The 29th International Technical Meeting of the Satellite Division of The Institute of Navigation

ION GNSS+ 2016

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Registration Hours
Monday, September 12 ........................................................... 8:00 a.m.–7:00 p.m.
Tuesday, September 13 .......................................................... 8:00 a.m.–7:00 p.m.
Wednesday, September 14 ...................................................... 8:00 a.m.–5:00 p.m.
Thursday, September 15 .......................................................... 8:00 a.m.–5:00 p.m.
Friday, September 16 .............................................................. 8:00 a.m.–12:00 p.m.

Mobile Services, Connectivity and Social Media
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 meeting rooms, will not work in the exhibit hall). Network Name is IONGNSS; no password is required.
Social Media: Follow us on Facebook, Twitter and Instagram at @ionavigation. The meeting hashtag is #iongnss.

Access to Technical Materials and Business Services
Technical Paper Copies Online: Registered attendees may download copies of conference presentations and technical papers online for free by logging in to the ION website at www.ion.org/gnss. Presentations will only be made available once the full technical paper is submitted. Only papers provided to the ION by the presenting authors will be available. If a desired paper is not available, please contact the author directly.
Conference Proceedings: Official conference proceedings are scheduled for distribution in November to eligible conference participants.
Customized Conference Schedule: Build a customized schedule of conference papers at www.ion.org/gnss.
Other Services: A Business Center will provide the use of computers, printer/copier and internet access on a self-service basis in the registration area. A baggage check will be offered on Friday.

MAX Light Rail Passes
A free pass for use September 12-16 is available to ION GNSS+ attendees, and can be picked up at the ION GNSS+ registration desk when you pick up your conference badge. Each attendee will be issued only one MAX pass. Please carry your transit pass with you at all times; we suggest you keep your pass in your badge holder. The pass will be valid upon receipt and will not require validation, stamping, ticket exchange or any additional step before riding the MAX light rail, streetcars or busses in the city of Portland. If you lose your pass, the adult fare is $2.50 for 2-hours or $5 for a one-day pass. The fine for riding MAX without a valid pass/ticket is $175.

Safety Information
The Oregon Convention Center is a public building. Attendees are encouraged to keep their personal property in their possession at all times and not assume their personal belongings will be safe if left unattended.

Photographs/Video Recording/Barcoded Badges
Your presence at ION GNSS+ constitutes your agreement to be photographed, filmed, videotaped or otherwise recorded by conference management, or its agents, and your agreement that your image or voice may be distributed in print or electronic communications media without any compensation being paid to you. Video recording by participants is not allowed without written permission of ION during any portion of the conference. Photographs of copyrighted presentations are for personal use only and are not to be reproduced or distributed. Do not photograph any images labeled as proprietary. Flash photography, or any form of photography, that disturbs those around you, is prohibited. Your badge features a barcode. With your permission, exhibitors may scan the barcode to obtain your name and contact information.
THANK YOU TO OUR EVENT SUPPORTERS:

- Mobile Application
- Self-Service Business Center
- Women in PNT
## ION GNSS+ 2016 Program Organizers

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<thead>
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<th>Role</th>
<th>Name</th>
<th>Organization</th>
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<tbody>
<tr>
<td>General Chair</td>
<td>Dr. John Betz</td>
<td>The MITRE Corporation</td>
</tr>
<tr>
<td>Program Co-Chair</td>
<td>Dr. Sherman Lo</td>
<td>Stanford University</td>
</tr>
<tr>
<td>Program Co-Chair</td>
<td>Mr. Neil Gerein</td>
<td>NovAtel, Inc., Canada</td>
</tr>
<tr>
<td>Tutorials Chair</td>
<td>Ms. Patricia Doherty</td>
<td>Boston College</td>
</tr>
<tr>
<td>Plenary Session Chair</td>
<td>Dr. Frank van Diggelen</td>
<td>Google</td>
</tr>
</tbody>
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## Technical Chairs

### Applications and Advances Tracks

- **Dr. Brent Ledvina**
  - Virginia Tech

- **Dr. Alex Stratton**
  - Rockwell Collins

- **Dr. Kurt Zimmerman**
  - Trimble

### Research and Innovations Tracks

- **Dr. Michael Veth**
  - Veth Research Associates

- **Dr. Heidi Kuusniemi**
  - Finnish Geospatial Research Institute, Finland

- **Dr. Jiyun Lee**
  - KAIST, South Korea

## Satellite Division Officers

<table>
<thead>
<tr>
<th>Role</th>
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<tbody>
<tr>
<td>Chair</td>
<td>Dr. John Betz</td>
<td>The MITRE Corporation</td>
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<tr>
<td>Vice Chair</td>
<td>Dr. Frank van Diggelen</td>
<td>Google</td>
</tr>
<tr>
<td>Secretary</td>
<td>Mr. Doug Taggart</td>
<td>Overlook Systems Technologies</td>
</tr>
<tr>
<td>Treasurer</td>
<td>Dr. Grace Gao</td>
<td>University of Illinois at Urbana-Champaign</td>
</tr>
<tr>
<td>Immediate Past Chair</td>
<td>Dr. Jade Morton</td>
<td>Colorado State University</td>
</tr>
<tr>
<td>European Technical Advisor</td>
<td>Dr. Terry Moore</td>
<td>University of Nottingham, UK</td>
</tr>
<tr>
<td>Pacific Rim Technical Advisor</td>
<td>Dr. Allison Kealy</td>
<td>The University of Melbourne, Australia</td>
</tr>
<tr>
<td>ION President</td>
<td>Dr. Dorota Grejner-Brzezinska</td>
<td>The Ohio State University</td>
</tr>
<tr>
<td>Technical Advisor</td>
<td>Dr. Sergey Karutin</td>
<td>Central Institute of Machine Building, Russia</td>
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<tr>
<td>Technical Advisor</td>
<td>Dr. Hiroaki Maeda</td>
<td>Lighthouse Technology and Consulting Co., Japan</td>
</tr>
<tr>
<td>Technical Advisor</td>
<td>Dr. José Angel Ávila Rodríguez</td>
<td>European Space Agency, The Netherlands</td>
</tr>
<tr>
<td>Technical Advisor</td>
<td>Dr. Yuanxi Yang</td>
<td>National Administration of GNSS and Applications, China</td>
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## ION GNSS+ 2017

**SAVE THE DATE:**

**ION GNSS+ 2017**

www.ion.org/gnss

The 30th International Technical Meeting of the Satellite Division of The Institute of Navigation

September 25 – 29, 2017
Show Dates: Sept. 27 – 28
Tutorials: Sept. 25 – 26

Oregon Convention Center
Portland, Oregon

An opportunity to show to the world’s leading authorities on global navigation satellite systems!
## Monday Concurrent Subcommittees  Room A105 • September 12, 2016

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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</table>
| 09:00-12:30 | **U.S. States and Local Government Session**  
James Arnold, U.S. Department of Transportation, Chair |
| 09:00  | Introductions, Opening and Administrative Items – James Arnold, U.S. Department of Transportation |
| 09:10  | NDGPS Program Update – Captain Russell Holmes, U.S. Coast Guard Navigation Center |
| 09:20  | GPS Forensics – Matt Peterson, Robson Forensics |
| 09:50  | GPS/GNSS Interference Mitigation – Jan Van Hess  
Septentrio Satellite Navigation |
| 10:20  | Break |
| 10:40  | The Future of the Plate Boundary Observatory (PBO)  
Geodetic Resource From Now to 2028 – UNAVCO |
| 11:10  | Testing PPP-RTK for RTN Integrity and Remote Projects –  
Gavin Schrock, Seattle Public Utilities |
| 11:40  | State Reports |
| 14:00-17:30 | **Timing Session**  
Dr. Wlodzimierz Lewandowski, Polish Central Office of Measures (GUM), Chair |
| 14:00  | Introduction – Dr. Wlodzimierz Lewandowski  
Polish Central Office of Measures |
| 14:10  | Report from NRL – Francine Vannicola  
Naval Research Laboratory (NRL) |
| 14:30  | Report from USNO – Stephen Mitchell  
U.S. Naval Observatory (USNO) |
| 14:55  | Report from NIST – Michael Lombardi,  
National Institute of Standards and Technology (NIST) |
| 15:20  | Break |
| 15:40  | Report from APL –  
Jeffrey Garstecki, Johns Hopkins Applied Physics Lab (APL) |
| 16:00  | How Industry Utilizes GPS for Traceable Frequency Measurements and Calibrations –  
Jeff Gust Chief Corporate Metrologist, Fluke Calibration |
| 16:20  | New, Robust High-Performance GPS Timing Receiver  
Bruce Penrod, EndRun Technologies |
| 16:40  | GPS and Time Synchronization in the Electric Industry  
Alison Silverstein, North American Synchrophasor Initiative (NASPI) |
| 17:00  | Using GPS Precise Point Positioning to Test the Theory of  
Relativity – Dr. Demetrios Matsakis, USNO |

## Monday Concurrent Subcommittees  Room A106 • September 12, 2016

<table>
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<tr>
<th>Time</th>
<th>Session</th>
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</table>
| 09:00-12:30 | **International Information Session**  
John Wilde, Global Strategic Sales, NAVBLUE, Chair |
| 09:00  | Introductions – John Wilde, NAVBLUE |
| 09:05  | SVN-23 - UK Effects and What Happened  
Charles Curry, Chronos Ltd |
| 09:30  | Quazi-Zenith Satellite System (QZSS) Update –  
Mr. Yoshiyuki Murai, NEC Corporation |
| 09:55  | Research Streams in GNSS for SESAR 2020 –  
Gerhard Berz, Expert EUROCONTROL |
| 10:20  | Break |
| 10:40  | "Singing in the RAIM" for Navigation and Surveillance  
John Wilde, NAVBLUE |
| 11:10  | "GPS and Galileo Monitoring with Jamming and Spoofing Navigation and Surveillance Detection System  
TBD, European GNSS Agency (GSA), Czech Republic |
| 14:00-17:30 | **Survey, Mapping and Geosciences Session**  
Dr. Giovanni Sella, National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS), Chair |
| 14:00  | CORS Network Status Update – Giovanni Sella, NOAA NGS |
| 14:10  | Recommended Procedure for Post-Processing Static GPS Surveys in OPUS-Projects –  
Dan Gillins, Daren Kerr, Oregon State University and Mark Armstrong, NOAA NGS |
| 14:40  | GPS Adjacent Band Compatibility Program –  
Karl Shalberg, Zeta Associates; Hadi Wassaf, USDOT/Volpe Center; and Stephen Mackey, USDOT/Volpe Center |
| 15:00  | Attributing GIS Data: Mitigating ”Death by GPS” –  
Rick Hamilton, Coast Guard Navigation Center |
| 15:20  | Break |
| 15:40  | From Decadal Time Series to High RateReal – Time Data Streams: The Temporal Spectrum of GNSS Data and Products from UNAVCO and the EarthScope Plate Boundary Observatory (PBO) –  
David Philips, UNAVCO |
| 16:20  | Space Weather Action Plan and the GPS/GNSS User Community –  
Robert Steenbrugh, NOAA-National Weather Service |
| 16:40  | Future NGS Datums and Updated Coordinates at CORS –  
Kevin Choi, NOAA-National Geodetic Survey |
| 17:00  | Group Discussion |
## 56th Meeting of the Civil GPS Service Interface Committee at the ION GNSS+ 2016 Conference

**Oregon Convention Center • Portland, Oregon**

**September 12 - 13, 2016**

*The CGSIC is open and free to all ION GNSS+ registrants*

### Tuesday, September 13, 2016

**Room A105/A106**

**09:00-12:00**

**CGSIC Plenary Session A**

- **09:00** Welcome/Opening – Karen Van Dyke, U.S. Department of Transportation, CGSIC Chair
- **09:05** Meeting Overview – Captain Russell Holmes, Commanding Officer, U.S. Coast Guard Navigation Center (NAVCEN), Deputy Chair
- **09:10** Key Note Address – Brigadier General Mark Baird, Vice Commander, Space and Missile Systems Center, Los Angeles Air Force Base
- **09:30** U.S. National Space-Based PNT Update – Mr. Harold Martin, Director, National Coordination Office for Space-Based Position, Navigation and Timing
- **09:50** GPS Program Update – Colonel Steven P. Whitney, Director, U.S. Air Force GPS Directorate
- **10:30** Break
- **10:45** U.S. GPS/GNSS International Activities Update – Mr. Jeffrey M. Auerbach, Senior GNSS Advisor, U.S. Department of State, Office of Space and Advanced Technology
- **11:10** DHS PNT Update – Mr. John Dragseth, Office of Infrastructure Protection, National Protection and Programs Directorate, U.S. Department of Homeland Security
- **11:35** Q/A Panel (Presenters)

**12:00 – 13:30 Lunch**

### Room A105/A106

**13:30-17:30**

**CGSIC Plenary Session B**

- **13:30** Subcommittee Reports
  - Report from International Information Subcommittee – Mr. John Wilde, NAVBLUE
  - Report from Timing Subcommittee – Dr. Wlodzimierz Lewandowski, Polish Central Office of Measures (GUM)
  - Report from Surveying, Mapping, and Geosciences Subcommittee – Giovanni Sella, National Geodetic Survey (NGS)
- **14:10** Navigation Programs Update – Ms. Deborah Lawrence, Navigation Programs Manager, Federal Aviation Administration, (FAA), U.S. Department of Transportation
- **14:30** NDGPS Program Update – Mr. James Arnold, U.S. Department of Transportation and Captain Russell Holmes, U.S. Coast Guard
- **14:50** GPS User Support Forum – Mr. Hank Skalski, GPS Civil Liaison, Air Force Space Command
- **15:30** Break
- **15:50** NGA Support to Civilian PNT – Mr. Robert Wong, Senior Analyst, GPS Support Division, National Geospatial-Intelligence Agency
- **16:10** Adjacent Band Compatibility Assessment – Ms. Karen Van Dyke, Mr. Stephen Mackey and Mr. Hadi Wassaf, U.S. Department of Transportation
- **16:30** GPS User Perspectives – Open Forum
- **17:00** Q/A Panel (Presenters)

**17:30 Adjourn**
ION GNSS+ 2016 TUTORIALS

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 at the Oregon Convention Center 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 Costs and Registration

Tutorial Cost: $400 per course if registered and paid by August 12; $450 per course if payment is received after August 12. Please reference the ION GNSS+ registration form for other registration policies.

Registration: Registration for the ION GNSS+ tutorials is accomplished online through the normal conference registration process. 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.

ION GNSS+ 2016 TUTORIALS SCHEDULE

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<tr>
<th>Date/Time</th>
<th>Course</th>
<th>Instructor</th>
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<tbody>
<tr>
<td><strong>Monday, September 12</strong></td>
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<tr>
<td>1:30 p.m.–5:00 p.m.</td>
<td><strong>Select from:</strong></td>
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<tr>
<td>Room B110/111</td>
<td>Fundamentals of GNSS 1: GPS Emphasis</td>
<td>Dr. Chris Bartone</td>
</tr>
<tr>
<td>Room B114/115/116</td>
<td>GNSS Receiver Design 1: RF Front-End Theory</td>
<td>Dr. Sanjeev Gunawardena</td>
</tr>
<tr>
<td>Room B118/119</td>
<td>Kalman Filter Applications to Integrated Navigation 1</td>
<td>Dr. James Farrell, Dr. Frank van Graas</td>
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<tr>
<td>Room B113</td>
<td>Real-Time Kinematic (RTK) GNSS Positioning</td>
<td>Dr. Mark Petovello</td>
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<td>6:00 p.m.–9:30 p.m.</td>
<td><strong>Select from:</strong></td>
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<tr>
<td>Room B110/111</td>
<td>Fundamentals of GNSS 2: GPS Emphasis</td>
<td>Dr. Chris Bartone</td>
</tr>
<tr>
<td>Room B114/115/116</td>
<td>GNSS Receiver Design 2: Baseband Signal Processing and Implementation</td>
<td>Dr. Sanjeev Gunawardena</td>
</tr>
<tr>
<td>Room B118/119</td>
<td>Kalman Filter Applications to Integrated Navigation 2</td>
<td>Dr. James Farrell, Dr. Frank van Graas</td>
</tr>
<tr>
<td>Room B113</td>
<td>Precise Point Positioning (PPP)</td>
<td>Dr. Sunil Bisnath</td>
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<td><strong>Tuesday, September 13</strong></td>
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<tr>
<td>9:00 a.m.–12:30 p.m.</td>
<td><strong>Select from:</strong></td>
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<tr>
<td>Room B118/119</td>
<td>Introduction to Multi-Constellation GNSS Signals</td>
<td>Dr. Christopher Hegarty</td>
</tr>
<tr>
<td>Room B110/111</td>
<td>Ubiquitous Positioning</td>
<td>Dr. Ramsey Faragher</td>
</tr>
<tr>
<td>Room B114/115/116</td>
<td>Approaches for Resilient and Robust PNT</td>
<td>Mr. Logan Scott</td>
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<tr>
<td>1:30 p.m.–5:00 p.m.</td>
<td><strong>Select from:</strong></td>
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<tr>
<td>Room B118/119</td>
<td>Guidance, Navigation and Control of Small UAVs</td>
<td>Dr. Demoz Gebre-Egziabher, Dr. Hamid Moktarzadeh</td>
</tr>
<tr>
<td>Room B114/115/116</td>
<td>Raw GNSS Measurements from Android Phones</td>
<td>Dr. Frank van Diggelen, Mr. Steve Malkos, Dr. Mohammed Khider</td>
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</table>
TUTORIALS—Monday, September 12

Fundamentals of GNSS 1: GPS Emphasis Room B110/111

This course covers the fundamentals of GNSS with major emphasis on GPS. The course begins with an overview of GNSS and GPS. Presentation of coordinate frames and spread spectrum techniques used in GNSS are illustrated. GPS signal structure and navigation data formats (legacy and modernized) will be discussed. (Only a brief over of other GNSS such as Galileo, GLONASS, BeiDou, QZSS, and IRNSS will be presented.) This course concludes with an overview of GNSS antenna and receiver technologies. Topics to be covered include:

- Introduction to positioning systems
- A brief historical timeline of GNSS
- GPS Segments: space segment and SV blocks; ground control & improvement programs; user segment and applications
- GPS Link Budget
- Fundamental concept of GNSS position and time determination
- Coordinate frames and datums used in the application of GNSS: Earth Centered Inertial; Earth Centered Earth Fixed; Latitude, Longitude, Height; Height: MSL/Orthometric height, Ellipsoid height, Geoid Undulation; WGS-84 and the International Terrestrial Reference Frame; Local Level Tangent; Coordinate Conversion
- GNSS signal structure formats; legacy and modernized signals: Direct Sequence Spread Spectrum; auto and cross correlation; Legacy GPS: C/A, P(Y) code formats; Motivation for modernized signal formats
- Modernized GPS: L2C signal format, status; L5 signal format, status; L1C signal format, status
- Other GNSSs (Galileo, GLONASS, BeiDou, QZSS, IRNSS)-brief overview
- Overview of GNSS antenna technologies: Antenna technologies vs. performance vs. application; Antenna Technologies: dipoles, helix, patches, multi-band GNSS; Ground plane effects
- Overview of GNSS receiver technologies: Carrier tracking loops (frequency and phase lock loops); Code tracking loops (order and delay variations)

Course Level: Beginner

Dr. Chris G. Barton. P.E. is a professor at Ohio University with over 30 years of professional experience. He received his PhD EE from Ohio University, a MSEE from the Naval Postgraduate School, and BSEE from Penn State. He previously worked for the Naval Air Warfare Center, performing RT&T on CNS systems. Dr. Barton has developed and teaches a number of GPS, radar, wave propagation and antenna classes. His research concentrates on all aspects of navigation.

GNSS Receiver Design 1: RF Front-End Theory and Design Room B114/115/116

This is the first of a two-part sequence covering the design and practical implementation of GNSS receivers using the latest RF and digital signal processing technologies. Topics to be covered are applicable to a wide range of GNSS user equipment design from reference receivers through aviation-grade, military and low-power consumer grade single chip devices.

Material will be presented from both a theoretical and practical perspective, with case studies as well as overviews of the latest commercial GNSS chipsets. The course includes several MATLAB® demos designed to enhance understanding of concepts. For those wishing to follow along in class, the GNSS software receiver toolbox is available through the instructor’s blog (ChameleonChips.com; min system requirements: Windows® OS and MATLAB 2007b). This section (Part 1) covers the design of GNSS RF front-ends from LNA to ADC. Topics to be covered include:

- Overview of received GNSS signals: Link budget and system noise figure, signal structures, PSD, spreading codes and their auto and cross-correlation properties
- Front-end architectures: Superheterodyne vs. direct conversion, analog vs. digital downconversion, baseband vs. IF, sampling, and direct RF sampling. Guidelines for selecting appropriate front-end architecture for given application
- Frequency planning and control: image frequencies, bandwidth and filter selection, reference clock types and parameters, PLL synthesizers, and cost-performance tradeoffs
- RF/IF component parameters important for GNSS applications including selection guidelines
- Implementation intricacies: Factors affecting the performance of GNSS receivers such as passband group delay variation and component-induced multipath
- Sampling subsystem: AGC, ADC specifications and dynamic range considerations
- Front-end design considerations for expected levels in-of-band and adjacent-band interference
- GNSS front-end implementation options including PCB-level design and commercial GNSS MMICs.
- Sample processing and analysis demonstrations for actual GNSS receiver front-ends of various center frequencies, bandwidths, sampling schemes and bit depths

Course Level: Beginner to Intermediate

Dr. Sanjeev Gunawardena is a research assistant professor with the Autonomy & Navigation Technology (ANT) Center at the Air Force Institute of Technology. Previously he was a senior research engineer and principal investigator with the Ohio University Avionics Engineering Center (AEC), where he served as lead developer of multi-frequency instrumentation-grade GNSS receiver front-ends, FPGA-based next-generation GNSS processors, and multi-sensor data collection systems for scientific research. He received the 2007 RTCA William E. Jackson Award for outstanding contribution to aviation for the application of transform-domain technology for high-fidelity GNSS performance monitoring. Dr. Gunawardena received a BS in engineering physics, and a BSEE, and PhD EE from Ohio University.

Kalman Filter Applications to Integrated Navigation 1 Room B118/119

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 variability 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.

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

Dr. James L. Farrell is an ION Fellow and author of over 80 journal and conference manuscripts. He authored Integrated Aircraft Navigation (Academic Press, 1976) and GPS Aided Navigation and Tracking (2007). His technical experience includes teaching appointments at Marquette and UCLA, Honeywell, Bendix-Pacific, and Westinghouse in design, simulation, and validation/test for modern estimation algorithms in navigation and tracking applications, and digital communications system design. As president and technical director of VIGIL INC. he has continued his teaching and consulting on inertial navigation and tracking for private industry, DOD, and university research.

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 an 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, inertial navigation, 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), Turlow (2002), and Burkà (2010) awards.
Tutorials: Monday Afternoon
1:30 p.m.–5:00 p.m.

Real-Time Kinematic (RTK) GNSS Positioning
Room B113

This course presents the key principles associated with high accuracy real-time kinematic (RTK) GNSS positioning. After briefly reviewing the relevant concepts of GNSS positioning, the course presents the different measurements and error sources that limit positioning accuracy. The geographic and temporal variability of the errors will be addressed, as appropriate.

Once the GNSS errors are understood, focus turns to mitigation of these errors through measurement differencing and linear measurement combinations. The motivation for these approaches will be explained in the context of trying to resolve the carrier phase ambiguities. To this end, ambiguity resolution strategies in the position and ambiguity domains are discussed. Mathematical formulations for the various approaches are introduced.

The course concludes with a look at how to predict the success of the ambiguity resolution process, the role of additional frequencies and systems in ambiguity resolution, and a brief look at multiple reference station approaches. Case studies will be included in electronic format only.

Users and programmers will gain knowledge in the wide range of aspects that need to be considered when trying to achieve high positioning accuracy with GNSS.

Course Level: Intermediate to Advanced

Dr. Mark Petovello is a professor in the Position, Location and Navigation (PLAN) group in the Department of Geomatics Engineering, University of Calgary. Since 1998 he has been involved in a variety of navigation research areas including satellite-based navigation, inertial and dead-reckoning navigation, ambiguity resolution, reliability analysis and software-based GNSS receivers. He has extensive experience in navigation algorithm development, implementation and refinement, and is co-creator of several navigation-related software packages.

Fundamentals of GNSS 2:
GPS Emphasis
B110/111

This course covers the fundamentals of GNSS with major emphasis on GPS regarding user functions, solutions, and performance. The core functions that need to be performed in obtaining a user solution using GPS in an error free environment will initially be explained. Atmospheric effects from the ionosphere and troposphere as well as error mitigation techniques will be covered from a stand-alone and differential perspective. A case study using real GPS data will be used throughout the course to illustrate user state solution and performance metrics (i.e., error, DOPs) for stand-alone (without atmospheric corrections), with atmospheric corrections, and differential positioning. Topics to be covered include:

- GNSS Observables: code, carrier, and date formats; RINEX, NMEA, and manufacture unique formats
- Calculation of the GPS space vehicle (SV) position using the broadcast Kepler parameters (ephemeris and almanac)
- SV clock, relativistic, and single-frequency corrections
- Transit time (i.e., Earth rotation) correction
- GPS Time Considerations: GPS week number, time of week, local time, UTC and the leap second
- Calculation of user state (i.e., position, velocity, and time): Ordinary-least squares solution
- Associated user solution performance parameters (i.e., dilution of precision terms)
- Case Study: Stand-alone performance illustration (no atmospheric corrections)
- Atmosphere Errors (“stand-alone” perspective): Ionosphere error sources and characterization, models and mitigation; Troposphere error sources and characterization, models and mitigation; Case Study: Stand-alone performance illustration (with atmospheric corrections)
- GPS error budget
- Error characterization for a “stand-alone” user: Satellite orbit and clock errors; Signal multipath error characterization, analysis, and mitigation techniques; Code-minus-Carrier Analysis; Smoothing
- General Types of Augmentation; (PPP, A-GPS, DGNSS)
- Differential GNSS and different ways to implement it: Correction-based methods (illustrated DGPS examples); Measurement-based methods; Single, double, and triple differencing techniques
- Case Study: DGPS performance illustration

Course Level: Beginner to Intermediate (This course is more advanced than a simple user’s introductory course; but not too detailed for the beginner.)

Dr. Chris G. Bartone

P.E.

is a professor at the Ohio University with over 30 years of professional experience. He received his PhD EE from Ohio University, a MSEE from the Naval Postgraduate School, and BSEE from Penn State.

He previously worked for the Naval Air Warfare Center, performing RTD&E on CNS systems. Dr. Bartone has developed and teaches a number of GPS, radar, wave propagation, and antenna classes. His research concentrates on all aspects of navigation.

GNSS Receiver Design 2:
Baseband Signal Processing and Implementation
Room B114/115/116

This is the second of a two-part sequence covering the design and practical implementation of GNSS receivers using the latest RF and digital signal processing technologies. Topics to be covered are applicable to a wide range of GNSS user equipment design from reference receivers through aviation-grade, military and low-power consumer grade single chip devices. Material will be presented from both a theoretical and practical perspective, with case studies as well as overviews of the latest commercial GNSS chips. The course includes several MATLAB® demos designed to enhance understanding of concepts. For those wishing to follow along in class, the GNSS software receiver toolbox used is available through the instructor’s blog (ChameleonicChips.com; min system requirements: Windows® OS and MATLAB® 2007b). This section (Part 2) covers digital signal processing from sample correlation through the formation of range measurements. Also covered are implementation techniques using dedicated hardware, programmable logic (FPGA), GPU, and CPU, including hardware/software partitioning strategies. Topics to be covered include:

- Overview of received GNSS signals: Signal structures of GPS, GLONASS, Galileo, BeiDou, QZSS and IRNSS
- Correlation processing: Time, frequency and transform-domain techniques. Advanced correlator architectures for multipath mitigation and signal degradation monitoring
- Complexity reduction for real-time implementation and impacts thereof
- Signal acquisition algorithms, rapid acquisition techniques, transition to tracking, bit/symbol synchronization, and state machine-based low-level channel control
- Tracking: FLL/PLL and DLL, carrier aided code, inter-frequency aiding, loop tightening techniques, noise bandwidth, tracking performance, block (batch) processing and open-loop tracking techniques
- Measurement computation: Navdata extraction/decoding, TOT/TOR registers, and formation of pseudo range and carrier phase
- Implementation techniques and platforms from MATLAB® to dedicated hardware
- Software signal acquisition and tracking demos for: GPS (L1-C/A, L2C, and L5), GLONASS (L1 and L2), Galileo (E1B/C, E5a, and E5b), BeiDou (B1I and B2I) and QZSS

Course Level: Beginner to Intermediate

Dr. Sanjeev Gunawardena

is a research assistant professor with the Autonomy & Navigation Technology (ANT) Center at the Air Force Institute of Technology. Previously he was a senior research engineer and principal investigator with the Ohio University Avionics Engineering Center (AEC), where he served as lead developer of multi-frequency instrumentation-grade GNSS receiver front-ends, FPGA-based next-generation GNSS processors, and multi-sensor data collection systems for scientific research. He received the 2007 RTCA William E. Jackson Award for outstanding contribution to aviation for the application of transform-domain technology for high-fidelity GNSS performance monitoring. Dr. Gunawardena received a BS in engineering physics, and a BSEE, MSEE and PhD EE from Ohio University.

Kalman Filter Applications to Integrated Navigation 2
Room B118/119

Integration of GPS with an Inertial Measurement Unit (GPS/IMU) is used to illustrate the application of Kalman Filtering to 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 enabled by a 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 below-mask ionospheric and tropospheric degradations, 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.

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

Dr. James L. Farrell is an ION Fellow and author of over 80 journal and conference manuscripts. He authored Integrated Aircraft Navigation (Academic Press, 1976) and GNSS Aided Navigation and Tracking (2007). His technical experience includes teaching appointments at Marquette and UCLA, Honeywell, Bendix-Pacific, and Westinghouse in design, simulation, and validation/test for modern estimation algorithms in navigation and tracking applications, and digital communications system design. As president and technical director of VIGIL INC. he has continued his teaching and consulting on inertial navigation and tracking for private industry, DOD, and university research.

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 an 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, inertial navigation, 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.

Precise Point Positioning (PPP) Room B113

This course will begin with the development of the Precise Point Positioning (PPP) GNSS measurement processing technique. A detailed treatment of the data processing mathematical models will follow, focusing on the parameterization of functional and stochastic models. Descriptions of the necessary error modeling will be given, including a discussion of solution sensitivity. The requisite sequential data filtering mathematics will be provided with examples. Positioning performance with various measurement inputs and modes (static, kinematic, single-/ dual-frequency, single-/ multi-constellation) will be investigated and illustrated with examples. Current scientific and commercial applications will be reviewed. Recent data processing advances will be described. The course will conclude with a discussion of the future prospects for the PPP technique.

Course Level: Beginner to Intermediate

Introduction to Multi-Constellation GNSS Signals Room B118/119

This course provides an overview of multi-constellation GNSS signals. Digital modulation techniques used for satellite navigation systems will be described, including a discussion of important characteristics such as pseudorandom noise codes, autocorrelation/cross-correlation properties, power levels, and polarization. Common features found in modern GNSS signal designs will be introduced, including dataless (pilot) components, square-wave subcarriers, secondary codes, forward error correction, and error detecting coding. The present and future signals of the Global Positioning System (GPS), including C/A-code, P(Y)- code, L2 civil (L2C), L5, M-code, and L1 civil (L1C) will be detailed, as will the signals for GLONASS, GALILEO, Beidou, satellite-based augmentation systems (SBAS), and other emerging satellite navigation systems. This class is intended for anyone with an interest in better understanding multi-constellation GNSS signals, including researchers, design engineers, application developers, end-users, systems engineers, managers and executives. Attendees are assumed to have a familiarity with the basic concepts of satellite navigation.

Course Level: Beginner to Intermediate

Dr. Ramsey Faragher is an expert in GNSS-denied positioning, sensor fusion, and machine-learning. He is the founder and CEO of Focal Point Positioning, a Fellow of the Royal Institute of Navigation, and a Bye Fellow of Queens’ College, Cambridge. Previously he has held research positions at the University of Cambridge and was a principal scientist at BAE Systems where he developed the NAVSOP opportunistic positioning suite and other GNSS-denied tracking technologies.

Approaches for Resilient & Robust Positioning, Navigation and Timing B114/115/116

GPS has been described as the stealth utility. Diverse elements of national infrastructure and military capability are critically reliant on GPS 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 GPS receivers and offers some possible threat mitigation approaches and policy recommendations. The tutorial starts with a discussion of how important GPS is to the US economy and some of the potential GPS threats and vulnerabilities.

Then, after a quick review of how GPS determines position, the focus is on the effects of various interference types on specific GPS signals. The effects of ground mobile propagation in limiting effective jammer range are examined. Military mitigations such adaptive arrays, and IMU aiding are discussed. Civil jamming examples and incidents are then covered along with methods to detect, identify and mitigate against their effects. In particular, the

Ubiquitous Positioning Room B110/111

Over $1 trillion of the US economy and over €800 billion of the European economy are dependent on GNSS for positioning or timing solutions. However, we typically spend over 80% of our time indoors, where GNSS does not yet penetrate. The global indoor location-based market is also expected to exceed $10 billion by the end of this decade.

The aim of a ubiquitous positioning system is to provide a tracking solution in all environments. Highly reliable ubiquitous positioning systems must not just cover indoor and outdoor operations, but must also be capable of providing outdoor tracking solutions when traditional GNSS receivers are experiencing jamming or spoofing.

This short course will open with an overview of the current commercial and military technologies that aim to address the ubiquitous positioning problem by providing multiple, redundant, indoor and outdoor positioning capabilities. The step-by-step development of a fully-functioning ubiquitous positioning system based around a smartphone sensor platform, particle filtering, and Simultaneous Localization and Mapping (SLAM) will then be demonstrated. While no knowledge of programming will be assumed for the course, the attendee will be provided with all the information needed to develop their own cutting-edge smartphone-based self-learning ubiquitous tracking system. We will also cover the benefits that can be provided by adding peripherals such as a low cost software-defined radio to a smartphone-based system. The course will wrap up with a look at some of the future technologies in this space that are currently under development by a range of technology providers.

Course Level: Beginner to Intermediate

Dr. Christopher J. Hegarty is the Director for CNS Engineering & Spectrum with The MITRE Corporation. He is the chair of RTCA’s Program Management Committee, co-chair of RTCA Special Committee 159, and associate editor of NAVIGATION. He was the recipient of the 2005 ION Johannes Kepler Award, and served as ION President in 2008. He is a Fellow of the ION, the IEEE, and the co-author of Understanding GPS: Principles and Applications, 2nd Edition.
Guidance, Navigation and Control of Small UAVs
Room B118/119

Small Unmanned Aerial Vehicles (SUAVs) present unique challenges when it comes to guidance, navigation and control. This is due to, in part, the severe size, weight, power and cost (SWAP) constraints associated with these vehicles. In this short course we will discuss the challenges and some solutions to the GNC problem associated with SUAVs.

Course Content:

1. Introduction: What are small UAVs? How do they differ from other aerial vehicles and what are the unique GNC challenges? Sample of growing applications: remote sensing, mapping, avionics research and development.
2. SUAV Flight Control System (FCS) architectures: What are the components for the small UAV autopilot?
3. GNC System and Design: Requirements and design of robust navigation, guidance and control systems for SUAVs.
4. Operational challenges: Requirements for legal operation of small UAVs.

Level: Beginner to Intermediate

Raw GNSS Measurements from Android Phones
Room B114/115/116

Google recently announced that raw GNSS measurements are available to apps in the Android N operating system. This means you can get Pseudoranges, Dopplers and Carrier Phase from a phone or tablet. In this 3½ hour class you will learn to access and use these raw measurements. The tutorial is hands-on; we will bring phones for you to use. You will collect, view, and process raw measurements. You will leave the class with the data, Google software tools, and the knowledge of how to use them.

The class comprises three parts:

1. Description of the available data: We will review the data that is accessible by developers (i.e. you) in Android. This is the theoretical part of the class, and we will review the definitions of the different types of GNSS measurements, their physical meaning, and how to use them for analysis and location.
2. The Android Software Stack: You will learn how data flows through the Android software stack. In this part of the course you will open your laptops, and we will show you where online to find the definitions of the different data structures. You'll learn which of these is available to you at the Application layer. At the end of this section we will provide Android N phones that you can use for the rest of the class.
3. Using the data: After a break to collect GNSS measurements outside, you will download the data from the phones and do some processing. We will provide software tools that you can use during and following the class. The tools allow you to log data from an Android N device, view the raw measurements, and do basic measurement analysis and position computation.

Finally, we will give you specific examples of research projects and applications that you can develop with the tools and knowledge obtained in the class. For example: How to build a GNSS data analysis app; how to build a crowd-sourced jammer detector; etc.

To tailor this tutorial to your own needs, visit this online form and let us know what you’d like us to cover in the class: http://bit.ly/1TJkmwW

Level: Beginner to Intermediate
ION GNSS+ Plenary Session
Tuesday, September 13, 2016 • 6:30 p.m.–8:30 p.m. • Oregon Ballroom

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

Opening of the Plenary Session
Satellite Division Vice-Chair
Dr. Frank van Diggelen
Google

Satellite Navigation and Technology for Africa
Patricia Doherty
Boston College
The Satellite Navigation and Technology for Africa program allows African scientists and engineers to explore GNSS applications to increase food security, manage natural resources, provide emergency location services, improve surveying and mapping, and make land, water and air navigation systems safer and more precise. This program, sponsored in part by the ION Satellite Division, will be presented.

Keynote Address: The Positioning System of the Brain
Nobel Laureate, Professor John O’Keefe
Neuroscientist and Professor at the Sainsbury Wellcome Centre for Neural Circuits and Behaviour and the Research Department of Cell and Developmental Biology at University College London

Professor John O’Keefe is the winner of the Nobel Prize in Physiology and Medicine for discovering cells that constitute a positioning system in the brain. He will explain how animals and humans find their way - by working out the relationship between where they are and where other things are. The brain does this by representing places (where you are now), and representing distances and directions. Prof. O’Keefe and his colleagues have established which part of the brain does this, and how it works. Your brain has cells that represent places; so when you are in a familiar environment different cells represent different locations in this environment. There are cells that represent directions, for where you are looking and where you are moving; and there are also cells that tell the distances moved in particular directions. All this together forms a so called “cognitive map”, which is a framework for identifying where you are, where other things are in your environment, and how to get from one place to another.

Program Overview by Track Chairs
The speakers will be given five minutes each to highlight the key hot topics that will be discussed during the week. It will be a fast and fun snapshot of what is happening in the world of GNSS+ and over the course of the conference.

Moderator: Alan Cameron, GPS World

Presenters:
Dr. Brent Ledvina, Virginia Tech
Dr. Alex Stratton, Rockwell Collins
Dr. Kurt Zimmerman, Trimble
Dr. Michael Veth, Veth Research Associates
Dr. Heidi Kuusniemi, Finnish Geospatial Research Institute, Finland
Dr. Jiyun Lee, KAIST, South Korea
Wednesday Morning, September 14, 8:30 a.m.–12:15 p.m.

Room A107/108/109
8:30 a.m.–12:15 p.m.
A1: Advances in GNSS Software-defined Receivers

Dr. Thomas Pang, IFEN GmbH, Germany

8:35 Demonstration of Cloud GNSS Signal Processing: V. Lucas-Sabola, G. Seco-Granados, J.A. López-Salcedo, Universitat Autonoma de Barcelona (UAB), Spain; J.A. García-Molina, European Space Agency (ESA) & HE Space, The Netherlands; M. Crisci, ESA, The Netherlands

9:05–10:35, Break. Refreshments in Exhibit Hall

8:35 Plug and Play Sensor Fusion for Lane-Level Positioning of Connected Cars in GNSS-Challenged Environments: A. Soloviev, M. Veth, C. Yang, QuNav


9:43 Implementation and Analysis of GNSS Software Receiver on Embedded CPU-GPU Heterogeneous Architecture: K.W. Park, W.J. Jang, Chungbuk National University, South Korea; M.J. Lee, Agency for Defense Development, South Korea; S. Kim, Hanyang University, South Korea; C. Park, Chungbuk National University, South Korea

10:05–10:35, Break. Refreshments in Exhibit Hall

10:40 Exploiting Standardized Metadata for GNSS SDR Remote Processing: A Case Study: A. Favenza, Istituto Superiore Mario Boella, Italy; N. Linty, F. Davio, Politecnico di Torino, Italy

11:03 Low Duty-Cycling of Direct GPS Positioning for Fast Continuou Navigation Estimation: Y. Ng and G.X. Gao, University of Illinois at Urbana-Champaign

11:26 Simultaneous Frequency Search with a Randomized Dirichlet Kernel for Fast GPS Signal Acquisition: C. Yang, Sigtem Technology, Inc.; A. Soloviev, QuNav; M. Veth, Veth Research Associates; E. Blasch, AFRL

11:48 Open-Loop Tracking of GNSS Signals at Audio Processing Rates: C.R. Benson and S.J. Qaiser, University of New South Wales Canberra, Australia

Alternates

2. GNSS SDR Based on Multi-channel Multi-Band Multi-System RFFE IC: D. Tcherniakovski, K. Veprev, F. Nikolai, A. Tsikhamirava, NTLab, Belarus

Room C120/121/122
8:30 a.m.–12:15 p.m.
B1: Multisensor Navigation in Challenging Environments 1

Dr. Patrick Robertson, Google

8:35 Plug and Play Sensor Fusion for Lane-Level Positioning of Connected Cars in GNSS-Challenged Environments: A. Soloviev, M. Veth, C. Yang, QuNav

9:05–10:35, Break. Refreshments in Exhibit Hall

8:35 Demonstration of Cloud GNSS Signal Processing: V. Lucas-Sabola, G. Seco-Granados, J.A. López-Salcedo, Universitat Autonoma de Barcelona (UAB), Spain; J.A. García-Molina, European Space Agency (ESA) & HE Space, The Netherlands; M. Crisci, ESA, The Netherlands


9:43 Implementation and Analysis of GNSS Software Receiver on Embedded CPU-GPU Heterogeneous Architecture: K.W. Park, W.J. Jang, Chungbuk National University, South Korea; M.J. Lee, Agency for Defense Development, South Korea; S. Kim, Hanyang University, South Korea; C. Park, Chungbuk National University, South Korea

10:05–10:35, Break. Refreshments in Exhibit Hall

10:40 Exploiting Standardized Metadata for GNSS SDR Remote Processing: A Case Study: A. Favenza, Istituto Superiore Mario Boella, Italy; N. Linty, F. Davio, Politecnico di Torino, Italy

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11:48 Open-Loop Tracking of GNSS Signals at Audio Processing Rates: C.R. Benson and S.J. Qaiser, University of New South Wales Canberra, Australia

Alternates

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Room B117/118/119
8:30 a.m.–12:15 p.m.
C1: GNSS Augmentation Systems and Integrity 1

Dr. Grace Gao, University of Illinois at Urbana-Champaign

8:35 Expanded Ionospheric Estimation and Threat Model Algorithms for SBAS: E. Bang, Korea Advanced Institute of Science and Technology, South Korea; J. Wang, BJTU, China

8:57 Satellite Selection for Multi-Constellation SBAS: T. Walter, J. Blanch, Stanford University; V. Kropf, University FAF Munich, Germany


9:43 Assessment of Alternation Techniques to Mitigate Differential Ionosphere for GBAS: J. Dennis, ISI/Pragmatics, Inc.

10:05–10:35, Break. Refreshments in Exhibit Hall

10:40 Experimental Validation of an Ionospheric Monitoring Scheme for Dual Frequency GBAS: M. Flexu, M.S. Circiu, D. Gerbeth, M. Caamano, German Aerospace Center, (DLR), Germany

11:03 Aviation-based GNSS Integrity Augmentation for UAS Mission Planning and Real-time Trajectory Optimisation: R. Sabatini, RMIT University, Australia; T. Moore, C. Hill, The University of Nottingham, UK

11:26 A Novel GNSS Integrity Augmentation System for Autonomous Airport Ground Operations: S. Bijahalli, S. Ramasamy and R. Sabatini, RMIT University, Australia

11:48 Exploitation of Existing Ground Infrastructure for GNSS-augmentation and Integrity in Road Applications: Feasibility Study and Performance Evaluation: S. Ugazio, M. Visintin, L. Lo Preti, Politecnico di Torino, Italy

Alternates
1. Analyses of Relation Between Motion in Flight and Response of Loosely-coupled GNSS Aided AHRS: M. Naruoka, Y. Shimizu, T. Fujiwara, T. Tsuji, Japan Aerospace Exploration Agency, Japan

2. An Enhanced Integrity Monitoring Technique for GNSS-based Positioning in the Railway Domain: S. Damy, A. Majumdar, W. Ochieng, Imperial College London, UK

3. Implementation of ARAIM using the Ground-based Regional Integrity Monitoring System (GRIMS) of China: L. Li, R. Xue, Y. Zhu, Beihang University, China


5. Integrity of SBAS Ionosphere Corrections for Equatorial Region: F. Haddad, M. Dall’Orso, T. Authié, Thales Alenia Space, France

Blue Text Indicates Student Paper Award Winner

Blue Text Indicates Student Paper Award Winner
Wednesday Morning, September 14, 8:30 a.m.–12:15 p.m.

### Room A105/106
8:30 a.m.–10:05 a.m.  
**D1a: Current Advances in Indoor Location (with demonstrations)**

- Dr. Di Qiu, Topcon, Japan
- Will Morrison, Qualcomm

This session provides an update on satellite-based navigation systems in operation or under development. 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 Discussion

- **Panel Topics**
  1. GPS: Col Steven Whitney, Director, Global Positioning Systems Directorate
  2. **GLONASS:** Dr. Sergey Karutin, Deputy Director General, Central Research Institute for Machine Building
  3. **Galileo Program Status:** Eric Chatre, European Space Agency, Belgium and Marco Falcone, European Space Agency Galileo System Manager, The Netherlands
  4. **BeiDou:** Dr. Jun Shen, Deputy Director, International Cooperation Center, China Satellite Navigation Office, China
  5. **QZSS:** Yoshiyuki Murai, Executive Director, Promotion of QZSS Utilization, Quasi-Zenith Satellite System Services inc., Japan

### Alternates for D1b Listed to the Right

1. The Indoor Location Technology Based on Mems IMU Assisted with Magnetometer and IMU: Z. Tao and Y. Min, Jiangxi Normal University, China
2. A New Smartphone-based Indoor GPS Positioning System: R. Xu, J. Liu, The Nanjing University of Aeronautics and Astronautics (NUAA), China; W. Chen, The Hong Kong Polytechnic University, Hong Kong; Li, N., China
3. Positioning Algorithm Adaptation of an Indoor Navigation System for Virtual Reality Game Applications: Z. Hao, M. Jia, Tonghua University, China; D. Dong, Beijing Sun Light Technology Co., Ltd., China; X. Cui, Tonghua University, China

### Room B113/114/115/116
8:30 a.m.–12:15 p.m.  
**E1: PANEL: Status of GPS, GLONASS, Galileo, BeiDou, and QZSS**

- Dr. John Bats, The MITRE Corporation
- Dr. José Angel Rotta, ESA, The Netherlands

### Room B110/111/112
8:30 a.m.–12:15 p.m.  
**F1: GNSS+ Augmentations for High Performance and Safety Critical Applications**

- Dr. Gary McGraw, Rockwell Collins
- Boubeker Belabbas, German Aerospace Center (DLR), Germany

- **SBAS DSVP:** An SBAS DMC Service Volume Software Prototype: D. Salos, M. Mabilleau, Egis Avia, France; C. Rodriguez, N. Suared, H. Secretan, CNES, France
- **New Orbit Determination and Clock Synchronisation Modules for EGNSOS:** A. Rouanet Labé, R. Lembachar, T. Authié, S. Trilles, Thales Alenia Space, France; F. Mercier, CNES, France
- **Assessment of Dual-Frequency Dual-constellation GBAS Processing Modes Based on Flight Trials:** M.-S. Ciric, German Aerospace Center (DLR) & RWTH Aachen University, Germany; M. Felix, D. Gerbeth, M. Caamaño, DLR, Germany; M. Meurer, DLR & RWTH Aachen University, Germany
- **Authentication Concepts for Satellite-Based Augmentation Systems:** A. Dalla Chiara, Qascom, Italy; I. Fernandez Hernandez, E. Chatre, EU Commission, Belgium; V. Rijmen, University of Leuven, Belgium; G. Da Broi, O. Pozzobon, Qascom, Italy; J. Caro Ramon, J. Fidalgo, GMW, Spain; N. Laurenti, G. Caparra, S. Sturaro, University of Padova, Italy

10:05–10:35, Break. Refreshments in Exhibit Hall

#### Panel Discussion

- **Panel Topics**
  1. GPS: Col Steven Whitney, Director, Global Positioning Systems Directorate
  2. **GLONASS:** Dr. Sergey Karutin, Deputy Director General, Central Research Institute for Machine Building
  3. **Galileo Program Status:** Eric Chatre, European Space Agency, Belgium and Marco Falcone, European Space Agency Galileo System Manager, The Netherlands
  4. **BeiDou:** Dr. Jun Shen, Deputy Director, International Cooperation Center, China Satellite Navigation Office, China
  5. **QZSS:** Yoshiyuki Murai, Executive Director, Promotion of QZSS Utilization, Quasi-Zenith Satellite System Services inc., Japan

2:12 Satellite Selection of Multi-GNSS: Y. Cheng, J. Dambeck, F. Holzapfel, Technical University of Munich, Germany


2:58 Demonstrated Interference Detection and Mitigation with a Multi-frequency High Precision Receiver: F. Gao and S. Kennedy, NovAtel Inc., Canada

3:25–3:55, Break. Refreshments in Exhibit Hall

4:00 INS Aided Multi-GNSS Robust Positioning with Centralized and Distributed Fusion Algorithm: B. Liu, X. Zhan, M. Chen, Shanghai Jiao Tong University, China

4:23 Potential Limitations of RAIM in Assured Navigation: J.-C. Juang, National Cheng Kung University, Taiwan

4:46 Computationally Efficient Unscanted Kalman Filtering Techniques for Launch Vehicle Navigation using a Space-borne GPS Receiver: S. Biswas, L. Qiao, A. Dempster, The University of New South Wales, Australia


Alternates
1. Enhanced Multi-GNSS PVT Solution When Using Chip Scale Atomic Clocks: T. Krawinkel and S. Schön, Leibniz Universität Hannover, Germany

2. The Advanced Replica Transformation & Storage (ARTS) Technique: A. Richardson, M. Turner, D. DeCastro, M. Batiste, Airbus, UK

3. Effects of Jamming on the Accuracy of GPS Position Solutions in an Experimental Set-up: B. Lubbers and P. OoNinch, Netherlands Defence Academy, The Netherlands

4. Effective Utilization of Space Service Volume through Combined GNSS: A. Rathinam, A.G. Dempster, University of New South Wales, Australia

5. Multi-Constellation GNSS: New Bounds on GDOP and a Related Satellite Selection Process: P.F. Swavez, University of Rhode Island; R.J. Hartnett, U.S. Coast Guard Academy; K.C. Seals, U.S. Coast Guard Academy

1:50 An Investigation of GPS Satellite Clock Offsets Prediction Accuracy with Different Update Intervals and Application to Real-Time PPP: H. Yang and Y. Gao, University of Calgary, Canada

2:12 Multi-receiver GPS Based Direct Time Estimation for PMS’s: S. Bhamidipati, Y. Ng and C.X. Gao, University of Illinois at Urbana-Champaign

2:35 TWSTFT for BDS: Status and Applications: S. Zhou, X. Hu, Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS), China; L. Liu, Beijing Satellite Navigation Center (BSSC), China; Y. Cao, SHAO, CAS, China; R. Guo, L. Zhu, Z. Chang, BSSC, China; C. Tang, X. Gong, R. Li, SHAO, CAS, China; J. Chen, Chen Top Communication Co., Ltd., China


3:25–3:55, Break. Refreshments in Exhibit Hall

4:00 The Performance Analysis of an UAV Borne Vector Gravimetry System: C-A. Lin, National Cheng Kung University, Taiwan


4:46 COREGAL: Exploring Galileo E5 Reflected Signals for Biomass Applications: T. Peres, J. Silva, P. Silva, DEIMOS Engenharia, Portugal; J.M. Palomo, DEIMOS Space, Spain; O. Penal, Tecnalia, Spain; L. Guerriero, University of Rome Tor Vergata, Italy; N. Cavallai, Max-Planck-Institute, Germany; O. Cartus, GAMMA Remote Sensing and Consulting, Switzerland; J. Colomina, Geonumerics, Spain

5:08 Evaluation of the Ionospheric F2 Characteristics Inferred from Radio Occultations Exploiting the Availability of Formosat-3/COSMIC Data Over Half a Solar Cycle: A. Aragon-Angel, EC, Joint Research Centre (JRC), Italy; M. Limberger, Technischen Universität München (DGFI-TUM), Germany; M. Hernández-Pajares, Universidad Politécnica de Cataluña, Spain; D. Altadill, Observatori de l’Ebre (OEB), CSIC, Universitat Ramon Llull, Spain; E. Erdogan, M. Schmidt, DGFI-TUM, Germany

Alternates

2. A New Network-Based Synchroization Approach for Pseudolite and Improvements on Robustness: T. Wang, Z. Yao, S. Yun, M. Lu, Tsinghua University, China

3. GPS Attitude Determination for VELOX-CI Near-Equatorial LED Microsatellites: G.X. Lee, F. Cao, Y-F. Tsai, S.T. Chiu, W.S. Lim, K.S. Low, K.V. Ling, E.K. Poh, C.S. Lim, Nanyang Technological University, Singapore

Blue Text Indicates Student Paper Award Winner

Wednesday Afternoon, September 14, 1:45 p.m.–5:30 p.m.
Fifty-four percent of the world’s population lives in urban areas, a proportion that is expected to increase to 66 percent by 2050. However, mobile positioning in urban environments continues to be a frustrating experience for users.

We have all experienced the difficulties of positioning in urban environments, whether it’s a car navigation system giving the wrong directions or our cell phone maps showing us several city blocks away from our true location. In addition to this, many mobile applications such as emergency caller location are demanding higher accuracy under all conditions.

GNSS positioning techniques suffer from several sources of measurement error in deep urban canyons. These include multipath reflections and non-line-of-sight signal tracking. These are compounded by poor sky-view leading to few usable satellites and high dilution of precision.

In recent years there have been a number of novel approaches to improving positioning performance in these challenging environments. We now have more options than just GNSS. MEMS sensors are now inexpensive and incorporated in most of our devices. We also have WiFi access point databases, other location beacons and other signals as well as a plethora of new GNSS constellations and bands with enhanced multipath resistance to add to our positioning arsenal.

The panelists will discuss ideas such as fusion of GNSS data with all these new sources of information as well as new, novel proposals. This panel will present candidate practical strategies to mitigate these large errors and will be available for audience questions after the presentations. Most recently, we have access to raw GNSS pseudoranges, Doppler and carrier phase in Android devices.

The panelists will discuss ideas such as fusion of GNSS data with all these new sources of information as well as new, novel proposals. This panel will present candidate practical strategies to mitigate these large errors and will be available for audience questions after the presentations.

1. An Open Testing Platform for BeiDou/GNSS: Haitao Wu, Academy of Opto-Electronics, Chinese Academy of Sciences, China
2. Precise Orbit Determination for Multi-GNSS Satellites in Wuhan IGS-MGEX Analysis Center: Qize Zhao, GNSS Research Center of Wuhan University, China
3. BDS Applications: From Experiments to Mass Deployment: Dr. Jun Shen, Beijing Uninstruct Science and Technology Co. Ltd., China
4. China GNSS Haoping Radio Observatory and Monitoring Results: Jin Wang, National Time Service Center, Chinese Academy of Sciences, China
5. BeiDou Signal Parameters Characterization During Strong Equatorial Ionospheric Scintillation: Dongyang Xu, Colorado State University

The deployment of Galileo has shifted into high gear and it is time to start paving the way for evolutions. Lessons learnt, and the ambition of Galileo to remain at the cutting edge of the world of satellite navigation, are the inspiration for Europe’s modernization program. This panel will provide an insight into how the next generation of Galileo could look. Invited panelists from the European Commission (EC), European Space Agency (ESA) and European GNSS Agency (GSA) will share their views and visions with the audience.

1. European Space Agency (ESTEC): Dr. Gustavo Lopez-Ruiseiro, Head of the Galileo 2nd Generation System Engineering Unit, ESA/ ESTEC, The Netherlands
2. European Commission (EC): Eric Chatre, Head of Sector–Exploitation and Services, DG for Internal Market, Industry, Entrepreneurship and SMEs, EU Satellite Navigation Programs, European Commission, Belgium
4. European GNSS Agency (GSA): Marco Caparrini, GNSS Service Evolution R&D Engineer, Galileo Exploitation Department, European GNSS Agency, Prague

1:50 Undifferented GLONASS Ambiguity Resolution Over Inhomogeneous Receivers: Introducing Ionosphere Corrections or Resolving Ionosphere-free Ambiguities?: J. Geng, X. Chen, Q. Wen, H. Chang, Wuhan University, China
2:12 Facing Some Critical Challenges in Real-Time Precise Point Positioning: A. El-Mowafy, Curtin University, Australia
2:35 JPL’s Real-Time Orbit Determination for GPS, GLONASS, BeiDou, and Galileo: M. Miller, Y. Bar-Sever, W. Bertiger, N. Harvey, L. Romans, A. Stiborhope, B. Sziagyi, M. Vallineri, Jet Propulsion Laboratory, California Institute of Technology
3:25–3:55, Break. Refreshments in Exhibit Hall
4:00 Integer Ambiguity Resolution Enabled PPP and RTK Solutions Using GPS and Glonass Observations: X. Liu, M. Goode, M. Stone, Fugro Intern ISOBV, The Netherlands; J. Tegedor, and R. Strandli, Fugro Satellite Positioning AS, Norway
4:23 PPP Integrity for Advanced Applications, Including Field Trials with Galileo, Geodetic and Low-Cost Receivers, and a Preliminary Safety Analysis: M.D. Lainez Samper, P.F. Navarro Madrid, I. Rodriguez Perez, J.D. Calle Calle, M. M. Romay Merino, GMV, Spain
5:08 Demonstration: ESB Signal Containing Value-Added Information Broadcast in Real Time via the SES ASTRA 3BG GEO Satellite: M. Aubault-Roudier, D. Laurchesse, CNES, France; H. Al Bitar, M. Raimondi, P. Lesage, A. Steir, M. Kleen, Thales Alenia Space, France; M. Sihrener, ESSP, France; N. Ramponi, SES Techcom, Luxembourg

Alternates
1. GAPS Single- and Dual-Frequency PPP Using GPS, BeiDou, and Galileo Observables: R.M. White, R.B. Langley, University of New Brunswick, Canada; S. Banville, Natural Resources Canada
2. BDS Fractional Cycle Bias (FCB) Estimation Augmented by Multipath Mitigation: M. Wang, H. Chai, D. Zhao, Zhengzhou Institute of Surveying and Mapping, China
3. Estimation Methods of Spherical Cap Harmonic Models Based on Kalman Filter for Regional Ionospheric Delays: M. Ohashi, The University of Shiga Prefecture, Japan; A. Yamada, Y. Yamamoto, Y. Kubo, S. Sugimoto, Ritsumeikan University, Japan
4. Compact SSR Messages with Integrity Information for Satellite Based PPP-RTK Service: R. Hirokawa, Y. Sato, S. Fujita, M. Miya, Mitsubishi Electric, Japan
Access to reliable and accurate PNT has become mission critical in diverse sectors. For example, without access to PNT, aircraft can’t fly safely, emergency responders can’t respond as efficiently as they need to, and military forces can’t readily coordinate actions. The number of critical dependencies on PNT is increasing rapidly and so there is a strong need to assure access and integrity, even under adverse conditions. This panel will explore how this might be accomplished.

Adversity comes in many forms; RF interference, and cyber attack to name a couple. The potential solutions also come in many forms; multi-GNSS, civil signal authentication, encryption, and enhanced navigation, LTE Proximity Services, magnetic sensing, WiFi, ranging, networked connected crowd sensing, and so forth. Differing combinations of sensors/methods will excel depending on the environment but only if they are correctly matched to the environment and can recognize and eliminate manipulated measurements. Diverse sensing methods can yield improved integrity through cross confirmations and consistency checks. Panelists will have the opportunity to expand upon their vision of how ubiquitous, high-integrity PNT might be achieved.

1. Karen Van Dyke, U.S. DOT/YOLFE Center
2. Rick Hamilton, U.S. Coast Guard Navigation Center
3. Prof. Charles Curty, Thales Technology Limited, UK
4. Dr. Paul Groves, University College London
5. Dr. Andrey Soloviev, QuNav
6. Dr. Michael Meurer, German Aerospace Center (DLR), Germany

As commercial, PNT-dependent location-based services (LBS)—e.g., electronic tolling, fleet/drive monitoring, mobile phone–based geolocation apps, etc.—continue to be rolled out, concerns about the security and authenticity of GNSS signals and positioning arise. While Gallei discusses the possibility to launch an OS authentication service, the industries and various GNSS communities are still searching for practical GPS anti-spoofing solutions. Furthermore, the concept and demand of and demand for location “trust,” which involves both security and integrity, is slowing arising.

At the same time, controversy about personal location privacy have accompanied these commercial developments and prompted legislative efforts to limit public and private surveillance of individuals as well as stimulated interest in finding technical solutions to protect geolocation privacy. In the United States, several bills have been introduced in Congress to address privacy concerns, including a Geolocation Privacy and Surveillance (“GPS”) Act, the Online Communications and Geolocation Protection Act, and the Location Privacy Protection Act. In Europe, the General Data Protection Regulation (GDPR), approved in April 2016, will replace 28 different EU Member States’ laws with a single, unifying data protection law that includes personal location. This panel will address the legal, technical, and operational aspects of PNT Privacy and Security.

1. Logan Scott, LS Consulting
2. Dr. Paul McBurney, Honeywell International
3. Dr. Grace Xingxin Gao, University of Minnesota, Minneapolis
4. Kimberley McCullough, Legislative Director/Counsel for Oregon ACLU (American Civil Liberties Union)
Thursday Morning, September 15, 8:30 a.m.–12:15 p.m

Room A105/106
8:30 a.m.–12:15 p.m.

D3: High Precision GNSS Positioning

Dr. Jianghui Geng, Wuhan University, China
Dr. Bernard Schnecker, Rockwell Collins

8:35 The Validation and Accuracy Analysis of BDS Solar Radiation Pressure Models: X. Wang, Q. Xiao, X. Hu, Shanghai Astronomical Observatory, CAS, China; R. Guo, Beijing Satellite Navigation Center, China

8:57 Improving Multi-GNSS Real-Time Precise Point Positioning Services: Y. Liu, Wuhan University, China & German Research Center for Geosciences (GFZ), Germany; M. Ge, GFZ, Germany; Y. Lou, C. Shi, Wuhan University, China

9:20 Integer Satellite Clock Combination for Precise Positioning with Ambiguity Resolution: G. Seepersad, York University & Natural Resources Canada (NRCan); S. Barville, P. Collins, NRCan, Canada; S. Bonnath, York University, Canada; F. Lahaye, NRCan, Canada

9:43 Real-time Estimation of BDS High-precision Satellite Clock Offsets with Prior Troposphere Constraints: Y. Li, Beijing Institute of Tracking and Telecommunications Technology, China; W. Fu, Q. Zhang, G. Huang, Chang’an University, China

10:05–10:35, Break. Refreshments in Exhibit Hall

10:40 Numerical Weather Prediction Based Troposphere Correction Service for Real Time Precise Point Positioning: L. Yang, C. Hill, T. Moore, The University of Nottingham, UK; J. Jones, UK Met Office, UK; R. Prieto-Cerdeira, ESA/ESTEC, The Netherlands

11:03 Fast PPP Convergence Using Multi-constellation and Triple-frequency Ambiguity Resolution: D. Laurichesse, CNES, France; A. Blot, CS-SI, France

11:26 Galileo, an Ace up in the Sleeve for PPP Techniques: I. Rodríguez Pérez, J.D. Calle Calle, L. Martínez Fernández, G. Tobias González, M. Romay, M.D. Lainez, P.F. Navarro, GMV, Spain

11:48 Phase Cycle Slip Mitigation by Piecewise Polynomial Doppler Fit: T.G. Dvorík, RAPID Advanced Defense Systems Ltd. Israel

Alternates

1. Multi-GNSS PPP Performance Assessment with Different Ranging Accuracies in Challenging Scenarios: J. Míguez Sánchez, European Space Agency (ESA) and Universitat Autònoma de Barcelona (UAB), Spain; J.V. Perello Gisbert, R. Orus Pérez, J. García Molina, ESA; F. Gonzales, ESA; X. Serena, GMV, Spain; G. Seco Granados, UAB, Spain; M. Crisci, ESA

2. Recommended Procedure for Post-Processing Static GPS Surveys in OPUS-Projects: D.T. Gillins, Oregon State University; D. Kerr, United States Military Academy; M.L. Armstrong, Geodesist, NOAA’s National Geodetic Survey

3. Characterising High Precision GNSS Receiver Positioning Performance using Internal Receiver Uncertainties from Repeatable Real World Signals: A.R. Tengku, A. Kealy, University of Melbourne, Australia; S. Fuller, ThinkSpatial, Australia

4. Integrity Monitoring for Advanced Driver Assistance Systems: A. El-Mowafy, Curtin University, Australia; N. Kubo, Tokyo University of Marine Science and Technology, Japan


9:43 Performance Differencing in a Tightly Coupled GNSS/INS Solution: R. Dixon and M. Bovy, NovAtel Inc., Canada

Alternates

1. EAS and gmvBRAVE: An Easy Solution for SBAS Algorithm Evaluation: L. García, E. Arnal, B. Ochoa, J. Cegarra, GMV-AD, Spain

2. Satellite Selection Methodology for Horizontal Navigation and Integrity Algorithms: D. Gerbeth, L. Martín, M. Rippl, A. Felix, German Aerospace Center (DLR), Germany

3. An On-board Autonomous Detection Method of Carrier Leaks in GNSS Signals: S. Zhiquang, Z. Hongbo, S. Hua, S. Chao, H. Zhijun, Beihang University, China

Room A107/108/109
8:30 a.m.–10:05 a.m.

E3a: GNSS Augmentation Systems and Integrity 2

Jonathan Haid, NovAtel, Inc., Canada
Angelo Joseph, Rockwell Collins

10:05–10:35, Break. Refreshments in Exhibit Hall

10:40 On the Inherent Tracking Error Caused by Imperfect Spreading Code of GNSS Signal: J. Zhang, Z. Yao, Tsinghua University, China; J. Shen, Beijing UniStrong Science & Technology Co., Ltd., China; M. Lu, Tsinghua University, China

11:03 Full Received System Time with a New Set of Secondary Code: M. Torroja and J. de Salas, Broadcom Ltd.

11:26 Dual Mode Galileo PRS and GPS PPS P(Y): Future of Secure Navigation: N. Davies, A. Evans, M. Jones, M. Macleod, R. Bowden, QinetiQ, UK; D. Hackett, G. Mayoh, D. Mathews, Rockwell Collins, UK

11:48 Data Integrity for GPS and Galileo Signals used by Civil Aviation: A. García-Pena and O. Julien, ENAC, France

Alternates

1. A Modified Min-Sum Decoding Algorithm for LDPC Codes Based on Analysis of Overestimate Value: X. Chen, H. Zhao, W. Feng, Z. He, C. Sun, Beihang University, China

2. GLOMASS Time Scale Interoperability with other GNSS: P.P. Bogdanov, A.V. Druzhin, T.V. Primakina, Institute of Radiolocation and Navigation, Russia

Room A107/108/109
10:35 a.m.–12:15 p.m.

E3b: Modernization of GNSS 1

Dr. Stuart Riley, Denali
Kazuma Gami, Stanford University

12:15 p.m.–1:15 p.m., Informal Luncheon, Exhibit Hall • 1:15 p.m.–1:45 p.m., Free Time in Exhibit Hall

Room B110/111/112
8:30 a.m.–12:15 p.m.

F3: Marine Applications

Dr. Alan Grant, General Lighthouse Authorities, U.K.
Dr. Richard Hartnett, US Coast Guard Academy


8:57 R-Mode: The Potential to Support Resilient PNT Through the re-use of Existing Maritime Infrastructure: A. Grant, P. Williams, General Lighthouse Authorities of the United Kingdom and Ireland; M. Hoppe, German Federal Waterways and Shipping Administration, Germany

9:20 Initial On-Air Experimentation of MF-DGNSS R-Mode as an Alternative Positioning Navigation and Timing Service: G.W. Johnson, Alion Science and Technology; P.F. Swasek, University of Rhode Island; J. al Berdering, Alberding GmbH, Germany; M. Hoppe, Federal Waterways and Shipping Administration, Germany

9:43 Performance Evaluation and A New Disaster Prevention System of Precise Point Positioning at Sea: E. Saito, N. Kubo, Tokyo University of Marine Science and Technology, Japan; K. Shimoda, National Institute for Sea Training, Japan

10:05–10:35, Break. Refreshments in Exhibit Hall

10:40 GNSS Receivers Jamming Resilience in the Close to the Shore Navigation Scenario: L. Bonenberg, University of Nottingham, UK; O. Glomsolv, The Royal Norwegian Naval Academy, Norway


11:26 EDAS for a DGPS Maritime Service: EGNS Based VRS Performance with Pre-Broadcast Integrity Monitoring: J. Morán, E. Lacarra, J. Vázquez, M.A. Sánchez, ESSP SAS, Spain; T. Horváth, Alberding GmbH, Germany

11:48 Maritime Resilient PNT in Europe... Where Now?: M. Bransby and P. Williams, General Lighthouse Authorities of the UK and Ireland

Alternates


2. Research of BDS International Standardization on IMO: S. Qian, China Waterborne Transport Research Institute, China; X. Hui, China Maritime Safety Administration, China

3. SBAS use in Maritime: A. Grant, G. Shaw, J. Safar and N. Ward, General Lighthouse Authorities of the United Kingdom and Ireland

EXHIBITOR DEMONSTRATION
11:00 a.m.–11:45 a.m.

LabSat Wideband: Every GNSS Signal, in a Tiny Package
Room C124

12:15 p.m.–1:15 p.m., Informal Luncheon, Exhibit Hall • 1:15 p.m.–1:45 p.m., Free Time in Exhibit Hall
Room B117/118/119
1:45 p.m.–5:30 p.m.
A4: Next Generation RF and Digital Signal Processing Receiver Techniques

Dr. Tabo Dovi, Politecnico di Torino, Italy
Dr. Gonzalo Seco-Granados, Universitat Autònoma de Barcelona, Spain

1:50 Self-contained Calibration Determination by Jointly Solving the Attitude Estimation and Calibration Problem: S. Zorn, RWTH Aachen University, Germany; M. Meurer, RWTH Aachen University, and German Aerospace Center (DLR), Germany

2:12 A Multi-band GNSS Signal Sampler Module with Open-Source Software Receiver: D. Akos, N.C. Shivaramiah, University of Colorado Boulder

2:35 Correlator Beamforming for Multipath Mitigation at Relatively Low Cost: Initial Performance Results: S. Gunawardena and J. Raquet, Air Force Institute of Technology

2:58 High-Performance GNSS Antennas with Phase-Reversal Quadrature Feeding Network and Parasitic Circular Array: N. Yang, and J. Freestone, NovAtel Inc., Canada

4:00 Performance Evaluation of High Sensitivity GNSS Techniques in Indoor, Urban and Space Environments: E. Dominguez, A. Pousinho, P. Boto, GMV, Spain; D. Gómez-Casco, S. Locubiche-Serra, G. Seco-Granados, J. A. López-Salcedo, UAB, Spain; H. Fragner, F. Zangerl, RUAG, Austria; O. Peña, Tecnalia, Spain; D. Jiménez-Baños, European Space Agency, The Netherlands

4:23 Opportunistic Use of Metropolitan RF Beacon Signals for Urban and Indoor Positioning: C. Yang, A. Soloviev, M. Veth, QuNav; D. Qi, Polaris Wireless

4:46 Performance Evaluation of VDFLL Architectures for a Dual Constellation L1/E1 GNSS Receiver in Challenging Environments: E. Shytermeja, A. García-Pena, D. Julien, ENAC, France

5:08 An Optimized Acquisition Scheme with Half Interleaving Code Patterns in a QZSS LEX Single Frequency Receiver: H. Zhang, Queensland University of Technology, Australia

Alternates
1. A New Tracking Loop Scheme for High Dynamics Real-Time GNSS Receivers with Hardware Correlators: P.A. Roncaglione and J.G. García, National University of la Plata (UNLP), Argentina
4. 4-channel Multiband All GNSS Compliant RF Front End IC: Bringing Professional Level Equipment to Mass Market: D. Tcherniakovski, I. Antonov, A. Kolotkin, A. Kavalascki, NTLab, Belarus

Blue Text Indicates Student Paper Award Winner

Room C120/121/122
1:45 p.m.–3:25 p.m.
B4a: Cooperative and Collaborative Navigation

Dr. Kevin Birck, Air Force Research Laboratory, Hanscom Air Force Base, Massachusetts

1:50 Collaborative Monocycle SLAM with Crowd Sourced Data: J. Huai, The Ohio State University; G. Józkw, Wrocław University of Environmental and Life Sciences, Poland; C. Toth, D. Grejner-Brzezinska, The Ohio State University


2:35 Shinerbot: Bio-inspired Collaborative Robot Swarm Navigation Platform: E. Luo, X.H. Fang, Y. Ng, G.X. Gao, University of Illinois at Urbana-Champaign

2:58 Virtual Coupling: A Cooperative and Collaborative Autonomous Navigation Application: A. Trzuskowski, M. Wehr, D. Abel, RWTH Aachen University, Germany

3:25–3:55, Break. Refreshments in Exhibit Hall

Alternates
3. Infrastructure vs Peer to Peer Cooperative Positioning: A Comparative Analysis: S. Goel, The University of Melbourne, Australia & Indian Institute of Technology Kanpur (IIT), India; A. Kealy, The University of Melbourne, Australia; B. Lohani, IIT Kanpur, India

Room C120/121/122
3:35 p.m.–5:30 p.m.
B4b: Advanced Inertial Sensing and Algorithms

Ralph Hopkins, Draper
Wayne Soehren, Honeywell

4:00 Toward a Navigation-Grade Miniaturized Gyroscope: M. Katoobi, B. Buchanan, T. Boeck, The Boeing Company

4:23 Thermal Control System for the FG-Based SINS with TEC: L. Fu, H. Lu, L. Wang, BeiHang University, China

4:46 Using Converted Linear Measurements Taken by a Human Operator for INS Aiding: T.J. Montgomery and M. Pachter, Air Force Institute of Technology

5:08 A Low Cost INS/GNSS/Vehicle Speed Integration Method for Land Vehicles: R. Sugiuira, Y. Nakai, Y. Kubo, S. Sugimoto, Ritsumeikan University, Japan; S. Mizukami, T. Inamura and H. Kumagai, Tamagawa Seiki Co., Ltd., Japan

Alternates
1. A Study on Tracking the Attitude of Agricultural Machines Based on Tightly-coupled GNSS/AHRS: D. Hai-feng, L. Cheng-qiang, P. Guo-fu, S. Ao-li, Hi-Target Survey Instruments Co., Ltd., China
2. Research of Rapid Relocation Technology Assisted by IMU in the GPS/SINS Ultra-tightly Coupled Navigation System: C. Jiaq, S. Chen, K. Chen, X. Qi, Nanjing University of Science and Technology, China

EXHIBITOR DEMONSTRATION
2:00 p.m.–2:45 p.m.
Where are your kids tonight—GPS performance Evaluation in a World of Jammers and Spoofers
Room C124

Autonomous vehicles (AV) are a reality and not a distant one. Commercial development of AV systems has entered the consumer phase. This is true across aviation, surface, and maritime modes where advances in propulsion, guidance, and control have enabled previously unachievable performance. Much like the personal communications revolution that has played out over the last two decades, AV technology has trickled down from very specialized applications to the consumer market at a breath-taking pace right into household use.

In this pair of sessions, we have invited leaders from across the AV sector to share their perspectives on those burgeoning fields of AV technology and future applications. We intend these exchanges to seed further connections between the navigation community and the wider AV community, by sharing not only technological insights but also broader consideration on the policy and economic aspects the AV sector. There is no shortage of examples where technical understanding out-paced legal, safety, and even environmental understanding. As the premier professional society for advancing a key technology—navigation—that enables AV systems and applications, ION is taking the initiative to bring technical experts and thought leaders together with the hope of drawing a more common technological, political, and economic understanding.
1:50 A Novel Approach for Processing GNSS Multi-systems/Multi-Frequencies for Geodesy and Remote Sensing Applications: G. Haj and Y. Bar-Sever, Jet Propulsion Laboratory

2:12 Track Constrained RTK for Railway Applications: A. Neri, Radiolabs, Italy; S. Sabina, Ansaldo STS, Italy; R. Capua, SOGEPI; S. Salvatori, University of Roma Tre, Italy

2:35 QZSS RTK-PPP Application to Autonomous Cars: K. Asari, S. Matsuoka, H. Amatani, Satellite Positioning and Research Application Center (SPAC), Japan

2:58 Analysis of BDS Ambiguity Resolution with Satellite-induced Code bias Correction: T. Geng, X. Xie, Q. Zhao, X. Su, Wuhan University, China

3:25–3:55, Break. Refreshments in Exhibit Hall

4:00 RTK in Urban Environment Using a Low Cost Single Frequency Receiver: Y. Wang and O. Julien, ENAC, France


4:46 Millimeter Accuracy of RTK Positioning Employing Helix Antennas with Offset Patterns: D. Tatarinov, A. Stepanenko, A. Astakhov, L. Rapoport, Topcon Technology Center, Russia

5:08 A Totally SDR Single-Frequency Augmentation Infrastructure for RTK Land Surveying: Development and Test: R. Capua, A. Caporale, L. Gattuso, M. Giangolini, D. Tulliello, C. D’Amico, D. Antonetti, Sogei, Italy; A. Bottaro, Geoweb, Italy; F.C. Ferrante, Italian Revenue Agency, Italy

Alternates

1. GPS/GLONASS Compact Network RTK for Land Vehicle Users Reducing Required Broadcast Bandwidth: J. Song, Seoul National University, South Korea; B. Park, Sejong University, South Korea; S. Jeon, C. Kee, Seoul National University, South Korea

2. An Algorithm of Detecting and Repairing One Cycle Wide Lane Integer Ambiguity Error for Short Baseline: S. Liu, L. Zhang, J. Li, M. Li, Beijing Institute of Technology, China

Alternates

1. Alternative MEO Constellation Configurations to Improve Coverage and Resiliency While Lowering Space Segment Cost: E. Anderson and F. Czopek, Microcosm Inc.


3. GPS OCX Program Update: W. Sullivan and S. Moran, Raytheon Intelligence, Information and Services

4. A Decentralized Method for BeiDou Satellite Autonomous Orbit Determination Based on Schmidt-Kalman Filter: Z. He, H. Zhao, W. Feng, C. Sun, Beihang University, China


1:50 Near-Earth Navigation Constellation Completely Autonomous Operation of Space-based Anchor Technology: C. Lucheng, Beijing Satellite Navigation Engineer Center, China

2:12 Galileo Simple Box-wing Model Plus ECOM2 for Improving Orbit and Clock Prediction Performances: A.J. García Sánchez, D.L. Arriero, G. Tobías, GMV, Spain


2:58 First Experimentation Results with the Full Galileo CS Demonstrator: D. Calle, S. Cancela, E. Carbonell, I. Rodriguez, G. Tobías, GMV, Spain; O. Pozzoobon, C. Sarto, Qascim, Italy; I. Fernández, European Commission, Belgium; J. Simón, GSA; G. Seco-Granados, University of Barcelona, Spain

3:25–3:55, Break. Refreshments in Exhibit Hall

4:00 NANO Analysis for 2007 through 2015: J.W. Lavrakas, Advanced Research Corporation


4:46 The GPS Block IIR Antenna Panel Pattern and its Use on-orbit: W. Marquis, Lockheed Martin

5:08 Maturation of GPS III Signal Integrity Improvements: A. Peckjian, A. Katronick and S. Shaw, Lockheed Martin

Alternates

1. Urban Environments, magicPPP Put to the Test: J.D. Calle Calle, P.F. Navarro Madrid, G. Tobías González, GMV, Spain


4. Low Cost MEMS Only DR (MoDR) Solution using GNSS and MEMS INS Sensor: Low Cost MEMS Only DR (MoDR) Solution using GNSS and MEMS INS Sensor: S. Shaw, Lockheed Martin

EXHIBITOR DEMONSTRATION

4:00 p.m.–4:45 p.m.

Galileo and LBS: Update on the Status and Future of Galileo-Enabled Devices Room C124
### Room A107/108/109
#### 8:30 a.m.–12:15 p.m.
#### A5: GNSS Receiver Processing and Navigation Algorithms 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:35</td>
<td>A Performance Analysis of Optimal Combinations for BeiDou Triple-frequency Observations: L. Shu, Technology and Engineering Center for Space Utilization (CSU), Chinese Academy of Sciences (CAS), China; R. Ding, Beijing Research Institute of Telemetry, China; H. Wei, China Aeronautical Radio Electronics Research Institute, China; W. Wang, CSU, CAS, China</td>
</tr>
<tr>
<td>10:05</td>
<td>A Novel Fast Direct Acquisition for P Code in the High Dynamic Circumstance: W. Ninguyan, F. Wenquan, Z. Hongbo, Ecole Centrale de Pekin, China</td>
</tr>
<tr>
<td>11:03</td>
<td>Acquisition of all 3 GNSS Signals of GPSL1CA, GPSL1C and GalileoE1OS Simultaneously in a Single Processing Chain: A. Albu-Ragha and I.A. Lami, University of Sfaxia, Iraq &amp; The University of Buckingham, UK</td>
</tr>
<tr>
<td>11:48</td>
<td>Dynamics-based System Noise Adaptation of an Extended Kalman Filter for GNSS-only Kinematic Processing: G. Boffi, A. Wieser, Institute of Geodesy and Photogrammetry ETH Zurich, Switzerland</td>
</tr>
</tbody>
</table>

#### Alternates

1. Multipath and NLOS Signals Identification and Satellite Selection Algorithms for Multi-Constellation Receivers: N.I. Ziedan, Zaqazig University, Egypt
2. A Joint Acquisition Algorithm Based on Primary Code and Secondary Code for GNSS Signals: Z. Liu, Z. Yao, M. Lu, Y. Zhao, National Digital Switching System Engineering Technology Center (CNSC), China
3. A BeiDou Weak Signal Acquisition Method with INS-aiding: F. Wu, Y. Fu, T. Jan, Y. Liang, Beihang University, China

### Room C120/121/122
#### 8:30 a.m.–12:15 p.m.
#### B5: Multisensor Navigation in Challenging Environments 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:35</td>
<td>Simultaneous Localization and Mapping in Multipath Environments: Mapping and Reusing of Virtual Transmitters: C. Gentner, B. Ma, R. Pohlmann, M. Ulmschneider, T. Jost, A. Dammann, German Aerospace Center (DLR), Germany</td>
</tr>
<tr>
<td>9:20</td>
<td>An Extended Kalman Filter for Autonomous Snow Removal, Featuring Ultra-Wideband Beacons: M. Klein, C. Hart, R. Quinn, Case Western Reserve University</td>
</tr>
<tr>
<td>10:40</td>
<td>Preconditions for a Reliable &amp; Robust Detection of Wrong-way Driving on Highways with GNSS and Autonomous Sensors: K. Frankl, H. Beckmann, Universität der Bundeswehr München, Germany; J. Wang, M. Metzner, V. Schwieger, University of Stuttgart, Germany; B. Eissfeller, Universität der Bundeswehr München, Germany</td>
</tr>
<tr>
<td>11:26</td>
<td>Integration of Code-Based Precise Point Positioning and Reduced Inertial Sensor System: H.E. Ibrahim, Ryerson University, Canada; T.B. Karamat, Royal Military College of Canada; A. El-Rabbany, Ryerson University; A. Noureldin, Royal Military College of Canada</td>
</tr>
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<td>11:48</td>
<td>GNSS-Receiver with Open Interface for Deeply Coupling and Vector Tracking: M. Overbeck, F. Garzia, S. Apelt, M. Saad, W. Felber, Fraunhofer IIS, Germany</td>
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1. Crowdsensing-based Organic Fingerprint for Wi-Fi Location: W. Gao, C. Xu, L. Pei, Shanghai Jiao Tong University, China
2. Detection of Magnetic Anomaly Based on a Classifier for Smartphone Attitude Estimation: S.Y. Park, S.J. Heo, C.G. Park, Seoul National University, South Korea
3. Optimized Anchor Node Selection Algorithm Considering Power and Accuracy for Indoor Integrated Navigation System Based on INS/UWB: M. Jia, X. Cui, M. Lu, Tsinghua University, China; T. Wang, Beijing Institute of Tracking and Telecommunication Technology, China

### Room B117/118/119
#### 8:30 a.m.–12:15 p.m.
#### C5: Atmospheric Science 1

<table>
<thead>
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</thead>
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<tr>
<td>8:35</td>
<td>Tropospheric Duct Anomaly Threat Model for High Integrity and High Accuracy Navigation: S. Khanafseh, Illinois Institute of Technology; A. Von Engel, UMESET; B. Pervan, Illinois Institute of Technology</td>
</tr>
<tr>
<td>8:57</td>
<td>Evaluation of Surface Variables from Global Reanalysis Models and their Application in Precipitable Water Vapour Retrieval from GNSS Observations over Nigeria: O.A. Isiye, University of Pretoria, South Africa</td>
</tr>
</tbody>
</table>

### Room A107/108/109
#### 9:20

#### A4: Navigation Algorithms 2

<table>
<thead>
<tr>
<th>Time</th>
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</tr>
</thead>
<tbody>
<tr>
<td>10:05</td>
<td>A Novel Fast Direct Acquisition for P Code in the High Dynamic Circumstance: W. Ninguyan, F. Wenquan, Z. Hongbo, Ecole Centrale de Pekin, China</td>
</tr>
<tr>
<td>11:03</td>
<td>Acquisition of all 3 GNSS Signals of GPSL1CA, GPSL1C and GalileoE1OS Simultaneously in a Single Processing Chain: A. Albu-Ragha and I.A. Lami, University of Sfaxia, Iraq &amp; The University of Buckingham, UK</td>
</tr>
<tr>
<td>11:48</td>
<td>Dynamics-based System Noise Adaptation of an Extended Kalman Filter for GNSS-only Kinematic Processing: G. Boffi, A. Wieser, Institute of Geodesy and Photogrammetry ETH Zurich, Switzerland</td>
</tr>
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### Room C120/121/122
#### 10:40

#### B5: Multisensor Navigation in Challenging Environments 2

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<td>Integration of Code-Based Precise Point Positioning and Reduced Inertial Sensor System: H.E. Ibrahim, Ryerson University, Canada; T.B. Karamat, Royal Military College of Canada; A. El-Rabbany, Ryerson University; A. Noureldin, Royal Military College of Canada</td>
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Friday Morning September 16, 8:30 a.m.—12:15 p.m.

Room B113/114/115/116
8:30 a.m.—10:05 a.m.
D5a: PANEL: Navigation 2026

What will the PNT environment look like in a decade’s time? The panel will also discuss recent and near-future developments in PNT technologies.

1. Jason Y. Kim: Senior Advisor, National Coordination Office for Space-Based Positioning, Navigation, and Timing
2. Dr. Bruno Bougard: Research and Development Director, Septentrio Satellite Navigation, Belgium
3. Dr. Matthew Cashen: Vice President of Sensors, ADsense Inc.
4. Ranwa Haddad: Principal Director, Navigation Division, The Aerospace Corporation
5. Dr. Randy Villahermosa: Principal Director at the Research and Program Development, The Aerospace Corporation The Aerospace Corporation
6. Caitlin Durkovich: Assistant Secretary for Infrastructure Protection (IP), Department of Homeland Security
7. Greg Turetzky, Strategic Business Development, Intel Corporation

Room B113/114/115/116
10:35 a.m.—12:15 p.m.
D5b: Next-generation Sensors in Phones, Tablets and Wearables

Room A105/106
8:30 a.m.—12:15 p.m.
E5: Methods for Authentication and Anti-spoofing

8:35 A Novel Navigation Message Authentication Scheme for GNSS Open Service: G. Caparra, S. Sturaro, N. Lauretini, University of Padova, Italy; C. Wullens, European Space Agency/ESTEC, TEC-ETN, The Netherlands
8:57 Message Authentication, Anti-Repay Protection and Channel Coding: J.T. Currer, EC Joint Research Centre, Italy; C. O’Driscoll, Independent Consultant, Ireland
9:20 GNSS Receiver Fingerprinting for Security-Enhanced Applications: D. Boro, C. Giaio, G. Baldini, J. Fortuny, EC Joint Research Centre, Italy; in Protection and Security of the Citizen (IPSC), Italy
10:40 An INS Monitor Against GNSS Spoofing Attacks during GBAS and SBAS-assisted Aircraft Landing Approaches: C. Tanis, S. Khanafseh, B. Fervan, Italian Institute of Technology
11:03 Using Tactical and MEMS Grade INS to Protect Against GNSS Spoofer in Automotive Applications: S. Manickam and K. O’Keefe, University of Calgary, Canada
11:48 Joint Antenna Array Attitude Tracking and Spoofing Detection Based on Phase Difference Measurements: M. Appel, A. Konовалов, M. Cuntz, German Aerospace Center (DLR), Germany; M. Meurer, DLR & RWTH Aachen University, Germany

Alternates
1. Detailed Analysis of the TEBAT Datasets Using a High Fidelity Software GPS Receiver: A. Lemmenes, P. Corbell, S. Gundawarden, Air Force Institute of Technology
2. Effect of Tracking Parameters on GNSS Receivers Vulnerability to Spoofing Attack: A. Broumandan, A. Jafarnia-Jahromi, S. Daneshmand, G. Lachapelle, University of Calgary, Canada
3. Spatial Spoofing Signal Suppression Using the Constellation Covariance Matrix: L. Kurz, S. Zorn, T.G. Noll, RWTH Aachen University, Germany
4. The First Steps Towards using Galileo Public Regulated Service (PRS) for Governmental Authorised Applications in the UK: E. Aguado, B. Wales, M. Dumville, Nottingham Scientific Limited (NSL), UK; P. Crudace, S. Hancock, Ordnance Survey of Great Britain, UK; P. Lindsay, C. Campbell, UK Space Agency, UK

Room B110/111/112
8:30 a.m.—12:15 p.m.
F5: Aerospace Applications 1

8:35 Error Analysis for the Combination of Angular, Ranging, and Barometric Measurements: E. Nossek, O. Osechas, German Aerospace Center (DLR), Germany; M. Meurer, DLR and RWTH Aachen University, Germany
9:20 Validation of GNSS Multilap Path Model For Space Proximity Operations Using the Hubble Servicing Mission 4 Experiment: B. Ashman, Goddard Space Flight Center; J. Veldman, P. Axelrad, University of Colorado; J. Garrison, Purdue University; L. Winternitz, Goddard Space Flight Center
10:05–10:35, Break. Refreshments served Lobby 8
10:40 Validation of a Space Mission Oriented INS/GNSS Navigator through Utilization of UAVs: M. Wis, M. Kerr, A. Latorre, V. Cevicione, DEIMOS SPACE SLU, Spain
11:48 An Aided Wide Area Multilateration System Using Aircraft Altitude Information: S.-L. Jheng and S.-S. Jan, National Cheng Kung University, Taiwan

Alternates
1. Multi-Receiver Direct Position Estimation based on Hardware-accelerated C++ Receiver: A-H.P. Chu and G.X. Gao, University of Illinois at Urbana-Champaign
The state of the art research related to real time kinematic positioning (RTK), and to precise point positioning (PPP) in real time and post mission. Factors limiting improvement in position accuracy and in convergence / initialization time will be discussed including ambiguity resolution. Panelists will also present their views on future performance considering multi constellation multi frequency methodologies for next generation high-accuracy GNSS positioning.

1. The NRCan PPP Service: Towards Fast Convergence: Dr. Simon Banville, Natural Resources Canada

2. Some Issues Still in the Way to Ultimate Precision: Dr. Oscar Colombo, USRA/NASA Goddard Space Flight Center

3. Think Globally, Act Locally: Challenges of an Australian PPP-RTK Service: Dr. Stavros Melachroinos, Geoscience Australia

4. The Ascent and Realities of PPP: Dr. Sunil Bisnath, York University, Canada

5. Increasing the Availability of High Accuracy Positioning: Sandra Kennedy, NovAtel, Inc., Canada

6. Galileo and High Accuracy Services: Alvaro Mozo, European GNSS Agency, Czech Republic

7. High-accuracy Positioning Solutions and Services-Technology and Applications: Dr. Rodrigo Leandro, Hemisphere GNSS

8. High Accuracy GNSS Positioning: Ubi Sumus? Quo Vadimus?: Dr. Richard Langley, University of New Brunswick, Canada

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**Room B110/111/112**

3:20 p.m.–4:50 p.m.

**A6b: Atmospheric Science**

**3:20 DCB Estimation Based on Uncombined PPP:** Y. Xiang, University of Calgary, Canada

**3:42 Ionospheric Storms of Solar Cycle 24 and Their Impact on the WAAS Ionospheric Threat Model:** L. Sparks, JPL California Institute of Technology; E. Altshuler, Sequoia Research

**4:04 Ionosphere Ray-Tracing of RF Signals and Solution Sensitivities to Model Parameters:** M.L. Pisiaki, Virginia Tech

**4:26 Real-time Ionosphere Monitoring by Three-dimensional Tomography Over Japan:** S. Saito, ENRI, Japan; S. Saito, M. Yamamoto, K. Kung University, Japan; C-H. Chen, National Cheng Kung University, Taiwan; A. Saito, Kyoto University, Japan

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**Room C120/121/122**

1:45 p.m.–4:50 p.m.

**B6: Navigation Using Environmental Features**

**1:50 Validation of a Magnetic Anomaly Navigation Model with Fight Test Data:** A. Canciani and J. Raquet, Air Force Institute of Technology

**2:12 Gaussian Mixture Filter for Multipath Assisted Positioning:** M. Ulmschneider, C. Gentner, Germany; R. Faragher, Focal Point Positioning, UK; T. Jost, DLR, Germany

**2:35 Smartphone Navigation Using Barometric Altitude and Topographic Maps:** P. Smagowski, Military Institute of Armament Technology, Poland; J. Raquet, Air Force Institute of Technology; K. Kauffman, VRA/ANT Center

**2:55 Direct Positioning Utilizing Non Line of Sight (NLOS) GPS Signals:** J. Ng and G.X. Gao, University of Illinois at Urbana-Champaign

**3:20 Sensitivity Analysis of 3D Building Model-Assisted Snapshot Positioning:** R. Kumar and M.G. Petrovello, University of Calgary, Canada

**3:42 Integration of GNSS Positioning and 3D Map using Particle Filter:** T. Suzuki, Waseda University, Japan


**4:26 Integrating Vision-Based Navigation with INS and GPS for Land Vehicle Navigation in Challenging GNSS Environments:** Y. Sun, Harbin Engineering University, China & Queen’s University, Canada; T.B. Karamat, Royal Military College of Canada; A. Noureldin, RMC & Queen’s University, Canada; Y. Gao, Harbin Engineering University, China

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**Room B117/118/119**

1:45 p.m.–4:50 p.m.

**C6: GNSS Augmentation Systems and Integrity 3**

**1:50 Mitigation of Short Duration Satellite Outages for Advanced RAIM and other GNSS Integrity Systems:** J. Blanch, T. Walter, P. Enge, Stanford University

**2:12 Exploiting Satellite Motion in ARAIM: Measurement Error Model Refinement Using Experimental Data:** M. Joerger and B. Pervan, Illinois Institute of Technology

**2:35 Requirements and Performance of Horizontal and Vertical ARAIM Exclusion Algorithms:** Y. Zhai, M. Joerger, B. Pervan, Illinois Institute of Technology

**2:58 Nominal Range Error Analysis to Support ARAIM:** S. Perey, M. Meurer, German Aerospace Center, DLR & RWTH Aachen, Germany; I. Martini, M. Rippl, DLR, Germany; M. Joerger, B. Pervan, Illinois Institute of Technology

**3:20 Kalman Filter-Based GNSS Integrity Monitoring:** S. Bhattacharyya, Indian Institute of Technology, India; D. Gebre-Egziabher, University of Minnesota, Twin Cities

**3:42 Signal Quality Monitoring for New GNSS Signals:** J-B. Pagot, P. Thevenon, O. Julien, ENAC, France; F. Amarillo-Fernandez, ESA, the Netherlands; D. Maillard, Cap Gemini, France

**4:04 Horizon-to-elevation Mask: A Potential Benefit to Ionospheric Gradient Monitoring:** S. Zaminiparadaz, Curtin University, Australia

**4:26 Robust Chi-Square Monitor Performance with Noise Covariance of Unknown Aspect-Ratio:** J. Rife, Tufts University

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**Alternates**

1. Experimental Evaluation in Multipath Scenarios of a Novel Framework for GNSS Integrity Based on the Transient Change Detection Theory: D. Egea-Roca, G. Seco-Granados, J.A. López-Antón, University Autónoma de Barcelona, Spain

2. Automated GPS Signal-in-Space Anomalies Monitoring Over More than 11 Years: C. Lopez de Echazarreta, ESA, GNSS Regional Augmentation Systems Division, France; A. Pande, Romanian Institute of Space Science (IAS), Romania; J. Sanz, J.M. Juan, Universitat Politècnica de Catalunya, Spain

3. GPS SISRE/URA Integrity Analysis for ARAIM: F. Mistrapau, B. Bija, G. Cuetos-Felgueroso, M. Odrizola, M. Azaola, A. Cezón, GMV, Spain; F. Amarillo, ESA

4. A Frequency Domain-Based Detection Technique for Digital Distortion on GNSS Signals: C. Sun, H. Zhao, C. Zhuang, W. Feng, Beihang University, China

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Blue Text Indicates Student Paper Award Winner
Friday Afternoon, September 16, 1:45 p.m.–4:50 p.m.

**Room A105/106**
1:45 p.m.–3:20 p.m.

**D6a: Complementary PNT 1**

- **2:12** Obstruction-Aware Bluetooth Low Energy Indoor Positioning: A. Affendi Juri and T. Arslan, University of Edinburgh, UK
- **2:35** Performance Characterization of Positioning in MISO LTE Systems: K. Shamaei, J. Khalifeh, and Z.M. Kassas, University of California, Riverside
- **2:58** The 5G Localization Waveform Ranging Accuracy over Time-Dispersive Channels—An Evaluation: E. Staudinger, M. Walter, A. Dammann, German Aerospace Center (DLR), Germany

**Alternates**

1. Sources of Error Characterization for Navigation Using Cellular CDMA Signals: J. Khalifeh and Z. M. Kassas, University of California, Riverside


**Room A105/106**
3:20 p.m.–4:50 p.m.

**D6b: Complementary PNT 2**

- **3:20** A Modular Approach to Integrity for APNT: O. Osechas, B. Belabas, E. Nossek, M. Meurer, German Aerospace Center (DLR), Germany
- **3:42** Navigating From Low Earth Orbit: T. Reid, A. Neish, T. Walter, P. Enge, Stanford University
- **4:04** Automated High Precision Optical Tracking of Aircraft and Non-cooperative Flying Objects: S. Guillaume, A. Geiger, Institute of Geodesy and Photogrammetry, ETH Zurich, Switzerland; M. Scaramuzza, Skyguide, Switzerland
- **4:26** Modelling the L-Band Air to Ground Channel for Navigation Applications: N. Schneckenburger, T. Jost, U.-C. Fleibig, German Aerospace Center (DLR), Germany

**Alternates**


2. Crowdsourced & Clustering-based WiFi Localization Technique Leveraging Range Query: B. Yu, T. Lee, H. Kim, J. S. Choi, M. Seo, Korea Institute of Science and Technology, South Korea

**Room A107/109**
1:45 p.m.–4:50 p.m.

**E6a: Interference and Spectrum Protection 1**

- **1:50** Method and Results of Testing GNSS Receivers’ Robustness Against RFI Signals: Y. Ying, T. Whitworth, M. Dumville, Nottingham Scientific Ltd, UK
- **2:12** Interference Localization using a Controlled Radiation Pattern Antenna (CRPA): G. Berez, P. Barret, Eurocontrol, Belgium; B. Desselkoen, M. Richard, Rockwell Collins; O. Bleeker, ADVE; V. Rocchia, F. Jacolot, DSNA; T. Bigham, FAA
- **2:58** Assessment of the Effect of Quantization on the Degradation Brought by Interference on a GNSS Receiver: O. Julien and A. Blais, ENAC, France

**Alternates**

1. Potential Threats by a Symmetric Deployment of Replay Devices Against Synchronization via a Navigation Satellite System: T. Iwamoto, Mitsubishi Electric Corporation, Japan

2. Monitor, Detect, Characterise, Mitigate and Protect—Introducing STRIKES: M. Paterson, M. Dumville, T. Ying, Nottingham Scientific Ltd., UK; Z. Bhuiyan, H. Kusniemi, Finnish Geospatial Research Institute, Finland; B. Gabrielson, A. Waern, Swedish Defence Research Agency (FOI), Sweden; M. Poleskey, Automotive & Rail Innovation Center (ARIC) of AGT mbH, Switzerland

3. Catapult Limited, N. Shivaramaiah, S. Kibe, GNSS Labs; S. Lee, ETRI, Japan; J. Reyes Gonzalez, European GNSS Agency (GSA)

- **3:20** Demonstration of UAV Based GPS Jammer Localization During a Live Interference Exercise: A. Perkins, L. Dressel, S. Lo, P. Enge, Stanford University

- **3:42** Jammer Localization: From Crowdsourcing to Synthetic Detection: D. Borio, C. Gioia, EC Joint Research Centre (JRC), Institute for the Protection and Security of the Citizen (IPS), Italy; A. Stern, F. Dimic, University of Ljubljana, Slovenia; G. Baldini, EC JRC, IPS, Italy


- **4:26** An Analysis of Near-band Harmful Interference on Civilian GPS Receivers: C. Brashar, New Mexico Institute of Mining and Technology

**Alternates**

1. **PROGRESS Project: Jamming and Spoofing Detection and Localization System for Protection of GNSS Ground-based Infrastructures**: G. Gamba, A. Dalla Chiara, O. Pozzobon, QCum3 s.r.l., Italy; N. Ribière-Tharaud, CEA; J-P. Vincent, Thales Alenia Space, France

2. From Agnostic to Model-Based GNSS Jamming Detection: D. Borio, A. Cane, C. Gioia, EC Joint Research Centre (JRC), Institute for the Protection and Security of the Citizen (IPS), Italy


4. More Accurate Model for GNSS Radio Frequency Compatibility Assessment: X. Huang, University, China; W. Liu, Shanghai Maritime University, China; X. Wang, B. Chen, Guangxi University, China

Blue Text Indicates Student Paper Award Winner

Friday, September 16

12:15 p.m.–1:30 p.m., ION GNSS+ Awards Luncheon, Oregon Ballroom

**Room B110/111/112**
1:45 p.m.–3:20 p.m.

**F6a: Aerospace Applications 2**

- **1:50** High Accuracy Near-Real-Time Orbit Determination of Low Earth Satellite in Support of Radio Occultations and Tactical Ocean Altimetry: Y. Bar-Sever, Jet Propulsion Laboratory, California Institute of Technology

- **2:12** Effects of IGS Products on GNSS-based Precise Orbit Determination: Z. Kang, B. Tapley, S. Bettadpur, Center of Space Research, The University of Texas at Austin

- **2:35** Precise Onboard Orbit Determination for LEO Satellites with Real-Time Orbit and Clock Corrections: A. Haushild, German Aerospace Center (DLR/GSOC), Germany; J. Tegedor, Fugro Satellite Positioning AS, Norway; O. Montenbruck, DLR/GSOC, Germany; H. Visser, Fugro Intersite BV, The Netherlands; M. Markgraf, DLR/GSOC, Germany

- **2:58** Chang‘E-5T Orbit Determination Using GNSS Observations: Q. Zhao, X. Su, T. Geng, X. Xie, Wuhan University, Wuhan, China

**Alternates**


2. Development and Verification of LOQ based Attitude Determination and Control Algorithm of Cube satellite “SNIUGLITE” using GPS and Multiple Sensors: J-Y. Jang, T. Kim, H. No, S-K. Yu, M. Choi, C. Kee, Seoul National University, South Korea


**Room B113/114/115/116**
4:05 p.m.–4:50 p.m.

**F6b: PANEL: Unmanned Safety Certification**

- **Mitoch Nantes, Strategic Synergies, LLC**

- **Ali Simon, Rockwell Collins**

This panel discussion will address certification and operational approval of high-performance unmanned aerial systems (UAS). Discussion will address progress on technical standards and policies for certifying and approving UAS; technology advancements that address operational hazards, security and privacy issues; technology gaps and vulnerability issues associated with UAS in civil airspace; roadmaps and plans for UAS certification.

1. Don Walker: Federal Aviation Administration Aircraft Cet.

2. John Moore: Rockwell Collins

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EXHIBIT HALL HOURS
Wednesday: 10:00 a.m.–8:00 p.m.
Thursday: 9:00 a.m.–6:00 p.m.

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<td>German Aerospace Center</td>
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<td><a href="mailto:Greg.Martzi@3com.com">Greg.Martzi@3com.com</a></td>
<td>104</td>
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<tr>
<td>GMV Aerospace and Defence S.A.U.</td>
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<td>GPS Networking, Inc</td>
<td>373 E Industrial Blvd. Pueblo West, CO 81007, USA</td>
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<td>GPS World</td>
<td>1360 E 9th St., Ste. 1070 Cleveland, OH 44114, USA</td>
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<td>Harris Corporation</td>
<td>400 Initiative Dr. Rochester, NY 14606, USA</td>
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<td><a href="mailto:bstone@idealraero.com">bstone@idealraero.com</a></td>
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<td>I-P-Solutions</td>
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<td>Jet Propulsion Laboratory</td>
<td>4800 Oak Grove Dr. Pasadena, CA 91109, USA</td>
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<td>Microsemi Frequency and Time Corporation</td>
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<td>Munich Satellite Navigation Summit</td>
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Co-located 2017 International Technical Meeting (ITM) and Precise Time and Time Interval (PTTI) Systems and Applications Meeting

ONE Registration Fee, TWO Technical Events and a Commercial Exhibit

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Pacific PNT 2017

May 1–4, 2017
Marriott Waikiki Beach, Honolulu, Hawaii

Where East Meets West in the Global Cooperative Development of Positioning, Navigation and Timing Technology

Register and reserve your hotel room by March 28 to take advantage of discounted rates

www.ion.org/pnt
**Wednesday, September 14**

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

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.

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**Women in PNT Networking Luncheon**

Keynote Presentation: Women Don’t Ask: Strategies for Optimizing Professional Development
12:15 p.m.–1:45 p.m.
Oregon Ballroom 201

Why are women hesitant to negotiate? Why do women not seek out leadership roles? Why don’t women ask? Participants will walk away with a greater understanding of why gender norms often discourage women from reaching their full professional potential. This workshop offers strategies for increasing your own professional growth. Topics include negotiating, knowing your value and networking.

All women attending the ION GNSS+ 2016 conference are invited to attend this luncheon, brought to you by Women in Positioning, Navigation and Timing (PNT). Women in PNT is a voluntary networking initiative designed to support and engage women who are in the early stages of their careers with women who are established professionals in the field.

**Keynote Speaker:** Nicole Nieto is a Program Manager at The Ohio State University (OSU), where she serves to advance women faculty through consultations, initiatives and leadership development.

This event will take place during the regular Wednesday lunch break. Attendance is free. Seating will be on a first come, first serve basis, based on availability.

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**Exhibitor Hosted Reception**
6:00 p.m.–8:00 p.m., Exhibit Hall A

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. Traveling companions 21 and older are welcome.

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**Wednesday, September 14**

(continued)

**30th Anniversary Celebration**
8:00 p.m.–10:00 p.m, Exhibit Hall B

Celebrate 30 years of ION GPS, ION GNSS, and ION GNSS+ with a 1980’s style celebration, featuring the decade’s best food, games, and music. 1980’s dress is encouraged; raffle tickets for prizes will be given to those who attend in costume. This event is included with all registrations. Traveling companions 21 years of age and older are welcome to attend.

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**Thursday, September 15**

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

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

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**Friday, September 16**

**Johannes Kepler and Bradford W. Parkinson Awards Luncheon**
12:15 p.m.–1:30 p.m., Oregon Ballroom 201

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. The deadline for submitting nominations for both awards is June 30. See www.ion.org/awards for application requirements.

This event is included with a full, 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.
ION GNSS+ 2016

Portland, Oregon
Sep. 13–16, 2016

ION Plenary Session: Tuesday, Sept. 13 • 6:30 p.m.–8:30 p.m. • Oregon Ballroom • Oregon Convention Center

The Positioning System of the Brain: Nobel Laureate, Professor John O’Keefe

Dr. Heidi Kurssnemi, Finnish Geospatial Research Institute, Finland
Dr. Michael Veth, Veth Research Associates
Dr. Jiyoung Lee, KAIST, South Korea
Dr. Brent Ledvina, Virginia Tech
Dr. Kurt Zimmerman, Trimble
Dr. Alex Stratton, Rockwell Collins

Green Titles = Research and Innovations Sessions
Blue Titles = Applications and Advances Sessions

8:30 a.m.–12:15 p.m.
A1: Advances in GNSS Software-defined Receivers
Room A107/108/109

8:30 a.m.–12:15 p.m.
B1: Multisensor Navigation in Challenging Environments 1
Room C120/121/122

8:30 a.m.–12:15 p.m.
C1: GNSS Augmentation Systems and Integrity 1
Room B117/118/119

8:30 a.m.–10:05 a.m.
D1a: Current Advances in Indoor Location (with demos)
Room A105/106

8:30 a.m.–12:15 p.m.
E1: PANEL: Status of GPS, GLONASS, Galileo, BeiDou and QZSS
Room B113/114/115/116

3:20 p.m.–4:50 p.m.
A6a: PANEL: High-Accuracy GNSS—How Good Does it Get?
Room B113/114/115/116

3:20 p.m.–4:50 p.m.
A6b: Atmospheric Science 2
Room B110/111/112

8:30 a.m.–10:05 a.m.
D1a: Current Advances in Indoor Location (with demos)
Room A105/106

10:35 a.m.–12:15 p.m.
D1b: Land Based Applications 1
Room A105/106

8:30 a.m.–12:15 p.m.
E1: PANEL: Status of GPS, GLONASS, Galileo, BeiDou and QZSS
Room B113/114/115/116

8:30 a.m.–12:15 p.m.
E1: PANEL: Status of GPS, GLONASS, Galileo, BeiDou and QZSS
Room B113/114/115/116

1:45 p.m.–3:25 p.m.
E2a: BeiDou Hosted by the Chinese Academy of Sciences
Room A105/106

3:55 p.m.–5:30 p.m.
E2b: PANEL: Galileo Evolutions
Room A105/106

1:45 p.m.–3:20 p.m.
A6a: PANEL: High-Accuracy GNSS—How Good Does it Get?
Room B113/114/115/116

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