccitielli, N. Pastori, A. Ferrario, L. German Aerospace Center (DLR), Germany
3:20  Detection and Identification of Faults in Clock Ensembles: C. Trainotti, G. Giorgi, J. Furthner, German Aerospace Center (DLR), Germany
4:04  Fast and Improved Ionospheric Correction for Galileo Mass Market Receivers: M.M. Hoque, N. Jakowski, O. Osechas, J. Berdermann, German Aerospace Center (DLR), Germany
4:26  Automatic Detection and Characterization of Ionospheric Scintillation-Like GNSS Satellite and Receiver Oscillator Anomaly: Y. Liu, Y.J. Morton, University of Colorado Boulder
Alternates
1. A Method for Realizing High-precision Monitoring of Satellite Clock Based on BeiDou’s Co-satellite RDSS and RNSS Signals: W. Liu, Academy of Opto-Electronics, Chinese Academy of Sciences (CAS), University of Chinese Academy of Sciences, China; H. Yuan, Academy of Opto-Electronics, CAS, China
2. Improving the Quality of Tomographic Image by Reducing the Voxel’s Size Partly: J. Yu, W. Wang, China University of Mining and Technology, China

Room: Monroe  
1:45 p.m.–4:50 p.m.  
Session F6: GNSS Signal Processing in Degraded Environments 2

1:50  Multipath Mitigation Based on Stationary Wavelet Transform: P. Michel, TéSA lab, France; M. Francois-Xavier, R. Thierry, CNES, France; A. Elie, B. Margaux, M3 Systems, France; M. Corinne, TéSA lab, France
2:12  Modified Open/Closed Loop Tracking Through VDFLL for LEO Satellites: S. Hrbek, D. Miralles, D. Akos, University of Colorado Boulder
2:35  Smart Exploration of Pseudorange and Pseudorange Rate Errors Characterization to Improve the PVT Solution: E.R. Matera, A. Garcia-Pena, C. Milner, B. Ekambi, ENAC & ABBA GNSS Technologies, France
2:58  Particle Filter Estimation of GNSS Signal Phase Transitions: B. Breitsch and J. Morton, University of Colorado Boulder
3:20  FFT-Based Acquisition of GPS Pseudo M-Code on a DSP: B.K. McLemore and M.L. Piastricki, Virginia Tech
3:42  Standalone Direct Acquisition of Weak Multi-Band Split-Spectrum Signals: C. Yang, A. Soloviev, QuNav; J.C. Ha, AFRL/RWY
Alternates
1. STFT-based Method Applied to GNSS Spoofing Estimation, Mitigation and Discrimination from Multipath: H. Jiang, C. Sun, H. Zhao, W. Feng, Beihang University, China
2. The Utilization of High-resolution Spectral Analysis for GNSS Interference Mitigation in Challenging Environment: H.Y. Elghamrawy, M.J. Korenberg, M. Karaim, H. Ragab, A. Noureldin, Queen’s University, Canada
3. Safeguarding NMA Enhanced Galileo OS Signals from Distance-Decreasing Attacks: K. Zhang, P. Papadimitratos, KTH Royal Institute of Technology, Sweden

Room: Brickell  
1:45 p.m.–4:50 p.m.  
Session G6: Aided GNSS and Sensor Fusion in Challenging Environments 2

1:50  Assessment of Differential Carrier Phase Measurements from Broadband LEO Satellite Signals for Opportunistic Navigation: J. Khalife and Z.M. Kassas; University of California, Irvine
2:12  NLOS and Multipath Detection Using Doppler Shift Measurements: L. Xu and J. Rife, Tufts University
2:35  The In-depth Theoretical Analysis of Feedback Delay Impact in INS-aided PLL: X. Tang, Southeast University; China; P. Wang, Shanghai Aerospace Control Technology Institute, China; Q. Meng, Hong Kong Polytechnic University, Hong Kong; X. Chen, Shanghai Jiao Tong University, China; T. Zhang, Southeast University, China
3:20  Performance Analysis of LQG based Ultra-Tightly Coupled Algorithm According to Coherent Integration Time: M. Park, C. Kee, Seoul National University; South Korea; M. Jeon, Kakao Mobility, South Korea
4:04  Convolutional Neural Network Architecture Comparison for Aerial Visual Localization: J.M. Berhold, R. Leshman, AFIT; D. Venable, Veth Research Associates
4:26  SLAM-based Integrity Monitoring Using GPS and Fisheye Camera: S. Bhamidipati, University of Illinois at Urbana-Champaign; G.X. Gao, Stanford University
EXHIBIT HALL FLOOR PLAN

EXHIBIT HALL HOURS

Wednesday:
10:00 a.m. – 5:30 p.m.    Hall Open
5:30 p.m. – 7:30 p.m.    Reception

Thursday:
9:00 a.m. – 4:00 p.m.    Hall Open

ION GNSS+ 2019 Exhibitors

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Email: admin@hvtechnologies.com  
Phone: 703-365-2330  
Web: emcsales@hvtechnologies.com
ION GNSS+ Special Events

**Wednesday, September 18**

**Attendee Luncheon**
12:15 p.m.–1:15 p.m., Exhibit Hall

This event is included with all full conference, student, exhibit only, and Wednesday single day registrations. See registration desk onsite to purchase tickets for guests.

**Exhibitor Hosted Reception**
5:30 p.m.–7:30 p.m., Exhibit Hall

Join this year’s exhibitors as they host a social evening of information and cuisine. All exhibit booths will be open. Take this opportunity to review developments in GNSS technology, talk shop, get the specifics directly from the vendors, and learn about what has been happening in the GNSS marketplace during the past year. This event is included with any type of registration. Spouses and traveling companions 21 and older are welcome.

**Thursday, September 19**

**Attendee Luncheon**
12:15 p.m.–1:15 p.m., Exhibit Hall

This event is included with all full conference, student, exhibit only and Thursday registrations. See registration desk to purchase guest tickets.

**Women in PNT: Roundtable Discussion Groups**
Informal discussions on issues important to women at work in PNT
5:30 p.m.–7:00 p.m., Hibiscus Room

Join us for an informal evening of roundtable discussions moderated by leaders in the field and formatted to promote intimate thought-provoking discussions on a variety of topics important to women in PNT. These roundtable discussions will provide a relaxing space to examine important issues and collectively share information with the goal of helping you effectively manage your professional career.

The ION’s Women in Positioning, Navigation and Timing (PNT) is a voluntary networking initiative designed to support and engage women who are in the early stages of their careers in and across all areas of PNT. The initiative provides a forum for PNT professionals to meet and discuss issues vital to women on topics including, but not limited to, professionalism, career development, leadership, networking and work-life balance issues.

Event Supported By:

**Discussion Topics May Include:**
Juggling Professional and Personal Priorities
- Time management skills
- Cultivating pleasures outside of work
- Using technology to organize
- Survival skills when facing challenges

Advancing Yourself Professionally
- Obtaining leadership roles
- Networking effectively
- Transitioning between professional sectors/markets
- Identifying a professional mentor and asking for help

These roundtable discussions are designed to promote fresh and innovating thinking while providing an opportunity for everyone to contribute.

**Schedule of Events**
5:30 p.m. Attendees arrive and are seated
5:45–6:10 p.m. Roundtable Session 1
6:15–6:40 p.m. Roundtable Session 2
6:45–7:00 p.m. Wrap up and Networking

**Friday, September 20**

**Johannes Kepler and Bradford W. Parkinson Awards Luncheon, Riverfront Hall South**
12:15 p.m.–1:30 p.m.

The purpose of the Kepler Award is to honor an individual for sustained and significant contributions to the development of satellite navigation.

The Bradford Parkinson Award, which honors Dr. Parkinson for his leadership in establishing both the U.S. Global Positioning Systems and the Satellite Division of The Institute of Navigation, is given to an outstanding graduate student in the field of Global Navigation Satellite Systems. See ion.org/awards for requirements.

This event is included with a full, student, or Friday single day, conference registration. Tickets for exhibitors, students and/or guests may be purchased during registration or by visiting the ION GNSS+ registration desk onsite.

Previous Kepler Award Winners at ION GNSS+ 2018 (left to right): Dr. Gary McGraw, Prof. Terry Moore, Dr. Dorota Grejner-Brzezinska, Dr. Todd Walter, Dr. Oliver Montenbruck, Dr. Frank van Diggelen, Dr. Penina Axelrad, Dr. Richard Langley, and Mr. Karl Kovach.
Mark Your Calendars!
With these Upcoming ION Events

ITM
INTERNATIONAL TECHNICAL MEETING
January 21–24, 2020
Hyatt Regency Mission Bay
San Diego, CA

PTTI
PRECISE TIME AND
TIME INTERVAL
SYSTEMS AND
APPLICATIONS
MEETING
One Registration Fee,
Two Technical Events
and a Commercial Exhibit

IEEE/ION
Position
Location and
Navigation
Symposium
(PLANS)

PORTLAND
MARK YOUR CALENDAR!

JOINT NAVIGATION CONFERENCE
2020
Military Navigation
Technology—The Foundation for
Military Ops
June 1–4, 2020
Northern Kentucky Convention Center
Cincinnati, OH
Classified Session hosted at
Air Force Institute of Technology

GNSS+
The 33rd International Technical Meeting of the
Satellite Division of the Institute of Navigation
September 21–25, 2020
Exhibit Hall: September 23 and 24
St. Louis Union Station Hotel
St. Louis, Missouri

For more information, please visit ion.org
<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:30 p.m.</td>
<td>CGSIC Subcommittee Meetings 9:00 a.m.–5:30 p.m. (Brickell/Orchid)</td>
</tr>
<tr>
<td>1:30 p.m.</td>
<td>GNSS 101: An Introduction (P. Misra) Room: Tuttle</td>
</tr>
<tr>
<td>1:30 p.m.</td>
<td>Introduction to Space Weather (P. Doherty) Room: Flagler</td>
</tr>
<tr>
<td>1:30 p.m.</td>
<td>Sensor Integration for Personal Navigation (D. Grejner-Brzezinska) Room: Monroe</td>
</tr>
<tr>
<td>3:30 p.m.</td>
<td>GNSS 102: Measurements from Phones, L1, L5, and Carrier Phase (F. van Diggelen) Room: Tuttle</td>
</tr>
<tr>
<td>3:30 p.m.</td>
<td>Approaches for Resilient and Robust Positioning, Navigation and Timing (L. Scott) Room: Flagler</td>
</tr>
<tr>
<td>3:30 p.m.</td>
<td>Using a Sextant: Celestial Navigation (R. Hartnett) Room: Monroe</td>
</tr>
<tr>
<td>TUESDAY, SEPTEMBER 17 • PRE-CONFERENCE TUTORIALS (additional registration required)</td>
<td></td>
</tr>
<tr>
<td>9:00 a.m.–12:30 p.m.</td>
<td>Multi-constellation GNSS Signals and Systems (C. Bartone) Room: Monroe</td>
</tr>
<tr>
<td>9:00 a.m.–12:30 p.m.</td>
<td>Fundamentals of Inertial Navigation Systems and Aiding (M. Braasch) Room: Tuttle</td>
</tr>
<tr>
<td>9:00 a.m.–12:30 p.m.</td>
<td>Kalman Filter Applications to Integrated Navigation 1 (J. Farrell/F. van Graas) Room: Flagler</td>
</tr>
<tr>
<td>Lunch on Your Own • 12:30 p.m.–1:30 p.m.</td>
<td></td>
</tr>
<tr>
<td>1:30 p.m.–5:00 p.m.</td>
<td>Introduction to Multiband and Multi-constellation Satellite Receivers using Python (S. Gunawardena) Room: Monroe</td>
</tr>
<tr>
<td>1:30 p.m.–5:00 p.m.</td>
<td>Autonomous System Navigation and Machine Learning (M. Veth / D. Venable) Room: Tuttle</td>
</tr>
<tr>
<td>1:30 p.m.–5:00 p.m.</td>
<td>Kalman Filter Applications to Integrated Navigation 2 (J. Farrell / F. van Graas) Room: Flagler</td>
</tr>
</tbody>
</table>

ION GNSS+ PLENARY SESSION • 6:30 p.m.–8:30 p.m. • Jasmine Room

WEDNESDAY, SEPTEMBER 18

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>TRACK A: SMIREFCHECK Mass Market and Commercial Applications</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>A1: Applications of Raw GNSS Measurements from Smartphones Room: Brickell</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>B1: GNSS Augmentation Systems and Integrity 1 Room: Flagler</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>C1: Land-Based Applications Room: Monroe</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>D1: Connected and Collaborative Autonomy Room: Tuttle</td>
</tr>
<tr>
<td>1:45 p.m.–5:30 p.m.</td>
<td>TRACK B: QIU Current Status and Future Trends in GNSS</td>
</tr>
<tr>
<td>1:45 p.m.–5:30 p.m.</td>
<td>B2: PANEL: Status of GPS, GLONASS, Galileo, BDS, QZSS and NavIC Room: Flagler</td>
</tr>
<tr>
<td>1:45 p.m.–5:30 p.m.</td>
<td>C2: Aviation and Aeronautics Room: Orchid</td>
</tr>
<tr>
<td>1:45 p.m.–5:30 p.m.</td>
<td>D2: Innovations for Robotic Vehicle Applications Room: Tuttle</td>
</tr>
<tr>
<td>1:45 p.m.–5:30 p.m.</td>
<td>D2: GNSS Augmentation Systems and Integrity 2 Room: Flagler</td>
</tr>
<tr>
<td>12:15 p.m.–1:15 p.m., Buffet Lunch in Exhibit Hall • 1:15 p.m.–1:45 p.m., Free Time in Exhibit Hall</td>
<td></td>
</tr>
<tr>
<td>12:15 p.m.–1:15 p.m.</td>
<td>Lunch on Your Own • 12:30 p.m.–1:30 p.m.</td>
</tr>
<tr>
<td>12:15 p.m.–1:15 p.m.</td>
<td>Lunch on Your Own • 12:30 p.m.–1:30 p.m.</td>
</tr>
<tr>
<td>3:30 p.m.–5:30 p.m.</td>
<td>TRACK C: POZZOBON High Performance and Safety Critical Applications</td>
</tr>
<tr>
<td>3:30 p.m.–5:30 p.m.</td>
<td>C3: Marine Applications and Search and Rescue Room: Orchid</td>
</tr>
<tr>
<td>3:30 p.m.–5:30 p.m.</td>
<td>C3: Navigation Using Environmental Features Room: Monroe</td>
</tr>
<tr>
<td>3:30 p.m.–5:30 p.m.</td>
<td>D3: Aided GNSS and Sensor Fusion in Challenging Environments 1 Room: Brickell</td>
</tr>
<tr>
<td>3:30 p.m.–5:30 p.m.</td>
<td>E3: Low-Cost High Precision GNSS Positioning Room: Tuttle</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>TRACK D: JOERGER Autonomous System Technology</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>D4: PANEL: Navigating Smart and Connected Cities Room: Jasmine</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>D4: Advanced Integrity Algorithms for Multi-Sensor Navigation Room: Monroe</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>F2: GNSS Signal Processing in Degraded Environments 1 Room: Monroe</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>F3: Next Generation RF, Antenna Techniques, and Receiver Processing Room: Orchid</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>F4: Next Generation RF, Antenna Techniques, and Receiver Processing Room: Orchid</td>
</tr>
<tr>
<td>12:15 p.m.–1:15 p.m., Buffet Lunch in Exhibit Hall • 1:15 p.m.–1:45 p.m., Free Time in Exhibit Hall</td>
<td></td>
</tr>
</tbody>
</table>

THURSDAY, SEPTEMBER 19

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:45 p.m.–3:25 p.m.</td>
<td>TRACK A: SMIREFCHECK Mass Market and Commercial Applications</td>
</tr>
<tr>
<td>1:45 p.m.–3:25 p.m.</td>
<td>A4a: GNSS Chipset Manufacturer Showcase Room: Brickell</td>
</tr>
<tr>
<td>1:45 p.m.–3:25 p.m.</td>
<td>B4: Spectrum: Protection and Optimization Room: Flagler</td>
</tr>
<tr>
<td>1:45 p.m.–3:25 p.m.</td>
<td>C4: Autonomous Applications Room: Tuttle</td>
</tr>
<tr>
<td>1:45 p.m.–3:25 p.m.</td>
<td>D4a: PANEL: Navigating Smart and Connected Cities Room: Jasmine</td>
</tr>
<tr>
<td>3:55 p.m.–5:30 p.m.</td>
<td>TRACK B: QIU Current Status and Future Trends in GNSS</td>
</tr>
<tr>
<td>3:55 p.m.–5:30 p.m.</td>
<td>D4b: PANEL: GNSS Challenges and Unsolved Problems Room: Jasmine</td>
</tr>
<tr>
<td>3:55 p.m.–5:30 p.m.</td>
<td>E4: Advanced Integrity Algorithms for Multi-Sensor Navigation Room: Monroe</td>
</tr>
<tr>
<td>3:55 p.m.–5:30 p.m.</td>
<td>F2: GNSS Signal Processing in Degraded Environments 1 Room: Monroe</td>
</tr>
</tbody>
</table>

FRIDAY, SEPTEMBER 20

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>TRACK A: SMIREFCHECK Mass Market and Commercial Applications</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>A5: Development of Indoor Positioning Room: Brickell</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>B5: Trends in Future Satellite Navigation Technology, System Design and Development Room: Flagler</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>C5: PANEL: Integrity and Cybersecurity: The Next Challenges for Safety Applications Room: Jasmine</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>D5: UAV Navigation Technology and Algorithms Room: Tuttle</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>E5: Interference Detection and Alternative PNT Navigation Room: Monroe</td>
</tr>
<tr>
<td>8:30 a.m.–12:15 p.m.</td>
<td>F5: Scientific Uses of Raw GNSS Measurements from Smartphones Room: Orchid</td>
</tr>
</tbody>
</table>

Awards Luncheon • 12:15 p.m.–1:30 p.m. (Lunch served until 12:45 p.m.; late arrivals will not be served)