ITM/PTTI 2018 Meeting Schedule

Monday, January 29
- CASSCA Workshop: 8:30 a.m. - 5:30 p.m.
- PTTI Tutorials: 9:00 a.m. - 5:00 p.m.

Tuesday, January 30
- Exhibit Hall Open: 8:30 a.m. - 5:00 p.m.
- Exhibitor Hosted Breakfast: 8:30 a.m. - 10:00 a.m.
- ITM/PTTI Plenary Session: 10:00 a.m. - 12:00 p.m.
- Lunch in Exhibit Hall: 12:00 p.m. - 1:30 p.m.
- Afternoon Sessions: 2:00 p.m. - 5:30 p.m.
- Working Group: 5:30 p.m. - 6:00 p.m.

Wednesday, January 31
- Exhibit Hall Open: 8:00 a.m. - 4:30 p.m.
- Morning Sessions: 8:30 a.m. - 12:00 p.m.
- Lunch in Exhibit Hall: 12:00 p.m. - 1:30 p.m.
- Afternoon Sessions: 2:00 p.m. - 5:30 p.m.

Thursday, February 1
- Morning Sessions: 8:30 a.m. - 12:00 p.m.
- Awards Luncheon: 12:00 p.m. - 2:00 p.m.
  (Lunch served until 12:20 p.m.; late arrivals will not be served.)
- Afternoon Sessions: 2:00 p.m. - 5:00 p.m.

www.ion.org
Pre-Conference Events: Monday, January 29

Co-Located Event:  
Cognizant Autonomous Systems for Safety Critical Applications (CASSCA) Workshop  
8:30 a.m. - 5:30 p.m. • Grand Ballroom F/G  
Separate Registration Required. Free.

PTTI Tutorial Sessions (Regency B)  
9:00 a.m. – 12:30 p.m.: Tutorials  
12:30 p.m. – 1:30 p.m. • Lunch on Your Own  
1:30 p.m. – 5:00 p.m.: Tutorials  
Must add tutorials on ITM/PTTI Registration Form. Additional Fee.

ITM/PTTI Technical Sessions

<table>
<thead>
<tr>
<th>ITM Track A</th>
<th>ITM Track B</th>
<th>ITM Track C</th>
<th>PTTI Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room: Grand Ballroom G</td>
<td>Room: Grand Ballroom F</td>
<td>Room: Grand Ballroom E</td>
<td>Room: Regency B</td>
</tr>
</tbody>
</table>

Exhibit Hall Open 8:30 a.m. – 5:00 p.m., Grand Ballroom A-D • 
Exhibitor Hosted Breakfast in Exhibit Hall 8:30 a.m.–10:00 a.m.

10:00 a.m. – 12:00 p.m. ITM/PTTI Plenary Session: When Navigators Become the Scientists: NASA’s Magnetospheric Multiscale Mission, Grand Ballroom FG

12:00 p.m. – 1:30 p.m. Lunch in Exhibit Hall, Grand Ballroom A-D

Tuesday, January 30

2:00 p.m. – 5:30 p.m.  
A1: Algorithms for GNSS Processing and Sensor Integration

2:00 p.m. – 5:30 p.m.  
B1: Advanced Integrity for Autonomous Systems

2:00 p.m. – 5:30 p.m.  
P1: Time Scales and Laboratory Activities

5:30 p.m. – 6:00 p.m.  
Working Group: GNSS Timing Receiver Resilience Working Group

Wednesday, January 31

8:30 a.m. – 12:00 p.m.  
A2: GNSS in Challenging Environments 1

8:30 a.m. – 12:00 p.m.  
B2: Autonomous Navigation

8:30 a.m. – 12:00 p.m.  
P2: PTTI Applications

12:00 p.m. – 1:30 p.m. Lunch in Exhibit Hall, Grand Ballroom A-D

A3: Next Generation Receiver and Antenna Technology

2:00 p.m. – 5:30 p.m.  
B3: GNSS Augmentation Systems

2:00 p.m. – 5:30 p.m.  
P3: Advanced Clocks and Measurement Techniques

Thursday, February 1

8:30 a.m. – 12:00 p.m.  
A4: GNSS in Challenging Environments 2

8:30 a.m. – 12:00 p.m.  
B4: Multi-Sensor Navigation

8:30 a.m. – 12:00 p.m.  
P4: Advances in Space-Based Time Transfer

12:00 p.m. – 2:00 p.m. Awards Luncheon, Grand Ballroom D (Late arrivals will not be served after 12:20 p.m.)

2:00 p.m. – 5:30 p.m.  
A5: Interference Mitigation and Spectrum Management

2:00 p.m. – 5:00 p.m.  
B5: Atmospheric Science and Space Applications

2:00 p.m. – 5:00 p.m.  
P5: Advanced Time Transfer Techniques

2:00 p.m. – 5:00 p.m.  
C5: Modernized and Emerging GNSS

2:00 p.m. – 5:00 p.m.  
C4a: GNSS Resilience Technologies

10:30 a.m. – 12:00 p.m.  
C4b: High Precision GNSS

Grand Ballroom A-D  
Exhibit Hall

Hyatt Floor Plan  
Second Floor Meeting Space

HYATT FLOOR PLAN

ITM/PTTI 2018  
January 29 - February 1, 2018 • Reston, Virginia  
www.ion.org
Special Events at ITM/PTTI 2018
The following special events are included in all full-conference registrations. Single day registrations include any special events taking place on the day the attendee is registered. Student and retired registrations include all meal functions located within the exhibit hall, however a ticket is required for the Thursday Awards Luncheon.

Exhibitor Hosted Breakfast
Tuesday, 8:30 a.m. - 10:00 a.m.
Exhibit Hall, Grand Ballroom A-D

Informal Luncheon
Tuesday, 12:00 p.m. - 1:30 p.m.
Exhibit Hall, Grand Ballroom A-D

Informal Luncheon
Wednesday, 12:00 p.m. - 1:30 p.m.
Exhibit Hall, Grand Ballroom A-D

Annual Awards Luncheon
Thursday, 12:00 p.m. - 2:00 p.m.
Late arrivals will not be served after 12:20 p.m.
Grand Ballroom D

Special Events for Speakers/Session Chairs
All session chairs and the presenting author of both primary and alternate presentations should attend the Speakers’ Meeting (Tuesday) or Speakers’ Breakfast (Wednesday-Thursday), taking place in the Lake Anne room on the day of their presentation(s). Speaker names will be checked at the door. Please attend the Speakers’ Meeting/Breakfast only on the morning(s) of your presentation(s). If you have not already uploaded your bio in AMP, please bring a printed copy for your session chair.

Access to Technical Papers and Presentations
Qualified attendees may download copies of conference presentations and papers online for FREE by logging into the ION website at www.ion.org/itm or www.ion.org/ptti. Only presentations and papers provided to the ION by the presenting author will be available. Presentations will only be made available once the full technical paper is submitted. If a desired document is not available, we recommend you contact the author directly. Official conference proceedings will be distributed electronically in March to all eligible conference participants.

Mobile Conference Site
Access the technical program, real-time attendee list, and other conference information from your mobile device. Point your mobile browser to m.ion.org.

Complimentary Internet
Free wireless internet is available to attendees in all session rooms and public areas:
Network ID: @Hyatt_WiFi_Events
Password: ion2018

Photography Policy
Your presence at ITM/PTTI 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.

Upgrade to Premium Professional Membership!

Receive up to 25 Complimentary Paper Downloads Each Month
The Institute of Navigation’s (ION) database has more than 10,000 highly-specialized technical papers, proceedings from Institute of Navigation technical conferences, and peer-reviewed articles related to the art and science and technology of positioning, navigation and timing.

www.ion.org
### Tutorial Descriptions and Instructor Biographies

#### GNSS Clocks: History and Present

The first Global Navigation Satellite System (GNSS) was the U.S. Navy Navigation Satellite System, also known as Transit, developed in the 1960's as part of the U.S. Navy's Fleet Ballistic Missile Program. That low altitude system was based on the Doppler shift of a signal transmitted from a low altitude orbiting satellite. As such it was only visible to a user on the surface of the Earth for about 20 minutes. The satellite's oscillator needed to be stable over that time in order to provide an accurate measurement. The Global Positioning System (GPS) followed in the 1970's developed out of investigations into passive ranging techniques and techniques for establishing constellations of satellites to provide global uniform coverage. Passive techniques offered the promise of rapid and three dimensional positioning measurements. However, passive techniques rely upon the capability of a ranging signal transmitted from a satellite to precisely measure the time of propagation and hence the range to a user's receiver. Precise synchronization between the transmitter and receiver is required. The means of establishing and maintaining synchronization of the satellites over the period of time that each satellite is visible to a point or near the surface of the Earth has been implemented using especially developed space qualified atomic clocks. Since the initial development by GPS there have been several development efforts into perfecting space qualified atomic clocks. This tutorial will describe those developments of the GPS program and of GNSS in general. The resulting capabilities provided will be introduced as well as performance measures. Statistical performance techniques will be introduced as a means of comparing the clocks involved and their contribution to GNSS performance.

**Ron Beard** was the Head of the Advanced Space PNT Branch (formerly the Space Applications Branch) at the Naval Research Laboratory (NRL) until he retired the end of September 2015, and is now re-employed with NRL as an annuitant. He has made significant contributions to the generation and dissemination of precise time from space over the course of his 40-year career. Mr. Beard joined the Navy and later NRL as the DoD was beginning to explore new concepts for a second-generation satellite-based navigation system. At NRL he worked for Roger Eaton, who proposed “passive ranging” from satellites with synchronized clocks in what became the TIMATION project. There was very limited experience with precise clocks in the space environment during those early days.

#### The Practice of Frequency Stability Analysis and Time Domain Statistics to Clock and Oscillator Measurements

Most users of precise timekeeping devices and frequency sources are familiar with phase noise and Allan deviation as performance specifications defining the quality of the device, where lower values are better (and typically more costly). Also, the concepts of short term stability, long term stability, time deviation and time interval error are often brought forward by device providers and system requirements in a self-referenced manner. More specifically, the presentations and proceedings of the PTTI generally require an attendee to have a basic working knowledge of these performance metrics to discern the extent of contribution to the improvement of the community's practice.

This tutorial will provide the information to unwrap the interpretation of clock and frequency source measurements, clock statistical characterization, and frequency stability analysis to bring about a workable understanding to the PTTI attendee. The tutorial will use NIST Special Publication 1065, Handbook of Frequency Stability Analysis by William J. Riley as a reference, so that subsequently, the user may be familiar with its application and techniques. The tutorial will also inject the work of Victor S. Reinhardt, David A. Howe, and Patrizia Tavella to supplement the material of NIST 1065. The tutorial will demonstrate analysis of measurement data from devices such as the Chip Scale Atomic Clock, GPS disciplined composite clock, and the ultra-stable oscillators on-board the New Horizons spacecraft. The use of these devices is intended to provide illustrative working examples for the identification, characterization, and assessment of both deterministic (systematic) properties and stochastic (noise) properties.

**Gregory L. Weaver** is a member of the Principle Professional Staff of JHU/APL and works within the RF Engineering Group of the Space Department. He is a technologist with extensive background in both the technical and business aspects of the frequency control industry and has held positions as a senior design engineer, technical manager and marketing strategist over a 30 year career history. He is a frequent contributor to the IEEE International Frequency Control Symposium, Precise Time and Time Interval Systems and Application Meeting and the European Frequency and Time Forum.

#### Timescales and GNSS: A GPS Clock Ensemble

In an earth centered, earth-fixed spatial and temporal reference frame, using timing signals from four known reference locations a navigator can solve for their position and time. Likewise, a timing user can solve for their time using a single ranging signal from a known reference location. In practice, generating, transmitting, receiving and utilizing timing signals for navigation and time transfer in a real-world system is challenging and requires tradeoffs in the overall enterprise system design. Currently, GNSS systems such as GPS trade greater complexity in the Space and Control Segments for simplicity, accuracy, reliability and lower power in the User Segment. Using a network of surveyed monitor station receivers, the GPS Control Segment (CS) estimates position and time for every (satellite) transmitter using the same satellite ranging signals as the User Segment. Position and time are delivered to the navigation and timing users in the form of predictions relative to a fixed time reference frame, GPS Time, and a fixed spatial reference frame, WGS-84.

(continued)
This tutorial will discuss the role of the broadcast clock reference time in user range error, and time transfer error. It outlines the formulation of a basic timescale from range measurements and briefly discusses the role of environmental clock effects on time transfer performance. For this tutorial, the estimation of transmitter position and the estimation of transmitter time are assumed to be largely uncorrelated.

Huascar Ascarrunz has been a Systems Engineer at Harris Corporation since 2008. At Harris, he worked on the GPS III Space Vehicle Timekeeping System and has been doing algorithm analysis work for the GPS Next Generation Control Segment Navigation Software since 2010. Huascar holds a Bachelors degree in Electrical Engineering from the University of Colorado at Boulder.

Anatomy of GNSS Signals and Receivers for Time/Frequency Determination

The use of the United States Global Positioning System (GPS) for affordable nanosecond-level time recovery and synchronization has become ubiquitous globally, permeating countless industries and institutions. The success of GPS has led other countries to implement or begin to implement their own Global Navigation Satellite Systems (GNSS) to provide timing and navigation either cooperatively with or independently from GPS. GNSS receivers are now available that can utilize individual constellations or a mixture of them to determine time and position. Time recovery from the GNSS signals is performed through a combination of satellite signal tracking, decoding of navigation data messages containing satellite ephemeris and other parameters and corrections, and implementation of the positioning solution. GNSS receivers track the transmitted signals code and integrated Doppler or carrier using correlators to detect the delay and Doppler of the satellite generated pseudo random code (PRN) against the receivers generated PRN and processed through code and carrier tracking loops. The GNSS constellations each have their own characteristics and structure and their civil broadcast service timing performances will be compared in this tutorial using multi-GNSS receivers that can track multiple constellations.

Douglas Boehm is an Electrical Engineer and a Senior Lead Engineer of the Naval Research Laboratory. Mr. Boehm received his Bachelors and Masters in Electrical Engineering at Rensselaer Polytechnic Institute spending summers and winters working at NRL. Mr. Boehm has been a full time Navy civilian employee at NRL for 10 years. While at NRL, Mr. Boehm has performed research, design, development, test and evaluation of satellite communications and precision network time transfer systems as well as for technologies that augment GPS receive systems. Mr. Boehm is currently the lead engineer testing the quality and precision of multi GNSS receivers.

O. Jay Oaks is an Electronics Engineer and Deputy Head of the Advanced Space Precision Navigation and Timing Branch at the Naval Research Laboratory. Mr. Oaks has been a Navy civilian employee for 45 years and at the NRL for 39 years. While at NRL, he was responsible for the design and development of several precision time transfer satellite receivers used in special scientific and military applications. Mr. Oaks led efforts that investigated GPS vulnerabilities in PNT applications and developed augmentation solutions. He currently leads a group of scientists and engineers on projects that require precise positioning, navigation, and time synchronization.

Precise GNSS Clock Corrections from Geodetic Analysis - Procedure, Examples, Applications

Precise positioning with GNSS is based on precise measurement of signal travel times. That GNSS is a one-way measurement system has important advantages. The user e.g. does not require a heavy communication unit. He can use the signals without registering for the service. A one-way system however has the fundamental drawback that two clocks are required to measure the signal travel time. As a consequence a precise synchronization - for precise applications at the few ps level - is crucial. The ingenious concept of GNSS - developed in the 1970s - is the capability of the system to synchronize the involved clocks based on the GNSS ranging signals themselves. As a consequence precise ranges can be measured even without involving ultra stable clocks. As a matter of fact every GNSS user carries in his iPhone a virtual atomic clock. Likewise the GNSS system is by concept a precise time and frequency transfer tool, e.g. used in the generation of International Atomic Time. With precise modeling of propagation effects - despite high correlation between parameter groups such as clock parameters, station coordinates, troposphere delay parameters - precise satellite and receiver clock corrections can be derived. This tutorial highlights the GNSS concept with focus on determination of clock corrections, gives examples for the performance of current GNSS clocks, and addresses the potential of using the stability of upcoming clocks for applications such as precise orbit determination or reconstruction precise kinematic trajectories and of troposphere parameters.

Prof. Urs Hugentobler is a full professor at the Institute for Astronomical and Physical Geodesy of Technische Universität München, Germany, and head of the Research Establishment Satellite Geodesy. His research activities focus on precise applications of GNSS such as positioning, precise orbit determination, reference frame realization, and time transfer.

Distributing Time and Frequency Data: Requirements and Methods

This course will describe the methods that are used to distribute time and frequency information, with special emphasis on methods that are independent of global navigation satellite systems. The course will illustrate these methods with the requirements of commercial and financial institutions and distributors of electrical power. In addition to the purely technical requirements, additional requirements that result from the need to demonstrate traceability to national standards will also be discussed. The level of accuracy that is required to support these applications is relatively modest from the perspective of the internal time scales of most National Metrology Institutes and timing laboratories, but satisfying the requirements becomes much more challenging when the need for extreme reliability and the limitations of many of the common distribution channels are included. None of the alternative solutions that have been proposed is completely adequate now and all of them will have increasing difficulty satisfying the increasing accuracy requirements in the future.

Dr. Judah Levine is a Fellow of the National Institute of Standards and Technology and is the leader of the Network Synchronization Project in the Time and Frequency Division, which is located in the NIST laboratories in Boulder, Colorado. He received his Ph.D. in Physics from New York University in 1966. Dr. Levine is a member of the IEEE and a Fellow of the American Physical Society.
Tuesday, January 30, 2018
10:00 a.m. – 12:00 p.m.
Grand Ballroom F/G

WELCOME AND INTRODUCTIONS

Dr. John Raquet
ION President
Air Force Institute of Technology

Dr. Jiyun Lee
ITM Program Chair
KAIST, South Korea

Dr. James Hanssen
PTTI Program Chair
US Naval Observatory

OPENING REMARKS

CAPT Michael Riggins, USN
Superintendent
US Naval Observatory

ITM/PTTI PLENARY SESSION:
When Navigators Become the Scientists:
NASA’s Magnetospheric Multiscale Mission
Dr. Barbara Giles
Associate Chief Geospace Physics Laboratory and Lead for the NASA MMS Fast Plasma Investigation
NASA Goddard Space Flight Center

At orbit apogee, about 43,600 miles above Earth, NASA's Magnetospheric Multiscale navigator system determines the position of each spacecraft with uncertainties better than 50 feet. Launched in March 2015, the mission consists of four spin-stabilized, formation-controlled spacecraft in highly elliptic orbits that, to our knowledge, achieve the highest-altitude operational use of GPS navigation to date. Our navigation personnel continuously adjust orbits, formations, and separations for the study of the phenomena of magnetic reconnection – a process that drives virtually all space weather events that disrupt orbiting spacecraft and lead to GPS, communications and power interruptions. This address shares some of our navigation team's adventures on this journey and highlights the many ways space weather can challenge navigation on Earth and in space.

Lunch in Exhibit Hall, 12:00- 1:30 p.m.
A1: Algorithms for GNSS Processing and Sensor Integration  
2:00 PM - 5:30 PM  
Room: Grand Ballroom G

Dr. Andrey Soloviev, QuaNav  
Dr. Sherman Lo, Stanford University

2:05 Statistical Analysis of User Range Errors on BDS for ARAIM: Zhipeng Wang, Wei Shao, Sikun Wang, Lei Zheng, Beihang University, China

2:35 Fixed Subset Selection to Reduce Advanced RAIM Complexity: Juan Blanch, Todd Walter and Per Enge, Stanford University

3:05 ARAIM Test Statistic Correlation: Eugene Bang, Carl Milner and Christophe Macabiau, Ecole Nationale de l'Aviation Civile (ENAC), France

3:30 - 3:55 p.m., Refreshment Break in Exhibit Hall

4:00 The Signal Quality Monitoring Method based on Multi-correlation Algorithm for GNSS Modernized Signals: Chen Zhuang, Chao Sun, Hongbo Zhao, Wenquan Feng, BeiHang University, China; Deyun Liu, Beijing Spacecraft, China

4:30 Attitude Independent Direction of Arrival-based Detection of Spatially Spread Repeaters and Spoofers: Manuel Appel, Omar Garcia-Crespillo, Andreas Illipolous, German Aerospace Center (DLR), Germany; Michael Meurer, DLR and RWTH Aachen University, Germany

5:00 Tightly Coupled GNSS/SINS Integrity Monitoring with MAIME for SGEs: Bocheng Zhu and Fanchen Meng, Peking University, Beijing; Weidong Qi, Changchun Institute of Applied Physics, China

B1: Advanced Integrity for Autonomous Systems  
2:00 PM - 5:30 PM  
Room: Grand Ballroom F

Dr. Oksuary Osechas, German Aerospace Center (DLR), Germany  
Dr. Mathieu Joergen, The University of Arizona

2:05 Design of Extended “Lock-in Range” Multi-Mode PLLs to Simultaneously Track and Demodulate for Two GNSS or any Received Signals: Maher Al-Aboodi, The University of Basrah, Iraq; Ihsan Alshahib Lami, The University of Buckingham, UK

2:35 An Unambiguous Acquisition Technique for Sine BOC(m,n) Signals: Tian Li, Jiaolong Wei, Zuiping Tang, Zhihui Zhou, Xuan Xia, Boyi Wang, Huazhong University of Science and Technology, China

3:05 Acquisition of 3 GNSS Signals of GPS/L1CA, GLONASS/L1 and GalileoE1(OS) Simultaneously in a Single Processing Chain that Halves Processing and Battery Power: Ali Abu-Rghaif, University of Diyala, Iraq; Ihsan Alshahib Lami, The University of Buckingham, UK

3:30 - 3:55 p.m., Refreshment Break in Exhibit Hall

4:00 High Precision Localization with Dual Constellation for Railway Applications: Jan-Joran Gehrt, Thomas Konrad, Jiaying Lin, Dirk Abel, Rene Zweigel, RWTH Aachen University, Germany

4:30 Initial Assessment of Service Performance of BDS-3 Experimental Satellites: Rui Zhang, National Time Service Center (NTSC)/Key Laboratory of Precision Navigation Positioning and Timing Technology (KLPNPTT), Chinese Academy of Sciences (CAS), China; Rui Tu, NTSC/KLPNPTT & University of Chinese Academy of Sciences (UCAS), China; Jinhai Liu, Ji Hong, NTSC/UCAS, China; Lihong Fan, NTSC & KLPNPTT, CAS, China; Pengfei Zhang, NTSC/UCS, China; Xiaochun Lu, NTSC/KLPNPTT & UCAS, China

5:00 Development and HILS Verification of Attitude Determination and Control Algorithm for “SNUGLITE” Cube Satellite: Minkyu Choi, Sunkyoung Yu, O-Jong Kim, Heekworn No, Hanjoon Shim and Changdon Kee, Seoul National University, Republic of Korea

P1: Time Scales and Laboratory Activities  
2:00 PM - 5:30 PM  
Room: Regency B

Ron Beard, Naval Research Laboratory  
Dr. Elizabeth Lauer, English National Physical Laboratory, UK

2:05 PTB’s Time and Frequency Services 2017: D. Pieter, A. Bauch, T. Becker, T. Polewka, F. Riedel, D. Sibold, E. Staliniene, K. Teichel, W. Vajen, Physikalisch-Technische Bundesanstalt (PTB), Germany

2:35 Time and Frequency Activities at the JHU Applied Physics Laboratory: Mihran Miranian, Erika A. Sanchez, Jeffery F. Garstecki, Richard A. Dragonette, Gregory L. Weaver, JHU/APL

3:05 First Experiments on Application of Rubidium Fountain Frequency Standards in Russian State Time and Frequency Standard Laboratory for TAI(SU) Time Scale Maintenance: I. Blinov, A. Boyko and N. Koshkelaevskii, VNIIFTRI Department of Metrology for Time and Space, Russia

3:30 - 3:55 p.m., Refreshment Break in Exhibit Hall

4:00 Incorporating an Optical Clock into a Time Scale at NIST: Real-Time Analysis: Jeffrey Sherman, Tara Fortier, Jian Yao, Thomas Parker, Judah Levine, Joshua Savory, Stefania Romisch, William McGrew, Xiaogang Zhang, Daniele Nicolodi, Robert Fasano, Stephan Schaeffer, Kyle Beloy, and Andrew Ludlow, Time and Frequency Division, National Institute of Standards and Technology

4:30 Investigation of Pole Placement Technique for Clock Steering: Tobias D. Schmidt, Marion Gödel and Johann Further, German Aerospace Center (DLR), Germany

5:00 Stability Analysis of Pulsar Aided Atomic Clocks: Po-Ting Chen and Jason L. Speyer, University of California Los Angeles

Alternates

1. Precision Timing at the University of Alabama - Progress and Future Center Plans: Adam J Hauser, University of Alabama

2. Using the RRS_Rapid Technique for Monitoring/Steering UTC(NIST): Jian Yao, Judah Levine, and Thomas Parker, Time and Frequency Division, National Institute of Standards and Technology

5:30 PM - 6:00 PM  
Room: Regency B

ITM/PTTI 2018 January 29 - February 1, 2018 - Reston, Virginia www.ion.org

9:05 Development and Test of a Space Capable Miniaturized GPS/GNSS Receiver for Space Applications: Yung-Fu Tsai, Min-Yu Hsieh, Hsin-Yuan Chang, and Chen-Tsung Lin, National Space Organization, Taiwan

9:35 Limits on GNSS Performance at High Latitudes: Peter F. Swaszek, University of Rhode Island; Richard J. Hartnett, Kelly C. Seals and Joseph D. Siciliano, U.S. Coast Guard Academy; Rebecca M.A. Swaszek, Boston University

10:00 - 10:25 a.m., Refreshment Break in Exhibit Hall

10:30 Preliminary Results of Impacts of Ionospheric Scintillations on GAST-D Ground Integrity Monitors: Susumu Saito, National Institute of Maritime, Port, and Aviation Technology (MPAT), Japan; Sabine Zureikat, MPAT, Japan/ENAC, France/swift Navigation Inc.; Takayuki Yoshihara, MPAT, Japan

11:00 Navigation Augmentation based on LEO Communication Satellite Constellations: Ruidan Luo, Huyan Yuan, Yang Zhang, Ying Xu, Academy of Opto-Electronics, Chinese Academy of Science, China

11:30 Video-based Classification of Railway Track Areas for GNSS-based Virtual Balise Solutions in the ERSAT GGC Project: Juliette Marais, IFSTTAR, France; Salvatore Sabina, ANSALDO STS, Massimiliano Ciaffi, RFI, France

Alternates
1. Improving Positioning Performance for Portable Devices using Raw GNSS Measurements: Bassem Sheta, Military Technical College, Egypt; Mohammed Yousef, Royal Military College of Canada
2. Uncented Kalman Filter based RAIM for GNSS Receivers FDE: Bocheng Zhu, Fanchen Meng, Peking University, China

8:35 Characterization of Feature Matching Errors for Consistent Estimation in Vision-Aided Navigation: Chun Yang, Ananth Vadlamani, Andrey Soloviev, Michael Veth, QuNav, LLC; Clark Taylor, AFRL/RYAR

9:05 Ground Reflection Elimination Algorithms for Enhanced Distance Measurement to the Curbs Using Ultrasonic Sensors: Joon Hye Rhee and Jiwon Seo, Yonsei University, South Korea

9:35 A Flexible Simulation and Design Environment for INS/GNSS Integration: Mohamed Maher Atia and Soroush Sheikhpour, Carleton University, Canada

10:00 - 10:25 a.m., Refreshment Break in Exhibit Hall


11:00 Improved Solution Continuity with Deep GNSS and Map Integration for Autonomous Vehicle Navigation: Emerson Pereira Cavalheri and Marcelo Carvalho dos Santos, University of New Brunswick, Canada

11:30 Assessing Indoor Environments with suAS through Real-Time Virtual Reality and Assured Navigation: Maarten Uijt de Haag, Adam Schultz, Jessie Robinson and Joel Huff, Ohio University

Alternates
1. Cooperative Navigation for GPS-Denied Environments via Simultaneous Online Localization Exchange: Denis Garagic, Fang Liu, Frank Stolle, BAE Systems; Maarten Uijt de Haag, Ohio University; Bradley J. Rhodes, BAE Systems
2. On the use of the Directional Wi-Fi Antennas for Land Vehicle Location Purposes in the Signal of Opportunity Context: Mendoça, Marco and Santos, Marcelo, University of New Brunswick, Canada

Lunch in Exhibit Hall, 12:00-1:30 p.m.
A3: Next Generation Receiver and Antenna Technology
2:00 PM - 5:30 PM
Room: Grand Ballroom G

2:05 Demonstrating Single Element Null Steering Antenna Direction Finding for Interference Detection: Yu-Hsuan Chen, Sherman Lo, Fabian Rothmaier, Stanford University; Dennis Akos, University of Colorado at Boulder; Per Enge, Stanford University

3:05 The Effect of Aircraft Antenna Group Delay Variations on Dual Solution Ionospheric Gradient Monitoring: Anurag Raghuvanshi and Frank van Gaas, Ohio University

4:05 GNSS Receivers: Hailong Xu, Xiaowei Cui, Shiyue Li, Tsinghua University, China; Wei Zhi, CETHIK Group Corporation Research Institute, China; Yuan Liu, Beihang University, China; Qian Sun, China Waterborne Transport Research Institute, China

5:05 Evaluation of Quasi – Zenith Satellite System L5S Signal: Chiu-Mei Wu and Shau-Chun Jan, National Cheng Kung University, Taiwan; Takeyasu Sakai, Electronic Navigation Research Institute (ENRI), Japan

B3: GNSS Augmentation Systems
2:00 PM - 5:30 PM
Room: Grand Ballroom F

2:05 WAAS at 15: Todd Walter, Stanford University; Karl Shallberg, Zeta Associates Incorporated; Eric Althueber, Sequoia Research Corporation; William Wanner, William J. Hughes FAA Technical Center; Chris Harris, FAA WAAS Engineering Team

2:35 An Availability Prediction Method of Ground-Based Augmentation System Based on Support Vector Machine Algorithm: Zhipeng Wang, Jingtian Du, Beihang University, China; Wei Zhi, CETHIK Group Corporation Research Institute, China; Yuan Liu, Beihang University, China; Qian Sun, China Waterborne Transport Research Institute, China

3:05 Evaluation of Quasi – Zenith Satellite System L5S Signal: Chiu-Mei Wu and Shau-Chun Jan, National Cheng Kung University, Taiwan; Takeyasu Sakai, Electronic Navigation Research Institute (ENRI), Japan

4:05 Development of DFMC SBAS Prototype System using L1 and L5 band Signals of GPS, Galileo, and QZSS: Mitsunori Kitamura, Takahiro Aso, Takeyasu Sakai, Kakuaki Hoshinoa, Electronic Navigation Research Institute (ENRI), Japan

4:35 Absolute Group Delay Characterization of GNSS Antennas for Reference Receiver Chains: Esteban Garbin Manfredini, Piotr Krystek an Ricardo Piriz from GMV, Spain; Andrew Dowd, Lithe Technology

5:05 Correlation Measurement of Co-located Hydrogen Masers using Fiber-based Frequency Synchronization Network: Yichen Guo, Bo Wang, Jingwen Dong, Hongwei Si and Lijun Wang, Tsinghua University China

Alternates
1. Avoiding Improper Modeling in SBAS Ionospheric Correction with Shrunk Observations: Takeyasu Sakai, Mitsunori Kitamura, Takahiro Aso, and Kakuaki Hoshinoa, National Institute of Maritime, Port and Aviation Technology, Japan

P3: Advanced Clocks and Measurement Techniques
2:00 PM - 5:30 PM
Room: Regency B


3:30 - 3:55 p.m., Refreshment Break in Exhibit Hall

4:00 Improved Temperature Compensation of Atomic Clocks and INS Instruments using Multivariate Model-based Design Optimized for Real-world Operating Conditions: Andrew Dowd, Lithe Technology

4:30 Absolute Group Delay Characterization of GNSS Antennas for Reference Receiver Chains: Esteban Garbin Manfredini, Piotr Krystek an Ricardo Piriz from GMV, Spain; Pierre Waller, Luis Rolo and Damiang Treanta from ESA, The Netherlands

5:00 Correlation Measurement of Co-located Hydrogen Masers using Fiber-based Frequency Synchronization Network: Yichen Guo, Bo Wang, Jingwen Dong, Hongwei Si and Lijun Wang, Tsinghua University China

Alternates
1. Robust Estimation of Allan Variance Based on Uncorrelated Difference: Hong Gong, Xiangwei Zhu, Jingyuan Li, Zengjun Liu, Jing Peng, Guangfu, Sun, National University of Defense Technology, China

2. Advanced DOCKO Meeting 100 ... 400 ns Time Interval Error its Design and Measurement: Aleksandr Kotyukov, Arkady Nikonov, Alexey Zaslavsky, Evgeny Belyaev, Morion, Inc., Russia
**ITM TECHNICAL SESSIONS**

**THURSDAY MORNING, FEBRUARY 1**

**A4: GNSS in Challenging Environments 2**
8:30 AM - 12:00 PM
Room: Grand Ballroom G

- Phase Lock Loop Performance Metrics Based on the Distribution the Discriminator Output: Stefan Stevanovic and Boris Pervan, Illinois Institute of Technology

- An Adaptive Inter-frequency Aiding Carrier Tracking Algorithm for the Mountain-top GPS Radio Occultation Signal: Rong Yang and Yu Morton, University of Colorado, Boulder

- Ionosphere Scintillation Effects on GPS Measurements, a New Carrier-Smoothing Technique, and Positioning Algorithms to Improve Accuracy: Greg Myer, Colorado State University and Yu (Jade) Morton, University of Colorado Boulder

10:00 - 10:25 a.m., Refreshment Break in Lobby


11:00 Interference Likelihood Mapping with Case Studies: Paul Alves, Carmen Wong, Matthew Clampitt, Eric Davis and Enjun Kwak, NovAtel Inc., Canada

11:30 Sensitivity Analysis of a Low Power Authentication Component for Open Service Signals: Elias Gkougkas, Markel Arizabaleta, Thomas Pany, Bernd Eissfeller, Universität der Bundeswehr München, Germany

Alternate

1. Moscow GPS Spoofing Investigation: Igor Tsarik, Amungo Navigation, Estonia

**B4: Multi-Sensor Navigation**
8:30 AM - 12:00 PM
Room: Grand Ballroom F

- Vehicular Lane-Level Positioning using Low-Cost Map-Aided GNSS/IMU Sensors Integration: Mohamed Mahir Atia, Carleton University, Canada; Allaa Hilal, Intelligent Mechatronics Systems (IMS) Inc., Canada


9:35 Automated Exploration with Multi-sensor Equipped UAV/UGV: Simon Batzdorfer, Markus Bobbe, Martin Becker, Ulf Bestmann, Institute of Flight Guidance, Technische Universität Braunschweig, Germany

10:00 - 10:25 a.m., Refreshment Break in Lobby

10:30 Real-time Game Theory Based Artificial Potential Field Method for Multiple Unmanned Aerial Vehicles Path Planning: Yuan Sun, Beijing University of Posts and Telecommunications, China; Li Fu, Beijing Institute of Aerospace Control Devices, China

11:00 New Compensation Method of Magnetometer Time-varying Bias for UAV: Heekwon No, Seoul National University, Republic of Korea; Am Cho, Korea Aerospace Research Institute, Republic of Korea; Changdon Kee, Seoul National University, Republic of Korea

11:30 Analysis of Limiting Factors in and Trade-offs for Positioning Performance Management: Chun Yang, Sigm Technology, Inc.; Andrey Soloviev, QuNav, LLC

Alternate

1. Distributed GPS Beamforming with Low-Cost Software Defined Radios: Wilbur L. Myrick, ENSCO, Inc.

2. Low Cost Precise Navigation in Urban Area with Multi-C constellation GNSS and Inertial-Aiding: Yu Wang and Olivier Julien, Signav, Telecom, ENAC, France

**C4a: GNSS Resilience Technologies**
8:30 AM - 10:00 AM
Room: Grand Ballroom E

- APNT for the North Atlantic Corridor Using Air-to-Air Ranging: Okuay Osechas, Thomas Graeupl, German Aerospace Center (DLR), Germany and Gerhard Berz, EUROCONTROL, Belgium

9:05 Recent PNT Improvements and Test Results based on Low Earth Orbit Satellites: Gregory Gutt, David Lawrence, H. Stewart Cobb, and Michael O’Connor, Satelles

9:35 Assessment of the De-Sense Criteria for Measuring GNSS Robustness to Interference: Bryan Townsend, Marino Phocas, Rui Zuo, Justin Satchwell, Daniel Schwartz, Esther Anayaebu, Intel Mobile Communications

10:00 - 10:25 a.m., Refreshment Break in Lobby

10:30 Flight Results of GPS-Based Attitude Determination for the Microsatellite Flying-Laptop: A. Hauschild, M. Markgraf, O. Montenbruck, German Aerospace Center (DLR), German Space Operations Center (GSOC), Germany; U. Mohr Institut für Raumfahrtsysteme (IRS), Universität Stuttgart, Germany

11:00 The Approach of BDS Real-time and Fast Point Positioning by Augmentation Information: Rui Tu, National Time Service Center (NTSC) & Key Lab of PNT Technology, Chinese Academy of Sciences, CAS and University of Chinese Academy of Sciences (UCAS), China; Rui Zhang, NTSC & Key Lab of PNT Technology, CAS, China; Pengfei Zhang, UCAS, China; Jinhai Liu, NTSC/UCAS, China; Xiaochun Lu, NTSC, UCAS and Key Lab of PNT Technology, China


Alternate

1. Analysis of CGPS Stations Data Applied to Morphometric Methods to Evaluate Earthquake Early Warnings Opportunities: Sabrina Ugazio, Erica Baird and Frank van Graas, Ohio University

---

**Annual Awards Luncheon, 12:00-2:00 p.m., Grand Ballroom D (Late arrivals will not be served after 12:20 p.m.)**

**ITM/PTTI 2018**
January 29 - February 1, 2018 • Reston, Virginia

www.ion.org
P4: Advances in Space-Based Time Transfer
8:30 AM - 12:00 PM
Room: Regency B

8:35 Zero-Doppler Pseudorange Biases: J.-M. Sleewaegen, W. De Wilde, Septentrio, Belgium

9:05 The Long Term Stability and Redundancy Test of GPS Multi-Receiver Ensemble: Shinn Yan Lin, Telecommunication Laboratories, Taiwan; Zhiheng Jiang, BIPM, France

9:35 Evaluation of BDS Time Transfer on Multiple Baselines for UTC: K. Liang, National Institute of Metrology (NIM), China and Bureau International des Poids et Mesures (BIPM), France; F. Arias, Z. Jiang, G. Petit, L. Tisserand, BIPM, France; Y. Wang, Z. Yang, NIM, China; P. Uhrich, G.D. Rovera, LNE-SYRTE, Observatoire de Paris (OP), PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, France; A. Bauch, T. Polewka, Physikalisch-Technische Bundesanstalt (PTB), Germany; N. Koshelyaevsky, Russian Metrological Institute of Technical Physics and Radio Engineering National Institute of Standards and Technology, (VNIIFTRI), Russia; S. Romisch, NIST, USA; C. Lin, National Standard Time and Frequency Laboratory, TL, Taiwan; E.D. Powers, S. Mitchell, USNO, USA; A. Zhang, Z. Fang, NIM, China

10:00 - 10:25 a.m., Refreshment Break in Lobby

10:30 BeiDou Time Transfer between PTB and NTSC: Wenjun Wu, National Time Service Center (NTSC), Chinese Academy of Science (CAS), China; Wei Guang, NTSC, CAS, University of Chinese Academy of Science (UCAS), China; Andreas Bauch, Physikalisch-Technische Bundesanstalt (PTB), Germany; Shaowu Dong, NTSC, CAS, UCAS, China; Weijin Qin, NTSC, China/PTB, Germany; Jihai Zhang, NTSC, CAS, China

11:00 Implementation of SDR TWSTFT in UTC Computation: Zhiheng Jiang, Felicitas Arias, Bureau International des Poids et Mesures (BIPM), France; Victor Zhang, NIST, USA; Yi-Jiun Huang, National Standard Time and Frequency Laboratory, Telecommunication Laboratories, (TL) Chungghwa Telecom, Taiwan; Joseph Achkar, LNE-SYRTE, Observatoire de Paris, Research University, Sorbonne Universités, France; Dirk Piester, Physikalisch-Technische Bundesanstalt, Germany; Kun Liang, BIPM, France/ National Institute of Metrology, China; Wenjun Wu, National Time Service Center, China; Andrey Naumov, Main Metrological Center for State Service of Time and Frequency, FGUP VNIIFTRI, Russia

11:30 Carrier Phase Timing with Single Satellite based on CAPS “Virtual Clock” Method: Wen-fang Jing, Key Laboratory for Precise Navigation, PNT, Chinese Academy of Sciences (CAS), China; Li-ye Xu, NTSC, University of Chinese Academy of Sciences (UCAS), China; Xiao-chun Lu, NTSC, CAS, Key Laboratory for Precise Navigation, PNT, CAS, UCAS, China

Alternate

1. NAVSTAR GPS, the Early Days: Joseph A. Strada, The Aerospace Corporation

Annual Awards Luncheon
12:00- 2:00 p.m., Grand Ballroom D
Late arrivals will not be served after 12:20 p.m.
ITM TECHNICAL SESSIONS

THURSDAY AFTERNOON, FEBRUARY 1

A5: Interference Mitigation and Spectrum Management
2:00 PM - 5:00 PM
Room: Grand Ballroom G

Dr. Alex Stratton, Rockwell Collins

2:05 Updated Assessment of GNSS Intrasysem and Inter sysem Interference for Airborne Equipment: Christopher Hegarty, Kevin Bean, The MITRE Corporation; Olivier Julien, ENAC, France; Sai Kalyanaraman, Rockwell Collins; A.J. Van Dierendonck, AJ Systems; Sam Pullen, Stanford University

2:35 Crowdsourcing GNSS Jammer Detection and Localization: Luka Strizic, University of Colorado Boulder/Luleå University of Technology, Sweden; Dennis M. Akos, University of Colorado Boulder & Stanford University; Sherman Lo, Stanford University

3:05 Variation Analysis of Satellite Navigation Message and its Application to Anti-Spoofing: Jianfeng Li, Hong Li, Fei Wang, Tsinghua University, China; Hang Ruan, Beijing Institute of Tracking & Telecommunications Technology, China; Zhongxiao Wang, Mingquan Lu, Tsinghua University, China

3:35 Development of a Prototype System for Spoofer Localization Based on TOA Measurements: Jian Wen, Hong Li, Fei Wang, Weiyi Gao, Jianfeng Li, Mingquan Lu, Tsinghua University, China

4:05 Effective GPS Spoofing Detection Utilizing Metrics from Commercial Receivers: Esteban Garbin Manfredini, GMV, Spain; Dennis Akos; University of Colorado; Yu-Hsuan Chen, Sherman Lo, Todd Walter Per Enge, Stanford University

4:35 Accurate Position and Attitude Determination in a Jammed or Spoofed Environment Using an Uncalibrated Multi-Antenna-System: Soeren Zorn, RWTH Aachen University, Germany; Tobias Bamberg, Michael Meurer, RWTH Aachen University & German Aerospace Center (DLR), Germany

Alternate
1. GNSS RFI Localization using a Hybrid TDOA/PDOA/Multi-Frequency Approach: Ryan Blay and Dennis Akos, University of Colorado Boulder

B5: Atmospheric Science and Space Applications
2:00 PM - 5:00 PM
Room: Grand Ballroom F

Dr. Susumu Saito, ENRI, Japan

2:05 Four Parameter Ionospheric Channel Model—Theory and Simulation: Ilir F. Progri, Giftet Inc.

2:35 Research on Klobuchar Improved Model Based on the Measured Data of BeiDou Satellite Navigation System in Tianjin Area: Kaimin Xue, Ruihuia Liu, Jian Wang, Jie Bai, Civil Aviation University of China, China


3:35 Study of the Spatial Scale of Plasma Bubbles for Ionospheric Threat Model for GBAS: Maho Nakamura, Susumu Saito, Takayuki Yoshihara, Electronic Navigation Research Institute, Japan

4:05 Spatial-Temporal Correlation Analysis of Ionospheric Delay in China based on iGMAS: Zhipeng Wang, Sikun Wei, Shao, Beihang University, China; Qian Sun, China Waterborne Transport Research Institute, China

4:35 Geomagnetic Storm Effects on the Occurrences of Ionospheric Irregularities over the African Equatorial/low-latitude Region: P.O. Amaechi, Chrisland University, Nigeria; E.O. Oyeyemi and A.O. Akala, University of Lagos, Nigeria

Alternate
1. The Response of African Equatorial/low-latitude Ionosphere to 2015 St. Patrick’s Day Geomagnetic Storm: P. O. Amaechi, Chrisland University, Nigeria; E.O. Oyeyemi, and A.O. Akala, University of Lagos, Nigeria

C5: Modernized and Emerging GNSS
2:00 PM - 5:00 PM
Room: Grand Ballroom E

Dr. Rezy Pradiptha, Boston College


2:35 New Solutions on the Design of a Galileo Acquisition-Aiding Signal to Improve the TTFF and the Sensitivity: Lorenzo Ortega Espluga, TSKA, France; Charly Poulliat, Marie-Laure Boucheret, ENSEEIHT, France; Marion Aubault, CNES, France; Hanai Al bitar Thales Alenia Space, France

3:05 An Open Source BDS-3 B1C/B2a SDR Receiver: Yafeng Li, Beijing Institute of Technology, China; Nagaraj C. Shivaramaiah, Dennis M. Akos, University of Colorado at Boulder


4:35 Dynamic Power Allocation with Constant Envelope Transmission for Next Generation Software-Defined GPS Payloads: Seeley Pentecost and Sanjeev Gunawardena, Air Force Institute of Technology

Alternates
1. Rapid Synchronization for Spread Spectrum Communication System: Kerry Frohling, Iris Technology

2. Utilize Aerostat to Realize Emergency Service of Integrated Network for Navigation and Communication: Weiyi Chen, Haidao Wu, Pingke Deng, Xiaoguang Zhang, Yi Qu, Chinese Academy of Science, China
P5: Advanced Time Transfer Techniques
2:00 PM - 5:00 PM
Room: Regency B

2:05 Optical Two-Way Time-Frequency Transfer Across Partially Reciprocal Free-Space Links: Martha I. Bodine, William C. Swann, Isaac H. Khader, Esther Baumann, National Institute of Standards and Technology (NIST); Jean-Daniel Deschenes, Université Laval, Canada; Nathan R. Newbury, NIST

2:35 Free-Space Two-way Optical Time-Frequency Transfer (FTWOTT) Based on GEO/IGSO and MEO Satellites: Yansong Meng, Zhongying Zhang, Guoyong Wang, Lang Bian, China Academy of Space Technology, China


3:35 Measurement and Analysis of Polarization Variations in an Optical Coherent Fiber Communication Network Utilized for Time and Frequency Distribution: S-C. Ebenhag, P.O. Hedekvist, L. Weddig, RISE Research Institutes of Sweden, Sweden; M. Karlsson, Chalmers University of Technology, Sweden

4:05 Traceable Time Dissemination with NTP: André Charbonneau, Rob Douglas and Marina Gertsvolf, National Research Council (NRC), Canada

4:35 Feasibility of Microsecond-Level Timing with a WWVB-Disciplined Rubidium Oscillator: Kevin Croissant, Sabrina Ugazio and Frank van Graas, Ohio University

Alternate
1. Improving Packet Synchronization in an NTP Server: Andrew N. Novick, Michael A. Lombardi, Time and Frequency Division, National Institute of Standards and Technology; Kevin Franzen, John Clark, Masterclock
EXHIBIT HALL

Exhibit Hall Floor Plan:

Entrance

Attendee Dining Area

20 18 7 6
19 17 8 5
22 15 10 3
23 14 11 2
24 13 1 1

Show Hours:
Tuesday, January 30
8:30 a.m. – 5:00 p.m. Exhibit Hall Open
8:30 a.m. – 10:00 a.m. Exhibitor Hosted Breakfast

Wednesday, January 31
8:00 a.m. – 4:30 p.m. Exhibit Hall Open

Exhibitors:
- Brandywine Communications (Booth 5)
- Carmel Instruments, LLC (Booth 14)
- CAST Navigation (Booth 22)
- ENSCO (Booth 24)
- Frequency Electronics, Inc. (Booth 10)
- GuideTech (Booth 2)
- IFEN, Inc. (Booth 6)
- ION (The Institute of Navigation) (Booth 8)
- Iris Technology (Booth 17)
- Linear Photonics, LLC (Booth 18)
- Masterclock, Inc. (Booth 3)
- Microsemi Frequency and Time Corporation (Booth 1)
- MITRE (Booth 4)
- Oscilloquartz SA (Booth 13)
- Septentrio (Booth 23)
- SpectraDynamics (Booth 20)
- Spirent Federal Systems (Booth 11)
- TimeTech GmbH (Booth 15)
- Vescent Photonics (Booth 19)

List current as of 1/8/18