### Plenary Session

**Terrain Relative Navigation for Deep Ocean Exploration:** S. Rock, *Stanford University* ........................................ 1

**A Low-Cost Approach to a High Performance Satellite Constellation:** R. Votel, *Skybox Imaging* .............................. 49

### Session A1: Augmentation Systems

**Near Term Improvements to WAAS Availability:** J. Blanch, T. Walter, R.E. Phelts, P. Enge, *Stanford University* .......... 71

**Presentation**

**L1/L5 SBAS MOPS Ephemeris Message to Support Multiple Orbit Classes:**
T. Reid, T. Walter, P. Enge, *Stanford University* ................................................................. 78

**Presentation**

**Signal Deformation Monitoring for Dual-Frequency WAAS:**
R.E. Phelts, G. Wong, T. Walter, P. Enge, *Stanford University* .................................................. 93

**Doppler Shift Characterization of Chinese Area Positioning System:** M. Wang & L. Ma,
*National Astronomical Observatories, Chinese Academy of Sciences, China* ........................................ 107

**Presentation**


**Multi-dimensional Ionospheric Gradient Detection for GBAS:** J. Jing, S. Khanafseh, S. Langel, F-C. Chan, B. Pervan,
*Illinois Institute of Technology* ..................................................................................................... 121

**Comparison Study of Wide Area Ionospheric Delay Models for GNSS User in the Asia Pacific Region:**
A-L. Tao, S-S. Jan, *National Cheng Kung University, Taiwan* .................................................. 129

### Session B1: Receiver & Antenna Technologies

**Performance Analysis of A USRP Based GNSS and GLONASS Signal Recording and Playback System:**

**Design Considerations for a WARP-Based Real-Time Software-Defined GPS Receiver:** J.L. Hershberger,
E.A. Thompson, *Indiana University/Purdue University Fort Wayne*; T.S. Loss, *Raytheon, Fort Wayne (retired)* .... 146

**Presentation**


**Antenna Induced Biases in GNSS Receiver Measurements:** Y.C. Chuang, I.J. Gupta, *The Ohio State University* ...... 164
Session C1: Quasi-Zenith Satellite System (QZSS)


First Evaluation of the Performance of RTK-QZSS Positioning: H. Yamada, T. Sakai, K. Ito, Electronic Navigation Research Institute, Japan

QZSS L1-SAIF Supporting GPS/GLONASS Multi-Constellation Augmentation: T. Sakai, H. Yamada, K. Hoshinoo, K. Ito, Electronic Navigation Research Institute, Japan

A2: Advanced Receiver Autonomous Integrity Monitoring (ARAIM)

Detecting Earth Orientation Parameter (EOP) Faults for High Integrity GNSS Aviation Applications: S. Langel, F-C. Chan, J. Meno, M. Joerger, B. Pervan, Illinois Institute of Technology

A New Sequential RAIM Algorithm for Multiple Failures Detection: H. Yun, C. Kee, Seoul National University, South Korea

Incorporating GLONASS into Aviation RAIM Receivers: T. Walter, J. Blanch, M.J. Choi, T. Reid, P. Enge, Stanford University

GNSS Inter-Constellation Phasing: Validation of the Worst Case Assumption: M. Rippl, German Aerospace Center (DLR), Germany

Results on the Optimal Detection Statistic for Integrity Monitoring: J. Blanch, T. Walter, P. Enge, Stanford University

Demonstration of Viability of ARAIM for LPV and LPV-200 Service Using Flight Data: K. Pham, T. McHugh, F. Lorge, DOT/FAA Technical Center Navigation Team

Velocity RAIM: B. Romney, Lockheed Martin Information Systems & Global Solutions

B2: GNSS Processing & Integration I

Sequential Best Integer Equivariant Estimation for Geodetic Network Solutions: A. Brack, P. Henkel, Technical University Munich, Germany; C. Günther, Technical University Munich, Germany and German Aerospace Center (DLR), Germany
An Efficient Precise Point Positioning Model for Near Real-Time Applications: M. Elsobeiey, A. El-Rabbany, Ryerson University, Canada  

Aiding GNSS Signal Tracking Loops using Vehicle Dead Reckoning Sensors:  
H-G. Buesing, U. Haak, P. Hecker, Institute of Flight Guidance, Technical University Braunschweig, Germany  

Vector Tracking Aiding for Carrier Phase Estimation in the Presence of Ionospheric Scintillation:  
L. Deambrogio, C. Macabiau, ENAC, France  

Reducing GPS Wide Lane Ambiguity Resolution Time: A Novel Carrier Phase Multipath Mitigation Technique:  
R. Moradi, W. Schuster, S. Feng, W. Ochieng, Imperial College London, UK  

Presentation  
An Open-Source Real-time Software Vector Tracking GNSS Receiver - Design, Tests and Results: X. Zhang, X. Zhan, Shanghai Jiao Tong University, China; J. Shen, BNStar Navigation Technology & System Co., Ltd., China  

C2: Marine Applications  

Performance of Multi-Beacon DGPS: S. Barr, P.F. Swaszek, University of Rhode Island; R.J. Hartnett, U.S. Coast Guard Academy; G.W. Johnson, Alion Science & Technology  

Presentation  

The Impact of using Non-approved PNT Devices at Sea: J. Safar, A. Grant, M. Bransby, N. Ward, The General Lighthouse Authorities of the United Kingdom and Ireland  

Precise Underwater Autonomous Vehicle Localization and Tracking in Unknown Areas with Sound Speed Variation: X. Liang, N. Liu, F. Yang, L. Ding, L. Qian, Shanghai Jiao Tong University, China  

UK eLoran - Initial Operational Capability at the Port of Dover: P. Williams, C. Hargreaves, The General Lighthouse Authorities of the United Kingdom and Ireland  

River Information and Navigation Service with BeiDou in China: S. Qian, China Waterborne Transport Research Institute, China; Y. Yuan, China Air Force Engineering University, China  

A3: Aviation Applications  

GBAS Approach Guidance Performance - A Comparison to ILS: M. Felux, T. Dautermann, H. Becker, German Aerospace Center DLR, Germany  

Aerodynamic Flight Simulation in Inertial Quality: L. Goercke, F. Holzapfel, J. Dambeck, Technical University Munich, Germany  

Potentials of Inertial Navigation Aided by Position Broadcasts and Relative Measurements:  
H. Mokhtarzadeh, D. Gebre-Egziabher, University of Minnesota, Twin Cities  

A Study of ADS-B Data Evaluation and Related Problems: B.S. Ali, W. Schuster, W. Ochieng, A. Majumdar, Imperial College London, UK; C.T. Kian, University of Malaya, Malaysia  

Presentation  

A Study of ADS-B Data Evaluation and Related Problems: B.S. Ali, W. Schuster, W. Ochieng, A. Majumdar, Imperial College London, UK; C.T. Kian, University of Malaya, Malaysia  

Presentation  

Proof of Concept: Real-Time Demonstration of a Measurement-Based ADS-B System: P. Duan, Ohio University; N. Peinecke, German Aerospace Center (DLR), Germany; M. Uijt de Haag, Ohio University  

Presentation  

Radar Weather Extracting System in Taipei Flight Information Region:  
S-J. Yeh, C-W. Lin, S-L. Jehg, S-S. Jan, National Cheng Kung University, Taiwan
State of the Art of Image-aided Navigation Techniques for Aircraft Approach and Landing:
J. Vezinet, A.C. Escher, ENAC, France; A. Guillet, AIRBUS, France; C. Macabiau, ENAC, France

B3: GNSS Processing & Integration II

DGPS Enhancement to GPS NMEA Output Data: DGPS by Correction Projection to Position-Domain:
B. Park, Sejong University, Republic of Korea; Y. Kim, H. Yun, C. Kee, Seoul National University, South Korea

Collaborative GNSS Receiver Architecture for Weak Signal Processing: A. Soloviev, Qunav; J. Dickman, Northrop Grumman, Navigation Systems Division; J. Campbell, Air Force Research Laboratory

Quantization-loss Reduction for 1-bit BOC Positioning: F. Wendler, M. Stein, A. Mezghani, J.A. Nossek, Technical University Munich, Germany

Two Dimensional Compressed Correlator for Fast Acquisition in GNSS:
B. Kim, S-H. Kong, KAIST, Republic of Korea

Analysis of L1C Acquisition by Combining Pilot and Data Components over Multiple Code Periods:
K.C. Seals, U.S. Coast Guard Academy; W.R. Michelson, Worcester Polytechnic Institute; P.F. Swaszek, University of Rhode Island; R.J. Hartnett, U.S. Coast Guard Academy

A New Adaptive Code Processing Scheme for High-Sensitivity Acquisition in Dual-Frequency GPS L1-L2C Receivers:
S.U. Qaisar, M. Khalaf-Allah, Umm Al Qura University, Saudi Arabia

C3: Space/Atmospheric Weather & Scientific Applications

International Space Weather Initiative: S. Gadimova, H. Haubold, United Nations Office at Vienna, Austria

The Effect of Tropospheric Delay Modeling on the Determination of GPS-Derived Ellipsoidal Height in Permanent GNSS Networks using OPUS-Projects: M.A. Ugur, T. Richardson, D.A. Grejner-Brzezinska, C. Toth, The Ohio State University; G.L. Mader, National Geodetic Survey

Optimized GNSS Network Station Selection to Support the Development of Ionospheric Threat Models for GBAS:
M. Kim, J. Lee, Korea Advanced Institute of Science and Technology, Republic of Korea; J. Lee, Korea Advanced Institute of Science and Technology, Republic of Korea; Tetra Tech AMT; S. Pullen, Stanford University; J. Gillespie, Federal Aviation Administration

Nighttime Medium-Scale Traveling Ionospheric Disturbance (MSTID) in GPS TEC Measurements:
G. Crowley, I. Azeem, A. Reynolds, J. Santana, ASTRA LLC; Q. Wu, High Altitude Observatory, National Center for Atmospheric Research

High Latitude Ionosphere Scintillation Characterization: Y. Jiao, Y. Morton, S. Taylor, Miami University; W. Pelgrum, Ohio University


On-board FFT Data Processing for GNSS Reflectometry: P.J. Buist, G.J. Vollmuller, National Laboratory NLR, The Netherlands

Individual Global Navigation Satellite Systems in the Space Service Volume:
D.A. Force, NASA Glenn Research Center
A4: Emerging GNSS & Modernization

**GNSS Survey - Signal Quality Assessment of the Latest GNSS Satellites:** S. Thoelert, J. Furthner, M. Meurer, German Aerospace Center (DLR), Germany 608

**Code Biases in Multi-GNSS Point Positioning:** O. Montenbruck, A. Hauschild, DLR/GSOC, Germany 616

**Constant Envelope Combination for Components on Different Carrier Frequencies with Unequal Power Allocation:** Z. Yao, M. Lu, Tsinghua University, China 629

**GNSS Data Message Performance: A New Methodology for its Understanding and Ideas for its Improvement:** M. Anghileri, M. Paonni, D. Fontanella, B. Eissfeller, University F AF Munich, Germany 638

**Evolution of Interplex Scheme with Variable Signal Constellation:** M. Vergara, F. Antreich, German Aerospace Center (DLR), Germany 651

B4: Alternative Sensors & Emerging Navigation Technologies

**Unified Model Technique for Inertial Navigation Aided by Vehicle Dynamics Model:** P. Crocoll, Karlsruhe Institute of Technology, Germany; L. Goercke, Technical University Munich, Germany; G.F. Trommer, Karlsruhe Institute of Technology, Germany; F. Holzapfel, Technical University Munich, Germany 657

**Sensor Performance Characteristic Pre-filter using Multiple Model Estimation for Navigation:** Y. Ma, Honeywell Aerospace; S. Rao, Honeywell Technology Solutions Lab, India 670

**Monte Carlo Error Characterization of EKF-Based Image Aided Navigation:** D.A. Marietta, K.A. Fisher, Air Force Institute of Technology; C.N. Taylor, Air Force Research Laboratory 675

**Boresighting a LiDAR without Accurate Range Measurements for Relative Navigation:** J. Curro, T. Pestak, J. Raquet, Air Force Institute of Technology 687

**Robust DME Carrier Phase Tracking under Flight Dynamics:** K. Li, W. Pelgrum, Ohio University 696

**Architecture for Asymmetric Collaborative Navigation – Considerations for Real Time Implementation of the Collaborative Robust Integrated Sensor Positioning (CRISP) System:** Z. Zhu, E. Boroson, S. Berardi, H. Park, Northrop Grumman Corporation; D. Venable, Air Force Research Laboratory 709

C4: Urban, Indoor & Terrestrial Applications I

**Bandwidth Efficient ATSC TDOA Positioning in GPS-Denied Environments:** K.L. Carter, Naval Postgraduate School; R. Ramlall, SPAWAR Systems Center Pacific; M. Tummala, J. McEachen, Naval Postgraduate School 717

**Indoor Geolocation with Cellular RF Pattern Matching and LEO Communication Satellite Signals:** D. Qiu, D.S. De Lorenzo, T. Bhattacharya, Polaris Wireless, Inc. 726

**WPI Precision Personnel Locator: Inverse Synthetic Array Reconciliation Tomography Performance:** A. Cavanaugh, M. Lowe, D. Cyganski, R. J. Duckworth, Worcester Polytechnic Institute 734


**An Enterprise Service Oriented Architecture-Based High Resolution WiFi Indoor Positioning System:** M.M. Atia, Trusted Positioning Inc. and Queen's University, Canada; J. Georgy, Trusted Positioning Inc., Canada; A. Noureldin, Royal Military College of Canada and Queen's University, Canada 752
A5: Autonomous & Remote Navigation


Vision Aided INS/GNSS Integration for Improving the Robustness of a Navigation System for Mini Unmanned Aerial Vehicles: C. Cheng, ISAE-Supaero, University of Toulouse, France/Northwestern Polytechnical (NPU) University, China; V. Calmettes, B. Priot, ISAE-Supaero, University of Toulouse, France; Q. Pan, NPU, China; J.-Y. Tourneret, ENSEEIHT-IRIT, University of Toulouse, France

Presentation


Multi-GNSS Precise Orbit Determination of the International Space Station: O. Montenbruck, M. Wermuth, A. Hauschild, DLR/GSO, Germany; G. Beyerle, GFZ, Germany; A. Helm, EADS/Astrium; S. Yudanov, JAVAD GNSS; A. Garcia, L. Cacciapuoti, ESA/ESTEC

Observability Analysis for Transfer Alignment Technique Considering the Lever Arm Effect with Time Delay: C-K. Yang, D-S. Shim, Chung-Ang University, Republic of Korea

B5: Interference & Spectrum Management

GNSS Jamming Interference: Characterization and Cancellation: G. Gabelli, R. Casile, A. Guidotti, G.E. Corazza, University of Bologna, Italy


GNSS Interference Detection Using a Compressed Sensing Analog to Information Converter Approach: A. Rügamer, I. Lukčin, G. Rohmer, Fraunhofer Institute for Integrated Circuits IIS, Germany; J. Thielecke, Friedrich-Alexander University of Erlangen-Nuremberg, Germany

In-Band Cancellation of Jamming for Robust GPS Navigation: R. Vosburgh, Physical Devices LLC; C. Wilson, North Carolina State University; V. Haridasan, Physical Devices LLC

Performance Analysis of Joint Multi-Antenna Spoofing Detection and Attitude Estimation: A. Konovaltsev, M. Cuntz, C. Haettich, M. Meurer, German Aerospace Center (DLR), Germany


Analysis of a Simple, Multi-Receiver GPS Spoof Detector: P.F. Swaszek, University Rhode Island; R.J. Hartnett, M.V. Kempe, U.S. Coast Guard Academy; G.W. Johnson, Alion Science & Technology

Studying the Effect of Interference on GNSS Signals: P. Craven, R. Wong, Spirent Positioning Technology, UK; N. Fédora, P. Crampton, Spirent Federal Systems
C5: Urban, Indoor & Terrestrial Applications II


Development of GNSS-based Transportation Infrastructure for Intelligent Transportation System: J-I. Park, E. Lee, M-B. Heo, Korea Aerospace research Institute, Republic of Korea

Presentation