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INSTITUTE OF NAVIGATION

January 21–24, 2020

**Hyatt Regency Mission Bay
San Diego, CA**

**INTERNATIONAL
TECHNICAL MEETING**

**PRECISE TIME AND
TIME INTERVAL
SYSTEMS AND
APPLICATIONS
MEETING**

**ONSITE
PROGRAM**

ITM

PTTI

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PROGRAM OVERVIEW

Pre-Conference Tutorials: Tuesday, January 21

PTTI Tutorial Sessions (Bayview Ballroom 3)

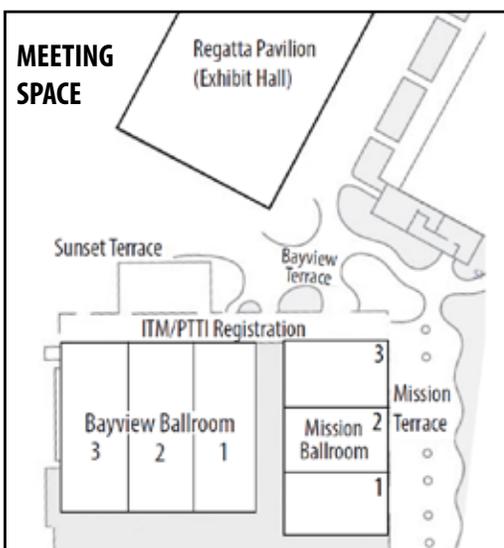
9:00 a.m.–12:00 p.m.: Tutorials
 12:00 p.m.–1:30 p.m. • Lunch on Your Own
 1:30 p.m.–5:45 p.m.: Tutorials

Must add tutorials on ITM/PTTI Registration Form. Additional Fee.

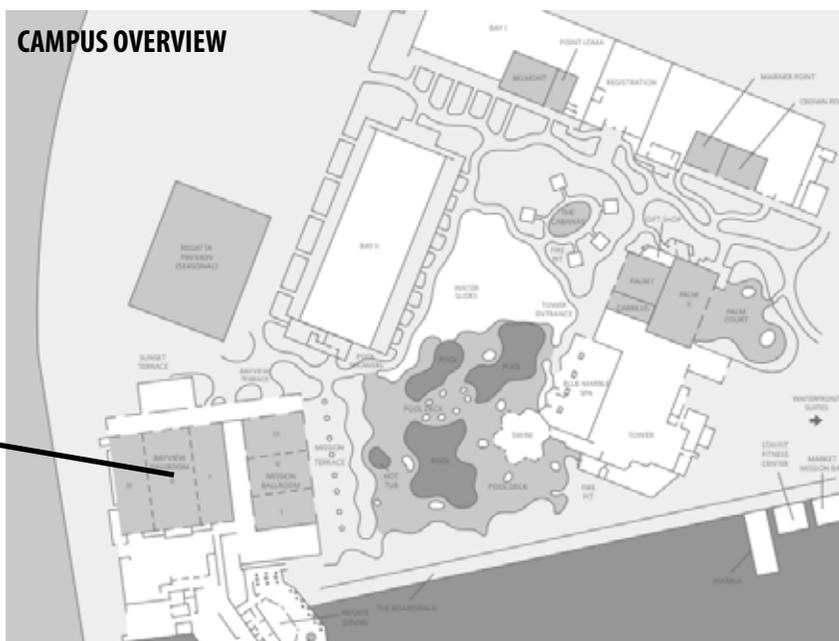
ITM/PTTI Technical Sessions

	ITM Track A Bayview Ballroom 1	ITM Track B Bayview Ballroom 2	PTTI Track Bayview Ballroom 3
Wednesday, January 22	Exhibit Hall Open 8:30 a.m.–5:00 p.m. (Regatta Pavilion) • Exhibitor Hosted Breakfast in Exhibit Hall 8:30 a.m.–9:30 a.m. (Regatta Pavilion)		
	9:30 a.m.–12:45 p.m. ITM/PTTI Plenary Session Keynotes and Exhibitor Presentations (Bayview Ballroom 1)		
	12:45 p.m.–1:45 p.m. Lunch in Exhibit Hall (Regatta Pavilion)		
	1:45 p.m. - 5:30 p.m. A1: DFMC Airborne Error Models	1:45 p.m. - 5:30 p.m. B1: Advanced Signal Processing for GNSS Receivers	1:45 p.m. - 5:10 p.m. P1a: Laboratory Reports and Activities 5:10 p.m. - 5:45 p.m. P1b: Poster Session
Thursday, January 23	Exhibit Hall Open 8:00 a.m.–4:30 p.m. (Regatta Pavilion)		
	8:30 a.m. - 12:15 p.m. A2: GNSS for Aviation: Integrity and Augmentation	8:30 a.m. - 12:15 p.m. B2: Precise GNSS Positioning	8:30 a.m. - 12:15 p.m. P2: Time and Frequency Transfer Beyond GNSS
	12:15 p.m.–1:45 p.m. Lunch in Exhibit Hall (Regatta Pavilion)		
	1:45 p.m. - 5:30 p.m. A3: Challenges for Unmanned Aerial Vehicles and Autonomous Systems	1:45 p.m. - 3:25 p.m. B3a: Pedestrian and Indoor Localization 3:55 p.m. - 5:30 p.m. B3b: High-Performance GNSS Receivers	1:45 p.m. - 3:25 p.m. P3a: Advances in Next Generation Clocks 3:55 p.m. - 5:30 p.m. P3b: Timekeeping in Commercial Applications
Friday, January 24	8:30 a.m. - 10:05 a.m. A4a: Challenges in Terrestrial and Urban Environments	8:30 a.m. - 12:15 p.m. B4: Atmospheric and Space Weather	8:30 a.m. - 10:05 a.m. P4a: Time and Frequency Transfer Using GNSS and RNSS
	10:15 a.m. - 12:15 p.m. A4b: Alternatives, Backups and Complements to GNSS		10:15 a.m. - 12:15 p.m. P4b: PTTI Applications and Techniques
	12:15 p.m.–1:45 p.m. Awards Luncheon (Regatta Pavilion) - Late Arrivals will not be served after 12:30 p.m.		
	2:00 p.m. - 5:10 p.m. A5: GNSS and Security: Jamming and Spoofing	2:00 p.m. - 3:10 p.m. B5a: Timing for PNT Resilience 3:35 p.m. - 5:10 p.m. B5b: Integrated Navigation Systems	2:00 p.m. - 3:35 p.m. P5a: Timescales and Algorithms 3:35 p.m. - 4:45 p.m. P5b: Emergent Timing Infrastructure for GNSS Providers (Joint PTTI/ITM Session)

HYATT CAMPUS MAP



CAMPUS OVERVIEW



SPECIAL EVENTS AND GENERAL CONFERENCE INFORMATION

Special Events at ITM/PTTI 2020

The following events are included in all full-conference and student registrations. Single day registrations include events taking place on the day the attendee is registered. Retired registrations include all meal functions located within the exhibit hall; a ticket is required for Friday's Awards Luncheon.

Exhibitor Hosted Breakfast

Wednesday, 8:30 a.m. - 9:30 a.m.

Exhibit Hall, Regatta Pavilion

Informal Luncheon

Wednesday, 12:45 p.m. - 1:45 p.m.

Exhibit Hall, Regatta Pavilion

Informal Luncheon

Thursday, 12:15 p.m. - 1:45 p.m.

Exhibit Hall, Regatta Pavilion

Annual Awards Luncheon

Friday, 12:15 p.m. - 1:45 p.m.

Late arrivals will not be served after 12:30 p.m.

Regatta Pavilion

Special Events for Speakers/Session Chairs

All session chairs and the presenting author of primary and alternate presentations should attend the Speakers' Meeting (Wednesday) or the Speakers' Breakfast (Thursday-Friday), taking place in Mission Ballroom 3 on the day of their presentation. Names will be checked at the door. Attend the Speakers' Meeting/Breakfast only on the morning of your presentation. If you have not 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 on at ion.org/itm or 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, exhibitor list and other conference information from your mobile device. Visit m.ion.org.

Complimentary Internet

Free wireless internet is available to attendees in all technical session rooms and meeting room lobbies.

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Allison Kealy, ION Member

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TUTORIAL INFORMATION AND COSTS

Pre-conference tutorials have been organized to provide in-depth learning prior to the start of the technical program. All courses will be taught in a classroom setting. Electronic notes will be made available for download by registered attendees from the meeting website; registered attendees are encouraged to download notes in advance of courses. Power will NOT be available to course attendees for individual laptop computers; please come prepared with adequate battery power if required. ION reserves the right to cancel a portion of the tutorial program based on availability of the instructor. Tutorial cost is \$400.00 for the full day or courses.

TUTORIAL SCHEDULE

Time	Course	Presenter
9:00 a.m. - 10:15 a.m.	Introduction to Optical Clocks	Dr. Pierre Dubé,
10:30 a.m. - 12:00 p.m.	Optical Frequency Combs: from Principles of Operation to Metrological Applications	Dr. Helen Margolis
12:00 p.m.–1:30 p.m. Lunch on Your Own		
1:30 p.m. - 2:45 p.m.	Realization of a UTC(k) Time Scale	Dr. Daniele Rovera
3:00 p.m. - 4:15 p.m.	Global Navigation Satellite System (GNSS) Overview with a Focus on Precise Time Disseminations and Standards	Ed Powers
4:30 p.m. - 5:45 p.m.	Optical Fiber and its Use for Time and Frequency Transfer	Dr. Sven-Christian Ebenhag

TUTORIAL DESCRIPTIONS

Introduction to Optical Clocks

In the first part of this tutorial the fundamental principles that led to the development of modern optical clocks will be presented. Optical clocks based on trapped neutral atoms in optical lattices or single ions in rf traps currently realize the most accurate frequency standards. Their performances are such that a re-definition of the SI second using an optical clock is expected to happen within the next decade. They outperform the accuracy of cesium fountain clocks that currently define the SI second by two orders of magnitude. An overview of these optical clocks and a comparison of their respective performances will be given. The primary focus of the second part will be on single-ion optical clocks. The optical clock developed at NRC, based on a trapped and laser-cooled single ion of 88Sr^+ , will be presented in more detail to provide a concrete example of the steps involved in achieving very low uncertainties. Many important topics will be covered, from the basic operation of our standard to a discussion of key systematic shifts that must be well-understood and controlled to achieve high accuracy. At present, the 88Sr^+ ion clock at NRC has an evaluated fractional uncertainty of 10^{-17} . Methods for reducing it to the 10^{-18} level will be discussed briefly. The tutorial will conclude with examples of optical clock applications in fundamental physics and relativistic geodesy.



Dr. Pierre Dubé received his Ph.D. in physics from the University of Toronto. He went on to be a postdoctoral fellow at JILA in Boulder, Colorado, with John Hall, and a postdoctoral fellow at TRIUMF, in Vancouver, Canada, with Otto Häusser. Since 2000, he has been working at the National Research Council of Canada, primarily on high-accuracy single-ion optical clocks.

Optical Frequency Combs: from Principles of Operation to Metrological Applications

Femtosecond optical frequency combs are highly versatile tools for precision measurements. Providing phase coherent frequency references across the entire optical spectrum, they offer users a unique combination of broad spectral coverage, high spectral resolution and a calibrated frequency scale. As a result, they have found numerous applications in frequency metrology and beyond. This tutorial will explain how femtosecond optical frequency combs work, covering both the fundamental principles and some practical details. The construction and major components of several of the most common types of frequency comb technology will be described. Differentiating factors that may influence the choice of technology for a particular application will be discussed. Finally, case studies will illustrate how optical frequency combs are applied in precision frequency metrology.



Dr. Helen Margolis is an NPL Fellow in Optical Frequency Standards and Metrology. She leads NPL's research activities in optical frequency metrology using femtosecond combs, which are part of the research programme to develop a new generation of high accuracy optical atomic clocks based on laser-cooled trapped ions and atoms.

TUTORIAL DESCRIPTIONS (Continued)

Realization of a UTC(k) Time Scale

Many different approaches can be found in literature for the realization of a time scale. Most of them consider the realization of an autonomous time scale without considering the specific needs of a UTC(k). This tutorial suggests an unconventional approach, oriented to the practical implementation of a physically available robust UTC(k) time scale. This tutorial is based on the assumption that an UTC(k) is a physical representation of UTC with the best availability and the lowest possible departure from UTC, taking into account the fact that the number and the quality of the available clock is limited by external constraint. The first part will be devoted to a description of UTC and of the expected characteristics of an UTC(k) time scale. The second part will describe the steering of an UTC(k) to UTC, with examples provided. The analysis of performances of some UTC(k) will be discussed.



Dr. Daniele Rovera has been a researcher at LNE-SYRTE Observatoire de Paris, (formerly LPTF) since 1989 where his current interests include atomic clocks, optical frequency measurements, time comparisons and time scales.

Global Navigation Satellite System (GNSS) Overview with a Focus on Precise Time Disseminations and Standards

GPS has provided an operational Position Navigation and Timing (PNT) services for more 25 years. The vast majority of PNT applications use GPS as its fundamental source for PNT data. GPS operates using very precise synchronized ranging signals, where in general every nanosecond of synchronization error can lead to one foot of navigation error. Because of this exquisite timing synchronization, GPS provides a precise timing service used to support many important user communities ranging from power grid, telecommunication networks, science and the banking industry. Today GPS is no longer the only GNSS system, there are now several other GNSS systems in either operations and/or system development. This tutorial will provide an overview of how GPS operates, discuss the other GNSS systems and the reference standard that underlay each system.



Ed Powers received his BS and MS degrees in Electronic Engineering and Instrumental Science from the University of Arkansas. Previously, he has worked at NRL on GPS clock development and at the USNO as the GPS Operations Division Chief. Ed joined the Aerospace Corp in October 2018 as Senior Project Engineer, GNSS Engineering & Technology.

Optical Fiber and its Use for Time and Frequency Transfer

The need to know the time in present and future society is increasing, whether it is in a time stamp of a financial transaction, or the data handover between two base stations in a 5G network. In many occasions it is satisfied with time through radio transmission, but with synchronization needs related to national security or international regulations, the security of an optical fibers is essential. The comparison of frequency from an optical clock is also fundamental for enhanced accuracy in measurements. While techniques for fiber optic communication are in constant development, with data rates exceeding 400 Gbit/s, the evolution of techniques for time or frequency transfer over fiber must follow a different path. While the necessary bandwidth is low, the requirements for stability and symmetry are huge, and not easily handled. The difference in transfer of frequency in comparison to time is also fundamental, since it relates either to the momentary change in phase or delay, or the accumulated changes. This tutorial will demonstrate the background of fiber optics, from the physics of light confinement in glass fibers to the limitations that must be overcome, including attenuation, dispersion, polarization and environmental variations. It will conclude with the presentation of the latest state-of-the-art time and frequency transfer results, which have been experimentally demonstrated around the globe.



Dr. Sven-Christian Ebnehag received his PhD from Chalmers University of Technology in Sweden. Since 2002 has he worked at the SP Technical Research Institute of Sweden, where he is one of the senior scientists in the implementations of time and frequency transfer over a national fiber communication network.

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MEETING ORGANIZERS



ITM General Chair
Dr. Olivier Julien
u-blox, Switzerland



ITM Program Chair
Dr. Okuary Osechas
German Aerospace Center (DLR), Germany



PTTI General Chair
Dr. Michael Coleman
Naval Research Laboratory



PTTI Program Chair
Dr. Jennifer Taylor
US Naval Observatory



PTTI Tutorials Chair
Dr. Marina Gertsvolf
National Research Council, Canada

PLENARY SESSION

ROOM: BAYVIEW BALLROOM 1

Wednesday, January 22, 9:30 a.m. - 12:45 p.m.

WELCOME AND INTRODUCTIONS



Dr. Y. Jade Morton
ION President
University of Colorado at Boulder



Dr. Okuary Osechas
ITM Program Chair
German Aerospace Center (DLR), Germany



Dr. Jennifer Taylor
PTTI Program Chair
US Naval Observatory

ITM/PTTI PLENARY KEYNOTES



Atomic Timekeeping as a Hobby
9:40 a.m. - 10:20 a.m.

Tom Van Baak
Leapsecond.com



Ancient Chinese Time Service and Navigation Technology
10:20 a.m. - 11:00 a.m.

Dr. Xiaochun Lu
Chinese Academy of Sciences, China



Galileo System Status and Challenges Ahead
11:00 a.m. - 11:40 a.m.

Marco Falcone
European Space Agency, The Netherlands

INTRODUCTION

9:30 a.m. - 9:40 a.m.

KEYNOTE PRESENTATIONS

9:40 a.m. - 11:40 a.m.

EXHIBITOR PRESENTATIONS

11:40 a.m. - 12:40 p.m.

LUNCH IN THE EXHIBIT HALL

12:45 p.m. - 1:45 p.m.

EXHIBITOR PRESENTATIONS (3 minutes each)

11:40 a.m. - 12:40 p.m.

Session A1: DFMC Airborne Error Models

Room: Bayview Ballroom 1

1:45 p.m. – 5:30 p.m.



Matteo Sgammini
European Commission, Italy



Markus Rippl
German Aerospace Center (DLR), Germany

- 1:50 **Standardization of New Airborne Multipath Models:** Michael Felux, Mihaela-Simona Circiu, Stefano Caizzone, Markus Rippl, German Aerospace Center (DLR), Germany; Pierre Durel, GSA; Matteo Sgammini, EC, Italy
- 2:12 **Multipath Suppression Capability and Indicators for Airborne Dual Frequency GNSS Antennas:** S. Caizzone, M.-S. Ciciu, W. Elmarissi, C. Enneking, A. Winterstein, German Aerospace Center (DLR), Germany
- 2:35 **Airborne Multipath Models for Dual-constellation Dual-frequency Aviation Applications:** Mihaela-Simona Ciciu, Michael Felux, Stefano Caizzone, Christoph Enneking, Friederike Fohlmeister, Markus Rippl, German Aerospace Center (DLR), Germany; Ioana Gulie, David Rüegg, Airbus Defence and Space GmbH, Germany; Joseph Griggs, Collins Aerospace; Rémy Lazzarini, Florent Hagemann, Francois Tranchet, Airbus Operation SAS; Pierre Bouniol, Thales Avionics; Matteo Sgammini, Joint Research Centre, Italy
- 2:58 **Effects of Preliminary DFMC Multipath Models on ARAIM Performance:** Joseph Griggs, Collins Aerospace; Markus Rippl, Mihaela-Simona Ciciu, Stefano Caizzone, German Aerospace Centre (DLR), Germany
- 3:25 - 3:55, Break. Refreshments in Exhibit Hall
- 4:00 **GMP-Overbound Parameter Determination for Measurement Error Time Correlation Modeling:** Sandeep Jada and Mathieu Joerges, Virginia Tech
- 4:23 **Impact of DME/TACAN on GNSS L5/E5a Receiver:** Axel Javier Garcia Pena, Christophe Macabiau, ENAC, France; Mikael Mabilieu, Pierre Durel, GSA, France
- 4:46 **Impact of Satellite Biases on the Position in Differential MFMC Applications:** Steffen Thoelert, Mihaela-Simona Ciciu, Michael Meurer, German Aerospace Center (DLR) and RWTH Aachen University, Germany

Session B1: Advanced Signal Processing for GNSS Receivers

Room: Bayview Ballroom 2

1:45 p.m. – 5:30 p.m.



Dr. Sabrina Ugazio
Ohio University



Dr. Chun Yang
QuNav, LLC

- 1:50 **GPS L1CA/BDS B1I NLOS Signal Measurements and Modeling in Dense Urban Area:** Xin Chen, Shanghai Jiao Tong University, China; Y. Jade Morton, University of Colorado Boulder; Di He, Shanghai Jiao Tong University, China
- 2:12 **Intermediate Frequency Level GPS Multipath Simulator based on Vector Tracking and Ray-tracing:** Bing Xu and Li-Ta Hsu, The Hong Kong Polytechnic University, Hong Kong; Taro Suzuki, Chiba Institute of Technology, Japan
- 2:35 **Extended Short Multipath Insensitive Code Loop:** Xu Weng, Yanhong Kou, Beihang University, China
- 2:58 **Robust Interference Mitigation: a Measurement and Position Domain Assessment:** D. Borio, C. Gioia, European Commission, Joint Research Centre, Ispra, Italy
- 3:25 - 3:55, Break. Refreshments in Exhibit Hall
- 4:00 **Hybrid Carrier Tracking and Position Determination using the Low Elevation Satellite Signals:** Rong Yang, Xingqun Zhan, Shanghai Jiao Tong University, China; Yang Wang, Y. Jade Morton, University of Colorado, Boulder; Jennifer S. Haase, University of California-San Diego
- 4:23 **Implementation and Analysis of a GPS Differential Vector Delay/Frequency Lock Loop (DVDFLL):** Tanner M. Watts, Scott M. Martin, David M. Bevil, Auburn University
- 4:46 **Measurements of GNSS Pseudorange Biases Induced by SIS Deformations:** Yanhong Kou, Yanshu Zhang, Huiwen Wu, Beihang University, China
- 5:08 **GNSS Interconstellation Time-Offset Estimates from LEO CubeSat and Performance Improvement Analysis on High Altitude SSV in Terms of GDOP:** Sabrina Ugazio, Brian C. Peters, Kevin Croissant, Gregory Jenkins, Ryan McKnight, and Frank van Graas, Ohio University

Alternates

1. **Performance Analysis of Reference Oscillators and Frequency Synthesizers for use in High-Fidelity Satellite Navigation Receivers:** Andrew D. Braun, Sanjeev Gunawardena, Air Force Institute of Technology
2. **Experimental Validation of IMM Algorithm for Carrier Phase Tracking Through Interference:** Wengxiang Zhao and Boris Pervan, Illinois Institute of Technology
3. **Exploitation of Pilot Signals for Rapid and Resilient Acquisition of Civil GNSS Navigation Signals:** Brian G. Agee, B3 Advanced Communication Systems
4. **Interference Detection based on Fractional Fourier Transform for GNSS Receivers:** Kewen Sun, Hefei University of Technology, China

Session P1a: Laboratory Reports and Activities

Room: Bayview Ballroom 3

1:45 p.m. – 5:10 p.m.



Victor Zhang
NIST



Francine Vannicola
Naval Research Laboratory

- 1:50 **PTB's Time and Frequency Services 2018 – 2019:** Dirk Piester, Andreas Bauch, Jürgen Becker, Martin Gutbrod, Tobias Klein, Thomas Polewka, Dieter Sibold, Egle Staliuniene, Kristof Teichel, Wilfried Vajen, Physikalisch-Technische Bundesanstalt (PTB), Germany
- 2:12 **Update on Time and Frequency Activities at NIST:** Elizabeth Donley, National Institute of Standards and Technology
- 2:35 **Time and Frequency Activities at the JHU Applied Physics Laboratory:** Mihran Miranian, Jeffrey F. Garstecki, Olukayode K. Okusaga, Richard A. Dragonette, Gregory L. Weaver, JHU/Applied Physics Laboratory
- 2:58 **Latest improvements at INRIM Time Laboratory:** A. Mura, D. Calonico, E. Cantoni, G. Cerretto, R. Costa, V. Formichella, A. Perucca, M. Sellone, I. Sesia, G. Signorile, P. Terzi, T. Thanh Thai and F. Levi, Istituto Nazionale di Ricerca Metrologica (INRIM), Italy
- 3:25 - 3:55, Break. Refreshments in Exhibit Hall
- 4:00 **Time and Frequency Laboratory Activities at RISE:** Carsten Rieck, Kenneth Jaldehag and Sven-Christian Ebenhag, Measurement Science and Technology, RISE, Sweden
- 4:23 **Homogeneous UTC: Timing Problems in Russia:** I. Blinov, S. Donchenko, A. Karaush, N. Kosheliaevskii, and A. Naumov, VNIIFTRI, Russia
- 4:46 **Report on UTC Lab Activities at ESA/ESTEC:** P. Waller, A. Samperi, R. Valceschini, ESA/ESTEC, Netherlands

Session P1b: Poster Session

Room: Bayview Foyer

5:10 p.m. – 5:45 p.m.



Ryan Dupuis
Excelitas Technologies



Dr. Michael Coleman
Naval Research Laboratory

1. **The Portable Cesium Clock Time Transfer at the Nano Second Level:** Shinn Yan Lin, Wen-Hung Tseng, Telecommunication Laboratories, Taiwan
2. **Alternative Spectral Windows for Precise Time Fibre Based Transport:** Josef Vojtech, Ondrej Havlis, Martin Slapak, Sarbojeet Bhowmick, Jan Radil, Petr Munster, Tomas Horvath, Radek Velc, Jan Kundrat, Lada Altmannova, Vladimir Smotlacha, Rudolf Vohnout, Martin Michal, Pavel Skoda, Michal Hazlinsky, Vaclav Kubernat, CESNE a.l.e., Czech Republic; Jan Hrabina, Martin Cizek, Lenka Pravdova, Simon Rerucha, Ondrej Cip, ISI CAS, Czech Republic

Session A2: GNSS for Aviation: Integrity and Augmentation

Room: Bayview Ballroom 1

8:30 a.m. – 12:15 p.m.



Deborah Lawrence
Federal Aviation Administration



Dr. Juan Blanch
Stanford University

- 8:35 GNSS Spoofing Detection and Identification Based on Clock Drift Monitoring Using Only One Signal: Shunshun Shang, Hong Li, Yimin Wei, Mingquan Lu, Tsinghua University, China
- 8:57 A Research on Modeling and Monitoring of New BDS B1C Signal Distortions In the Context of Beidou Satellite Based Augmentation System: Kefan Wei, Xiaowei Cui, Mingquan Lu, Tsinghua University, China
- 9:20 EWF Monitoring in SBAS Applied to Galileo E1c and E5a Signals Using SQM2b and Code-Carrier Incoherence Monitor: Ikhlas Selmi, Paul Thevenon, Christophe Macabiau, ENAC, France; Mikael Mabilieu, Pierre Durel GSA, France
- 9:43 GBAS Integrity Performance Evaluation Based on the Mixed g-and-h Distribution: Ludan Song, Kun Fang, Jisi Fang, Zhipeng Wang, Beihang University, China
- 10:05-10:35, Break. Refreshments in Exhibit Hall
- 10:40 Evaluating PPP Integrity for Aviation Using Flight Data: R. Eric Phelts, Kazuma Gunning, Juan Blanch, Todd Walter, Stanford University
- 11:03 Fault Detection and SiS Error Validation Method Tailored for an ARAIM ISM Generator Including Recommendations on the Ground Network: Matteo Sgammini, European Commission, Joint Research Centre (JRC), Italy; Ilaria Martini, European Commission, Belgium
- 11:26 ARAIM Continuity and Availability Assumptions, Assertions, and Evaluation Methods: Mathieu Joerger, Virginia Tech; Yawei Zhai, Illinois Institute of Technology; Shanghai Jiao, Tong University, China; Juan Blanch, Stanford University; Ilaria Martini, European Commission, Belgium; Boris Pervan, Illinois Institute of Technology
- 11:48 Stress Testing Advanced RAIM Airborne Algorithms: Juan Blanch and Todd Walter, Stanford University

Alternate

1. The Post-broadcast Integrity System of Qianxun for SSR Service: Qilong Zhao, Hailin Guo, Shuai Jing, Jianhong Wu, Pumin Xin, Wenjia Mei, Jianping Wang, Yantong Feng, Xiaowei Hou, Yingming Jiang, Jie Chen, Shuai Li and Shaojun Feng, Qianxun Spatial Intelligence Inc., China

Session B2: Precise GNSS Positioning

Room: Bayview Ballroom 2

8:30 a.m. – 12:15 p.m.



Dr. Adria Rovira-Garcia
Universitat Politècnica Catalunya, Spain



Dr. Robert Odolinski
University of Otago, New Zealand

- 8:35 Improvement of RTK Performances Using an Array of Receivers with Known Geometry: Xiao Hu, Paul Thevenon, Christophe Macabiau, ENAC, France
- 8:57 High-Accuracy Baseline Estimation using Differential NavIC and GPS: A. Althaf and Hari Hablani, DAASE, Indian Institute of Technology Indore, India
- 9:20 Research on Ambiguity Solution Integrity Monitoring for Moving Base RTK: Xiaopeng Hou, Kun Fang, Zhipeng Wang, Beihang University, China; Qiang Li, Beihang University & Aviation Data Communication Corporation, China; Jisi Fang, Aviation Data Communication Corporation, China
- 9:43 Impact of Satellite Elevation Mask in GPS+Galileo RTK Positioning: J. Manuel Castro-Arvizu, Daniel Medina, Ralf Ziebold, German Aerospace Center (DLR), Germany
- 10:05-10:35, Break. Refreshments in Exhibit Hall
- 10:40 Combined Precise Orbit Determination for BDS-2 and BDS-3 Satellites: Hanbing Peng, Technische Universität Berlin (TU Berlin) & GFZ German Research Centre for Geosciences, Germany; Maorong Ge, GFZ German Research Centre for Geosciences, Germany; Yuanxi Yang, Xi'an Research Institute of Surveying and Mapping, National Key Lab of Geo-information Engineering, China; Harald Schuh, GFZ German Research Centre for Geosciences & TU Berlin, Germany; Roman Galas, TU Berlin, Germany
- 11:03 Experimental Analysis of a Candidate Galileo E6-B Data Dissemination Scheme: D. Borio, European Commission, Joint Research Centre, T. Senni, European Commission, I. Fernandez-Hernandez, European Commission, DG GROW
- 11:26 GNSS PPP Navigation in Obstructed Environments Using Clock Coasting: Sihan Yang and Sunil Bisnath, York University, Canada
- 11:48 State-space Positioning Corrections with Single-receiver GNSS Data: A. Khodabandeh and N. Nadarajah, The University of Melbourne, Australia

Alternates

1. Best Integer Equivariant Estimation for Low-cost, Single- and Dual-frequency, Multi-GNSS RTK Positioning: R. Odolinski, University of Otago, New Zealand; P.J.G. Teunissen, Curtin University of Technology, Australia; and Delft University of Technology, The Netherlands
2. Application of GNSS-Reflectometry for Vertical Datum Determination in Alaska: Su-Kyung Kim, Jihye Park, Oregon State University
3. Optimal GNSS Satellites Selection Using Second-Order Cone Programming: L.B. Rapoport, Topcon and Institute of Control Sciences; T.A. Tormagov, MIPT and Institute of Control Sciences, Russia

Session P2: Time and Frequency Transfer Beyond GNSS

Room: Bayview Ballroom 3

8:30 a.m. – 12:15 p.m.



Dr. Sven-Christian Ebenhag
RISE Research Institute of Sweden



Angela McKinley
US Naval Observatory

- 8:35 Suitability of Network Time Protocol (NTP) for Time Dissemination: Steven Sommars, OnlyTime
- 8:57 The WRITE Project: Fibre Propagation Asymmetry in White Rabbit Time Transfer Links: Elizabeth Laier English, Conway Langham, Peter Whibberley, National Physical Laboratory, UK
- 9:20 Time and Frequency Dissemination for Aerospace Industry using the White Rabbit Precision Time Protocol: Mura Alberto, Istituto Nazionale di Ricerca Metrologica - INRIM, Italy; Beretta Simone, Leonardo SpA, Italy; Calonico Davide, Clivati Cecilia, Levi Filippo, INRIM, Italy; Massare Maurizio, Leonardo SpA, Italy; Sarcevic Sani, Institute of Metrology of Bosnia and Herzegovina - IMBIH, Italy; Sapia Adalberto, Leonardo SpA, Italy
- 9:43 Absolute Phase Synchronization over Optical Fiber Links: Hongwei Si, Bo Wang, Lijun Wang, State Key Laboratory of Precision Measurement Technology and Instruments, Tsinghua University, China
- 10:05-10:35, Break. Refreshments in Exhibit Hall
- 10:40 Timing Accuracy Test of Non-GPS-Based Positioning System at White Sands Missile Range (WSMR): Christopher Black, 746th Test Squadron, Holloman AFB
- 11:03 Two-Way Time and Frequency Transfer via Ground-to-Satellite Optical Communications Links: Michael T. Taylor, Joseph M. Kahn, Leo Hollberg, Stanford University
- 11:26 Carrier Phase Based Time and Frequency Dissemination in Satellite-ground Link: H. J. Liang, T. B. Zhang, C. H. Yan, S. G. Wang, L. J. Wang, Tsinghua University, China
- 11:48 Estimation of Chip Scale Atomic Clocks Under Influence of Space Environmental Effects Onboard CubeSat Missions: Margaret Rybak, Penina Axelrad, Jill Seubert, Todd Ely, University of Colorado, Boulder

12:15 p.m. - 1:45 p.m. • Lunch in Exhibit Hall • Regatta Pavilion

Session A3: Challenges for Unmanned Aerial Vehicles and Autonomous Systems
Room: Bayview Ballroom 1
1:45 p.m. – 5:30 p.m.



Dr. Mathieu Joerger
Virginia Tech



Dr. Li-Ta Hsu
The Hong Kong Polytechnic University, China

- 1:50 **Integrity Monitoring and Prediction Concept and Prototype for Fully Autonomous Vehicle Resilience and Safety:** R. Tiwari and T. Stacey, Nottingham Scientific Ltd., UK; Felix Toran, European Space Agency (ESA), EGNOS Project Office, France
- 2:12 **Error Bounds of the GNSS/INS Integrated System Against GNSS Fault for Integrity Monitoring:** Wei Liu, Dan Song, Zhipeng Wang, Yanbo Zhu, Qiang Li, Beihang University, China
- 2:35 **GNSS/INS Tightly Coupled Scheme with Weighting and FDE for Rail Applications:** Xin Han, BJTU/Ifsttar, France; Syed Ali Kazim, Ifsttar, France; Nourdine Ait Tmazirte, IRT Railenium, France; Juliette Marais, Univ. Gustave Eiffel, France; Debiao Lu, BJTU, China
- 2:58 **Observing User-segment Faults in the Residuals of a Consensus-based Multi-GNSS Solution:** Zhen Zhu, East Carolina University; Eric Vinande, Jason Pontious, AFRL - Sensors Directorate
- 3:25 - 3:55, Break. Refreshments in Exhibit Hall
- 4:00 **A Low-Cost High-Precision Vehicle Navigation System for Urban Environment using Time Differenced Carrier Phase Measurements:** Jungbeom Kim and Changdon Kee, Seoul National University, South Korea
- 4:23 **A Multi-Sensor Navigation System for Outdoor and Indoor Environments:** Karsten Mueller, Jamal Atman, Institute of Systems Optimization (ITE), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany; Gert F. Trommer, ITE, KIT, Germany and ITMO University, Russia
- 4:46 **GNSS Spoofing Detection using Raw IMU Measurements and Pre-integration:** Yimin Wei, Hong Li, and Mingquan Lu, Tsinghua University, China
- 5:08 **Development of a Model and Estimation Method to Represent Team Search with Uncertain Detection:** Audrey Balaska and Jason H. Rife, Tufts University

Alternate

- 1. **Vulnerability Assessment of Integrated GNSS Receivers to Spoofing Attacks:** Akmal Rustamov, Turin Polytechnic University, Italy; Alex Minetto, Fabio Dovis, Politecnico di Torino, Italy

Session B3a: Pedestrian and Indoor Localization
Room: Bayview Ballroom 2
1:45 p.m. – 3:25 p.m.



Dr. Liang Chen
Wuhan University, China



Dr. Ramsey Faragher
Focal Point Navigation, UK

- 1:50 **Effects of Stereo Vision Camera Positioning on Relative Navigation Accuracy:** Kirill A. Sarantsev, Clark N. Taylor, Scott L. Nykl, The Air Force Institute of Technology
- 2:12 **TOA Estimation for Positioning with 5G NR Signals in Indoor Field Tests:** Liang Chen, Xin Zhou, Feifei Chen and Ruizhi Chen, Wuhan University, China
- 2:35 **Pedestrian Navigation in Urban Area Using GNSS Raw Data with Smartphones:** Shinya Miyai, Yusuke Amano and Yukihiro Kubo, Ritsumeikan University, Japan
- 2:58 **Pedestrian Navigation Fusing Artificial Neural Networks for Localization and Pedestrian Dead Reckoning with an Extended Kalman Filter:** David J. Ellis, Joseph A. Curro, Clark Taylor, Air Force Institute of Technology
- 3:25 - 3:55, Break. Refreshments in Exhibit Hall

Session B3b: High-Performance GNSS Receivers
Room: Bayview Ballroom 2
3:55 p.m. – 5:30 p.m.



Friedrike Fohlmeister
German Aerospace Center (DLR), Germany



Dr. Sai Kalyanaraman
Collins Aerospace

- 4:00 **GNSS C/N0 Degradation Model in Presence of Continuous Wave and Pulsed Interference:** Axel Javier Garcia Pena, Christophe Macabiau, ENAC, France; Mikael Mabillean, Pierre Durel, GSA, France
- 4:23 **Modeling Multipath Effects on Frequency Locked Loops:** Liangchun Xu and Jason H. Rife, Tufts University
- 4:46 **Combining and Integration Schemes for Acquisition of Weak GNSS Split-Spectrum Signals:** Chun Yang, Andrey Soloviev, QuNav; Jung C. Ha, AFRL/RWYN
- 5:08 **A New Satellite Selection Method based on the Artificial Fish Swarm Optimization Algorithm:** Ershen Wang, Sun Caimiao, Pingping Qu, Tao Pang, Chuanyun Wang, He He, Xu Song, Shenyang Aerospace University, China

Alternates

- 1. **Verification of Space GPS Receiver Navigation Performance Using a Cube Satellite:** S. Yu, O. Kim, Y. Bae, H. Sim, C. Kee, Seoul National University, South Korea
- 2. **Robust GNSS Estimation using Factor Graphs, Modified Gaussian Mixture Model and a Transformed Domain Method:** Xin Zhang, Shanghai Jiao Tong University, China; Min Xu, Zhenjun Zhang, ComNav Technology, Co., Ltd., China

Session P3a: Advances in Next Generation Clocks
Room: Bayview Ballroom 3
1:45 p.m. – 3:25 p.m.



Dr. Lin Yi
Jet Propulsion Laboratory



Dr. Alexander Radnaev
NIST

- 1:50 **A Molecular Clock Architecture for Deep Space Inter-SmallSat Radio Occultation:** Lin Yi, Jet Propulsion Laboratory, California Institute of Technology; Mina Kim, Zhi Hu, Massachusetts Institute of Technology; Chi Ao, Eric Burt, Robert Tjoelker, Imran Mehdi, Jet Propulsion Laboratory, California Institute of Technology; Ruonan Han, Massachusetts Institute of Technology
- 2:12 **Portable Cold Rubidium Atom Frequency Standard:** Miao Zhu, Kisra Egodapitiya, Brian Patton, Alan Bell, Thang Tran, Doug Harvey, Brenton Young, Gerald Wong, Frank Roller, Joshua Zirbel, Guillaume Plateau, Nathan Shou, Jamil Abo-Shaeer, Martin Boyd, AOSense, Inc.
- 2:35 **Development of a High-Accuracy Transportable Single Ion Optical Clock at NRC:** Pierre Dubé, John E. Bernard, Bin Jian, National Research Council Canada
- 2:58 **Spectral Purity Transfer at the 1E-18 Level and Frequency Chain Assessment with Three Different Optical Frequency Combs:** Héctor Álvarez-Martínez, Real Instituto y Observatorio de la Armada, Spain; Christian Bærentsen, Yann Le Coq, and Rodolphe Le Targat, LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, France
- 3:25 - 3:55, Break. Refreshments in Exhibit Hall

Session P3b: Timekeeping in Commercial Applications
Room: Bayview Ballroom 3
3:55 p.m. – 5:30 p.m.



Peter Cash
Microchip



Dr. Judah Levine
NIST

- 4:00 **Resilient Timekeeping for Critical Infrastructure:** John Fischer, Orolia
- 4:23 **Industrial "5G" Telecom Infrastructure Time and Frequency Reference:** Jean-Charles Billebault, Didier Thorax, Nicolas Gufflet, Alexander Kovach, Vincent Candelier, Hamdi Henchiri, Ullas Kumar, Frédéric Vittrant, Rakon, France
- 4:46 **Common Calendar Timestamp System:** Brooks Harris, EdImax LLC

Session A4a: Challenges in Terrestrial and Urban Environments

Room: Bayview Ballroom 1

8:30 a.m. – 10:05 a.m.



Dr. Andrew Hansen
DOT



Dr. Juliette Marais
Université Gustave Eiffel, France

- 8:35 **Robust Estimators in Multiconstellation GNSS Positioning for Urban Environments:** Omar Garcia Crespillo, Alice Andreetti, Anja Grosch, German Aerospace Center (DLR), Germany
 - 8:57 **Prediction of RTK-GNSS Performance in Urban Environments Using 3D Model and Continuous LoS Method:** Rei Furukawa, Tokyo University of Marine Science and Technology / KOZO KEIKAKU ENGINEERING. Inc., Japan; Nobuaki Kubo, Tokyo University of Marine Science and Technology, Japan; Ahmed El-Mowafy, Curtin University, Australia
 - 9:20 **Improved Integration Method of Wide-area RTK/PPP with IMU and Odometer:** Nobuaki Kubo, Daisuke Hatta, Kaito Kobayashi, Kyohei Aoki, TUMSAT, Japan
 - 9:43 **Improved Urban Navigation with Specular Matching and Direct Positioning:** Kirsten L. Strandjord, Draper & University of Colorado Boulder; Penina Axelrad, University of Colorado Boulder; Shan Mohiuddin, Draper
- 10:05-10:35, Break. Refreshments in Foyer

Session A4b: Alternatives, Backups and Complements to GNSS

Room: Bayview Ballroom 1

10:35 a.m. – 12:15 p.m.



Dr. Maurizio Scaramuzza
Skyguide, Switzerland



Dr. Jiwon Seo
Yonsei University, South Korea

- 10:40 **BDS/AeroMACS Integrated Positioning Algorithm for Airport Surface Surveillance:** Wang Zhipeng, Gao Zhen, Du Jingtian, Zhu Yanbo, Beihang University, China
- 11:03 **Pseudorange Measurements with LTE Physical Channels:** Auryon Pink Soderini, Paul Thevenon, Christophe Macabiau, ENAC, France; Laurent Borgagni, John Fischer, Orolia
- 11:26 **Description of VBOC2(alpha1,alpha2) GMGM Special Cases Waveforms ACF--- Theory, Computation, Simulations, and Animation:** Ilir F. Progni, Giffet Inc.
- 11:48 **Integrated THz Relative Positioning: Navigation Algorithm and Simulation:** John Scott Parker, Tufts University & Draper; Jason Rife, Tufts University

Alternate

1. **Sky-wave Error Mitigation Approaches for the Medium-frequency R-Mode Radio Navigation System:** Niklas Hehenkamp, Lars Grundhoefer, and Stefan Gewies, German Aerospace Center (DLR), Germany

Session B4: Atmospheric and Space Weather

Room: Bayview Ballroom 2

8:30 a.m. – 12:15 p.m.



Dr. Alex Stratton,
Collins Aerospace



Dr. Jun Wang
NOAA

- 8:35 **Unscented Kalman Filter based Carrier Tracking to Mitigate Ionospheric Scintillation Threat in High-latitude for Maritime PNT:** R. Tiwari and J. Yin, Nottingham Scientific Ltd., UK; Stig Erik Christiansen, Kongsberg Seatex AS, Norway
- 8:57 **One Year GNSS Ionospheric Scintillations Recording in the Arctic Aboard of Icebreaker 'Polarstern':** Friederike Fohlmeister, Lothar Kurz, Simon Plass, Martin Kriegel, German Aerospace Center, (DLR), Germany
- 9:20 **Performance Benefit from Dual-Frequency GNSS-based Aviation Applications under Ionospheric Scintillation: A New Approach on Fading Process Modeling:** Kiyoung Sun, Hyecheon Chang, and Jiyun Lee, Korea Advanced Institute of Science and Technology, South Korea; Jiwon Seo, Yonsei University, South Korea; Y. Jade Morton, University of Colorado Boulder; Sam Pullen, Stanford University
- 9:43 **Errors Analysis and Improvement on Estimating Low Latitude Ionospheric Delay Gradient Based on GPS/BDS Observations:** Qiang Li, Yanbo Zhu, Beihang University & Aviation Data Communication Corporation, China; Zhipeng Wang, Wei Liu, Zhen Gao, Beihang University, China

10:05-10:35, Break. Refreshments in Foyer

- 10:40 **Ionosphere Scintillation-Induced Phase Transitions in Triple-Frequency GPS Measurements:** Brian Breitsch, Y. Jade Morton, University of Colorado, Boulder; Dongyang Xu, Hexagon, Canada
- 11:03 **Climatology of High and Low Latitude Scintillation in the Last Solar Cycle by Means of the Geodetic Detrending Technique:** A. Rovira-García, G.Gonzalez-Casado, J.M. Juan, J. Sanz, Universitat Politècnica de Catalunya (UPC), Spain; Raúl Orús-Pérez, European Space Agency (ESA)
- 11:26 **Statistical Detection Threshold for Traveling Ionospheric Disturbances Induced by Tsunami Using GNSS Measurements of LEO Satellite:** Bugeom Kim, O-Jong Kim, Changdon Kee, Seoul National University, South Korea
- 11:48 **Impact of Tropospheric Anomalies on GBAS Integrity:** Yuanyuan Zhuang, Zhipeng Wang, Kun Fang, Yanbo Zhu, Beihang University, China

Session P4a: Time and Frequency Transfer Using GNSS and RNSS

Room: Bayview Ballroom 3

8:30 a.m. – 10:05 a.m.



Dr. Joerg Hahn
ESA/ ESTEC, The Netherlands



Ed Powers
The Aerospace Corporation

- 8:35 **Recent Results of Galileo Timing Services for Professional and Metrological Users:** P. Waller, A. Samperi, R. Valceschini, ESA/ESTEC, The Netherlands
 - 8:57 **Using Broadcast Time Offsets for Multi-Constellation Users in Harsh Environments:** Floor Melman, Rafael Lucas Rodriguez, Paolo Crosta, Gaetano Galluzzo, Xurxo Otero Villamide, Joerg Hahn, European Space Agency, The Netherlands
 - 9:20 **An Update on the use of GNSS Signals at PTB:** Dirk Piester, Andreas Bauch, Thomas Polewka, Egle Staliuniene, Physikalisch-Technische Bundesanstalt (PTB), Germany
 - 9:43 **A New Approach to Improve Satellite Clock Estimates, Removing the Inter-day Jumps:** J.M Juan, J. Sanz, A. Rovira-García, G. González-Casado, Universitat Politècnica de Catalunya (UPC), Spain; J. Ventura-Traveset, L. Cacciapuoti, E. Schoenemann, European Space Agency (ESA), France
- 10:05-10:35, Break. Refreshments in Foyer

Session P4b: PTTI Applications and Techniques

Room: Bayview Ballroom 3

10:35 a.m. – 12:15 p.m.



Dr. Olukayode (Kami) Okusaga
JHU/APL



Dr. John Janis
L3Harris Technologies

- 10:40 **Galileo Timing and Synchronisation Application Offering Architecture:** Valeria Catalano, Reinhard Blasi, European GNSS Agency – GSA, Czech Republic; Carla Filotico, SpaceTec Partners; Franco Gottifredi, GEAspace
- 11:03 **Experimental Plans for the Navigation Timing Satellite (NTS-3) with Regards to the Time Keeping System:** Kyle W. Martin, Applied Technology Associates; John Janis, L3Harris; Joanna Hinks, John Elgin, Gordon Lott, Air Force Research Laboratory Space Vehicles Directorate; Benjamin K. Stuhl, Space Dynamics Laboratory
- 11:26 **A Master/Slave Ensembling Algorithm for CubeSat Missions:** James Camparo, Travis Driskell, The Aerospace Corporation
- 11:48 **Extensive Cosmic Showers Detection: Metrological Characterization and Optimization of the EEE Timing System:** G. Cerretto, D. Calónico, E. Cantoni, F. Levi, A. Mura, M. Sellone, Istituto Nazionale di Ricerca Metrologica (INRIM), Italy; and the EEE Collaboration, Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Italy

Session A5: GNSS and Security: Jamming and Spoofing
Room: Bayview Ballroom 1
2:00 p.m. – 5:10 p.m.



Dr. Chris Hegarty
The MITRE Corporation



Dr. Micaela Troglia Gamba
LINKS Foundation, Italy

- 2:05 **Independent Time Synchronisation for Resilient GNSS Receivers:** Ignacio Fernández-Hernández, European Commission, Belgium; Todd Walter, Andrew Neish, Stanford University
- 2:27 **A Real-time OSNMA-ready Software Receiver:** Beatrice Motella, Micaela Troglia Gamba, Mario Nicola, LINKS Foundation, Italy
- 2:49 **A Flexible Replay Delay Control Method for GNSS Direct Meaconing Signal:** Shunshun Shang, Hong Li, Yimin Wei, Mingquan Lu, Tsinghua University, China
- 3:11 **Improving Dual Polarization Antenna (DPA) Direction of Arrival Based GNSS Spoof Detection Using a Software Defined Radio:** Sherman Lo, Yu-Hsuan Chen, Godwin Zhang, Fabian Rothmaier, Stanford University; Wei Lee, Edwards Air Force Base
- 3:40 **Polyphase Decomposition based Space Frequency Adaptive Processing in Antenna Array GNSS Receivers:** Xiangming Chang, Xiaowei Cui, Mingquan Lu, Tsinghua University, China
- 4:02 **Positioning, Navigation, and Timing Trust Inference Engine:** Andres Molina-Markham Joseph J. Rushanan, The MITRE Corporation
- 4:24 **GNSS Anti-jam RF-to-RF On Board Unit for ERTMS Train Control:** Cosimo Stallo, Pietro Salvatori, Andrea Coluccia, Radiolabs, Italy; Alessandro Neri, Massimo Massaro, University of Roma TRE, Italy; Francesco Rispoli, Hitachi Rail STS, Italy; Massimiliano Ciaffi, RFI, Italy
- 4:46 **Receiver States for SBAS Data Authentication:** Andrew Neish, Todd Walter, Stanford University; Ignacio Fernandez-Hernandez, European Commission, Belgium

Session B5a: Timing for PNT Resilience
Room: Bayview Ballroom 2
2:00 p.m. – 3:10 p.m.



Dr. Todd Walter
Stanford University



Dr. James Camparo
The Aerospace Corporation

- 2:05 **A Next-generation, Miniaturized Rb Atomic Clock Reference for Mobile, GNSS-denied Environments:** William Krzewick, Jamie Mitchell, John Bollettiero, Peter Cash, Kevin Wellwood, Igor Kosvin, Microchip Technology Inc.
- 2:27 **Precise and Continuous Time and Frequency Transfer with Carrier Phase Compensation in Satellite Ground Link:** H. J. Liang, S.C. Sun, Y. Bai, S.G. Wang, L.J. Wang, Tsinghua University, China
- 2:49 **Moving Receiver PVT Solution Authentication Based on Monitoring the Combination of Clock Bias and Drift:** Zhiyuan Chen, Hong Li, Shunshun Shang, Yimin Wei, Mingquan Lu, Tsinghua University, China

Session B5b: Integrated Navigation Systems
Room: Bayview Ballroom 2
3:35 p.m. – 5:10 p.m.



Jamal Atman
Karlsruhe Institute of Technology, Germany



Dr. Jason Rife
Tufts University

- 3:40 **Integrity/Continuity Algorithm of a Tightly-coupled KF based GNSS/IMU Navigation System with Redundant IMUs:** Jinsil Lee, Dongwoo Kim, Dongchan Min, Kihun Nam, and Jiyun Lee, Korea Advanced Institute of Science and Technology, South Korea
- 4:02 **Mitigation of Odometry Drift with a Single Ranging Link in GNSS-limited Environments:** Young-Hee Lee, Technical University of Munich (TUM), Germany; Chen Zhu, Gabriele Giorgi, German Aerospace Center (DLR), Germany; Christoph Günther, TUM and DLR, Germany
- 4:24 **Wheel-based Aiding of Low-cost IMU for Land Vehicle Navigation in GNSS Challenging Environment:** M. Moussa, A. Moussa, University of Calgary, Canada; M. Elhabiby, Ain Shams University, Egypt; N. El-Sheimy, University of Calgary, Canada
- 4:46 **Resilient Sensor Management for Dismounted Assured-PNT:** Shahram Moafipoor, Lydia Bock, Jeffrey A. Fayman, Geodetics Inc.

Alternates

- 1. **A New Navigation System for Unmanned Aerial Vehicles in Global Positioning System-Denied Environments Based on Image Registration with Mutual Information and Deep Learning:** Cagla Sahin, TOBB University of Economics and Technology and Turkish Aerospace, Turkey; Imam Samil Yetik, TOBB University of Economics and Technology, Turkey

Session P5a: Timescales and Algorithms
Room: Bayview Ballroom 3
2:00 p.m. – 3:35 p.m.



Dr. Michael Coleman
Naval Research Laboratory



Dr. Johann Furthner
German Aerospace Center (DLR), Germany

- 2:05 **Proportional-Integral-Derivative (PID) Controllers and “Real-world” Clocks:** Demetrios Matsakis, Masterclock, Inc.
- 2:27 **Analysis of the Long-term Stability of a Homogenous Cesium Standard Ensemble for Future System Time Generation:** Ludwig Blümel, Tobias D. Schmidt, Christian Trainotti, German Aerospace Center (DLR), Germany; Johann Furthner, Galileo Competence Center, DLR, Germany
- 2:49 **Reliable and Robust Real-time Time Scale Generation: Developments and Experimental Results at INRiM:** V. Formichella, G. Signorile, T. T. Thai, A. Perucca, E. Cantoni, M. Sellone, A. Mura, Quantum Metrology and Nano Technologies Division, INRiM, Italy; M. Siccardi, SKK Electronics, Italy; G. D. Rovera, LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, France; I. Sesia, F. Levi, Quantum Metrology and Nano Technologies Division, INRiM, Italy
- 3:11 **Use of a Precise Ensemble Clock to Combine the Outputs of Frequency and Time Standards Getting an Even More Precise Output Signal:** Werner Lange, Lange-Electronic GmbH, Germany

Session P5b: Emergent Timing Infrastructure for GNSS Providers
(Joint PTTI/ITM Session)
Room: Bayview Ballroom 3
3:35 p.m. – 4:45 p.m.



Dr. James Camparo
The Aerospace Corporation



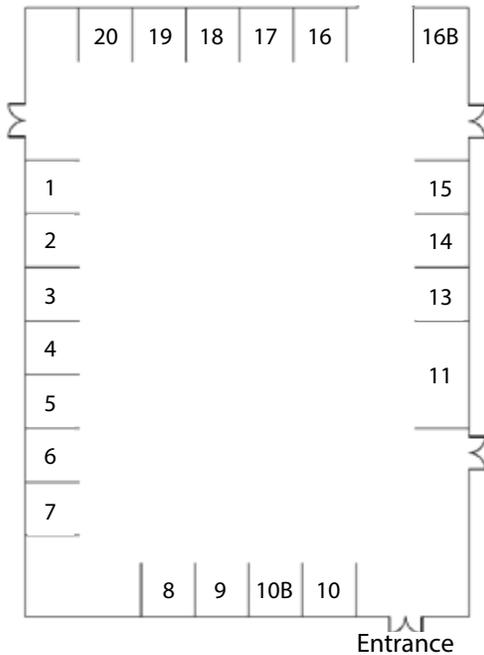
Dr. Tobias Schmidt
German Aerospace Center (DLR), Germany

- 3:40 **Detection and Identification of Phase and Frequency Drifts in Clock Ensembles:** Christian Trainotti and Gabriele Giorgi, German Aerospace Center (DLR), Germany
- 4:02 **Machine Learning-based Automatic Detection and Characterization of GNSS Satellite Clock Anomaly Using Dual Frequency Signals:** Yunxiang Liu and Y. Jade Morton, University of Colorado Boulder
- 4:24 **The GIANO Project: Development of a Galileo-Based Timing Receiver for Increasing Critical Infrastructures Resilience:** Livio Marradi, Gianluca Franzoni, Marco Puccitelli, Roberto Campana, Thales Alenia Space, Italy; Valeria Catalano, European GNSS Agency; Roberto Muscinelli, Business Integration Partners, Italy; Pawel Nogas, PikTime Systems, Poland; Jerzy Nawrocki, Edoardo Detoma, Space Research Center PAS, Poland; Ricardo Prata, Deimos, Portugal

Refreshments will be available in the Foyer at 3:30 p.m.

EXHIBIT HALL

Exhibit Hall Floor Plan:



Show Hours:

Wednesday, January 22

8:30 a.m. – 5:00 p.m. Exhibit Hall Open

8:30 a.m. – 9:30 a.m. Exhibitor Hosted Breakfast

Thursday, January 23

8:00 a.m. – 4:30 p.m. Exhibit Hall Open

Exhibitors:

- ALBEDO TELECOM, Inc. (Booth 13)
- Brandywine Communications (Booth 14)
- Cycle GmbH (Booth 10B)
- **CAST Navigation (Booth 3)**
- **Frequency Electronics, Inc. (Booth 8)**
- GuideTech (Booth 7)
- IFEN, Inc. (Booth 9)
- **Jackson Labs Technologies, Inc. (Booth 10)**
- **Labsat By Racelogic (Booth 18)**
- **Masterclock Inc. (Booth 5)**
- **Microchip Technology Inc. (Booth 6)**
- NEL Frequency Controls, Inc (Booth 16)
- Orolia Switzerland inc. (Booth 2)
- Oscilloquartz SA (Booth 15)
- Pendulum Instruments Inc. (Booth 19)
- Spectradynamics Inc. (Booth 17)
- **Spirent Federal Systems (Booth 11)**
- Syntony GNSS (Booth 20)
- The Institute of Navigation (Booth 16B)
- TimeTech GmbH (Booth 4)
- Vescent Photonics (Booth 1)

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