ION INSTITUTE OF NAVIGATION

JOINT NAVIGATION CONFERENCE 2021

Enhancing Dominance and Resilience for Warfighting and Homeland Security PNT

August 24-27, 2021
Northern Kentucky Convention Center
Covington, Kentucky

ONSITE PROGRAM

ion.org/jnc

JNC access is restricted. Conference badges are controlled and will not be replaced. Photo ID may be requested at any time.
Technical Program Overview

**TUESDAY, AUGUST 24: MORNING TUTORIALS AND AFTERNOON FEDCON - U.S. ONLY SESSIONS**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Resilient &amp; Robust PNT</td>
</tr>
<tr>
<td>10:30 a.m. - 12:00 p.m.</td>
<td>An Introduction to Cryptography with Attention to Navigation - Ballroom C</td>
</tr>
<tr>
<td>1:45 p.m. - 3:15 p.m.</td>
<td>A1: Space and Satellite Applications, NTS-3 Overview - Ballroom E</td>
</tr>
<tr>
<td>4:00 p.m. - 5:30 p.m.</td>
<td>A2: Space and Satellite Applications</td>
</tr>
<tr>
<td>10:45 a.m. - 12:15 p.m.</td>
<td>Track A: John Del Colliano - CCDC/C5ISR</td>
</tr>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Track B: Dr. Keith McDonald - The MITRE Corporation</td>
</tr>
<tr>
<td>10:45 a.m. - 12:15 p.m.</td>
<td>Track C: Dr. Greg Reynolds - US Army</td>
</tr>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Track D: David Wolfe - US Coast Guard C3/5ISR</td>
</tr>
</tbody>
</table>

**WEDNESDAY, AUGUST 25: FEDCON - U.S. ONLY SESSIONS**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>A2: Space and Satellite Applications</td>
</tr>
<tr>
<td>10:45 a.m. - 12:15 p.m.</td>
<td>Track A: John Del Colliano - CCDC/C5ISR</td>
</tr>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Track B: Dr. Keith McDonald - The MITRE Corporation</td>
</tr>
<tr>
<td>10:45 a.m. - 12:15 p.m.</td>
<td>Track C: Dr. Greg Reynolds - US Army</td>
</tr>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Track D: David Wolfe - US Coast Guard C3/5ISR</td>
</tr>
</tbody>
</table>

**THURSDAY, AUGUST 26: FEDCON - U.S. ONLY SESSIONS**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>A6: Reconfigurable SatNav</td>
</tr>
<tr>
<td>10:45 a.m. - 12:15 p.m.</td>
<td>Track A: John Del Colliano - CCDC/C5ISR</td>
</tr>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Track B: Dr. Keith McDonald - The MITRE Corporation</td>
</tr>
<tr>
<td>10:45 a.m. - 12:15 p.m.</td>
<td>Track C: Dr. Greg Reynolds - US Army</td>
</tr>
<tr>
<td>8:30 a.m. - 10:00 a.m.</td>
<td>Track D: David Wolfe - US Coast Guard C3/5ISR</td>
</tr>
</tbody>
</table>

**FRIDAY, AUGUST 27: JNWC FACILITATED SESSIONS HELD AT NKYCC, BALLROOM B, CONFERENCE LEVEL (U.S. ONLY SESSIONS)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m. - 8:45 a.m.</td>
<td>Welcome - Ballroom B</td>
</tr>
<tr>
<td>8:45 a.m. - 10:10 a.m.</td>
<td>E9: JNWC Facilitated Program: Keynote Address Featuring Major General DeAnna M. Burt - Ballroom B</td>
</tr>
<tr>
<td>10:50 a.m. - 12:20 p.m.</td>
<td>E10: PANEL: Combatant Command Joint Urgent Operational Need (JUON): Warfighter Requirement and Solutions - Ballroom B</td>
</tr>
<tr>
<td>1:50 p.m. - 3:20 p.m.</td>
<td>E11: PANEL: Warfighters</td>
</tr>
<tr>
<td>3:20 p.m. - 4:10 p.m.</td>
<td>E12: JNWC Facilitated Program</td>
</tr>
<tr>
<td>4:10 p.m. - 5:10 p.m.</td>
<td>E12: JNWC Facilitated Program (Continued)</td>
</tr>
</tbody>
</table>
JNC Government Liaisons

ION Military Division Chair
John Langer
The Aerospace Corporation

ION Military Division Chair
Jan Ancapoger
Draper

Program Chair
Joseph Schnecker
NIWC Pacific

Program Vice-chair and Track: A
John Del Colliano
CCDC/C5ISR

Track: B
Dr. Jacob Campbell
AFRL Sensors Directorate

Track: C
Dr. Greg Reynolds
US Army

Track: D
David Wolfe
US Coast Guard CSJSC

Tutorials Chair
Paul Olson
CCDC/C5ISR

Plenary Chair
Dr. Thomas Powell
The Aerospace Corporation

Eddy Emile
SMC/Production Corps U/E

Elliott Kaplan
The MITRE Corporation

Dr. J.P. Laine
Draper

Dr. Steven Lewis
The Aerospace Corporation

Dr. Keith McDonald
The MITRE Corporation

Dr. Madeleine Naudeau
AFRL

Chad Pinkelman
NIWC Pacific

Fay Spellerberg
Joint Navigation Warfare Center

Ben Wash
Joint Navigation Warfare Center

ION Military Division Chair
John Langer
The Aerospace Corporation

Tutorials Chair
Paul Olson
CCDC/C5ISR

Plenary Chair
Dr. Thomas Powell
The Aerospace Corporation

EXHIBIT HALL
(Event Center II)

LUNCHES AND BBQ DINNER
(Event Center I)

Conference Level (Third Floor)
Conference Information

Conference Dress
Battledress uniform or business casual.

JNC Mobile Website: m.ion.org
During the meeting, point your mobile device's web browser to m.ion.org to access JNC information such as:
• Real-time conference program
• Current exhibit hall map
• Local area info/weather
• Restaurant reservations

Conferece Proceedings
Electronic FEDCON conference proceedings are scheduled for distribution in September to all eligible conference participants. You will receive an emailed link from registration@ion.org to the verified email address you used when registering. This link is unique to your account and cannot be shared. You will have 30 days to download the proceedings, after which your link will expire. ION is unable to distribute conference proceedings after the 30 day period has expired.

Photography Policy
Your presence at JNC 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. Photography, audio recording, or video recording of any FEDCON presentation is strictly prohibited.

Clearance Information

FEDCON U.S. ONLY SESSIONS
(Tuesday, August 24 - Friday, August 27)
All sessions will be held in a Federal Employee and Contractors Only (FEDCON) environment at the Northern Kentucky Convention Center. To attend you must provide the following:
1. Proof of U.S. citizenship
2. Visit Request/including a Need-to-Know Statement
   (Need-to-Know not required if using DISS)
3. Photo ID
4. JNC Conference Badge and Paid Registration

Visit Request and Need-to-Know Statements:
All Visit Requests must be received by July 23, 2021 and be verified by the JNWC Security Office. Visit authorization requests received after July 23, 2021 may not be processed.

Prospective U.S. attendees must submit their Visit Authorization Requests through DISS to DISS SMO: JNC. DISS visit request POC field must be filled with “JNC 2021” instead of a POC name. For your convenience, if DISS is not an option, a Visit Request Form can be found at ion.org/jnc.
Fax all FEDCON Visit Requests to:
Deborah Renteria, Security Specialist
Joint Navigation Warfare Center
Phone: 505-853-6360
Fax: 505-853-6677
Email: Deborah.Renteria.ctr@us.af.mil
JNC Exhibitors and Exhibit Hall Information

JNC 2021 Floor Plan

List of Exhibitors

ACUTRONIC USA, Inc. (Booth 111)
AEVEX Aerospace - Geodetics Products (Booth 316)
Air Force Research Laboratory (Booth 210)
Analog Devices (Booth 114)
Antcom (Booth 229)
Autonomy & Navigation Technology Center/AFIT (Booth 218)
BAE Systems (Booth 112)
Brandywine Communications (Booth 127)
CAST Navigation (Booth 300)
Chelton Limited (Booth 132)
Collins Aerospace (Booth 324)
EMCORE Corporation (Booth 211)
ENSCO, Inc. (Booth 102)
Fibermetrics (Booth 217)
Frequency Electronics, Inc. (Booth 213)
General Dynamics Mission Systems (Booth 110)
GPS Networking (Booth 124)
Honeywell International (Virtual Exhibitor)
Ideal Aerosmith (Booth 228)
Inertial Labs Inc. (Booth 230)
Inside GNSS (Booth 100)
Integrated Solutions for Systems (Booth 131)
ixblue Defense Systems, Inc. (Booth 125)
KBR (Booth 232)
Kearfott Corporation (Booth 219)
KVH Industries, Inc. (Booth 224)
L3Harris (Booth 310)
LinQuest Corporation (Booth 227)
Lockheed Martin Space Systems Co. (Booth 201)
Mayflower Communications Company, Inc. (Booth 330)
Microchip Technology (Booth 101)
NAL Research (Booth 115)
Northrop Grumman (Booth 314)
NovAtel, Inc. (Booth 231)
Orolia Defense & Security (Booth 117)
Raytheon Intelligence and Space (Booth 326)
Sechan Electronics, Inc./ NAVSYS Corporation (Booth 103)
Silicon Designs, Inc. (Booth 116)
Spirent Federal Systems (Booth 200)
The Institute of Navigation (Booth 104)
US Army DEVCOM CSISR Center (Booth 129)
VectorNav Technologies (Booth 318)
Vermeer (Booth 304)

Bold = Corporate Member  ★ = Event Partner

Exhibit Hall Access

Wednesday, August 25
10:00 a.m. - 7:00 p.m.
Exhibits Open

Thursday, August 26
10:00 a.m. - 4:00 p.m.
Exhibits Open

JNC Conference Events

Tuesday, August 24
Informal Lunch:
12:00 p.m. - 1:30 p.m., Event Center I
This event is included in the price of a full or Tuesday single-day registration.

Wednesday, August 25
Informal Lunch:
12:15 p.m. - 1:30 p.m., Event Center I
This event is included in the price of a full or Wednesday single-day registration.

JNC Barbecue Dinner:
7:00 p.m. - 8:00 p.m., Event Center I
Informal barbecue dinner and cash bar.
This event is included in the price of a full or Wednesday single-day registration.

Thursday, August 26
Informal Lunch:
12:15 p.m. - 1:30 p.m.
This event is included in the price of a full registration, or a Friday single-day registration.

Friday, August 27
Informal Lunch:
12:20 p.m. - 1:30 p.m.
This event is included in the price of a full registration, or a Friday single-day registration.

Exhibit Hall is Publicly Releasable; please restrict all conversations to those permissible in the public domain.

Visit the JNC exhibitors online profiles at ion.org/jnc/exhibits.cfm
Tutorials will be held Tuesday, August 24, in a FEDCON U.S. ONLY environment. Tutorials are included in a Full Conference or Tuesday registration.

**Resilient & Robust Positioning, Navigation, and Timing (PNT) - Ballroom B**

Diverse elements of international infrastructure are critically reliant on GNSS for precise location and time, often in ways that are not obvious. This tutorial will provide a high-level perspective on the effects of interference on GNSS receivers and offer possible threat mitigation approaches. The tutorial will start with a discussion of potential GNSS threats and vulnerabilities. Then, after a quick review of how GNSS receivers process incoming signals to determine position, the focus will be on the effects of various interference types. The unique vulnerability of GNSS receivers on cold start will be discussed. Mitigations such as extended coherent integration, adaptive antenna arrays, and IMU aiding will be discussed. Civil jamming examples and incidents will be covered, along with methods to detect, identify and mitigate against their effects. In particular, the importance of maintaining situational awareness for establishing environmental context will be examined. Techniques for detecting spoofing and authenticating signals will be discussed. Use of LEO satellites as a backup for traditional GNSS will be highlighted as a mitigation of and deterrent to intentional interference. This course will present a discussion on celestial navigation techniques and system implementations, in the modern context. The course will consider air, sea and land operations, and explore celestial navigation technology solutions that are available today or in the near future. This course will appeal to R&D and systems engineers, managers and executives, and is accessible to both experienced and novice practitioners.

**GPS/GNSS 101 - Ballroom C**

This course presents the fundamentals of the GPS, and other GNSS, and is intended for people with a technical background who do not have significant GPS experience. Topics covered include time-of-arrival positioning, overall system design of GPS, signal structure, error characterization, Dilution of Precision (DOP), differential GPS, GPS modernization, and other GNSS systems.

**Introduction to SatNav SDRs using Python: Part 1 - Ballroom D**

This two-part course aims to provide attendees with a solid understanding of the fundamentals of satellite timing and navigation (satnav) software receivers and associated signal processing. The course is divided into multiple modules, each comprised of a short lecture followed by a python code demonstration that reinforces the topics covered. By the end of this course, attendees will have an understanding of how the provided satnav software receiver works which includes capabilities such as processing of multiband live-sky sampled data files, acquisition and tracking of visible open GNSS signals, and outputting signal observables. This open-source receiver may be further developed to yield a functional satnav SDR that is ideal for research.

**CTS-153 Software - Ballroom E**

With procurement of ground-based, handheld and embedded card variants of military GPS receivers, a need to have a reliable tool to facilitate testing and evaluation of these receivers was addressed with the Compliance Fester Software for the IS-GPS-153 Interface (CTS-153) test tool. CTS-153 was originally developed at the request of the GPS Joint Program Office (now part of SMC’s Production Corp), to provide a means for test organizations and program offices (representing platforms integrating GPS) to evaluate the interface characteristics, and/or facilitate integration of military GPS receivers compliant with the various revisions of the IS-GPS-153 Interface. The range of GPS receivers conforming to the IS-GPS-153 includes the Precise Positioning Service Security Module (PPS-SM) based PLGR, Selective Availability/Anti-Spoofing Module (SAASM) based DAGR and GB-GRAM, and the M-Code based GB-GRAM-M. The purpose of the CTS-153 tutorial is to provide prospective users and interested parties with an understanding of basic operation of the test tool and useful features available to aid in successful integration of an IS-GPS-153 compliant GPS receiver. With the increasing availability of Military GPS User Equipment (MGUE) and IS M-Code cards, this tutorial provides M-Code integrators timely exposure to the free CTS-153 test tool.

This presentation will consist of a real-time demonstration of useful CTS-153 features, including GPS receiver emulator function, RSAM error test function, as well as the data transfer and Hot Start process. Additionally, the presentation will provide an overview of basic IS-GPS-153 concepts and structure, with an emphasis on best ways to optimize integration of M-Code ground-based receivers. A focus will be placed on newly introduced MSID defined messages, which take advantage of the enhanced capabilities/functions of M-Code signals.

**About the Instructors**

Dr. Todd E. Humphreys is an associate professor in the department of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin, and Director of the UT Radiionavigation Laboratory. He received a B.S. and M.S. in Electrical and Computer Engineering from Utah State University and a Ph.D. in Aerospace Engineering from Cornell University. He specializes in applying optimal estimation and signal processing techniques to problems in radio-navigation. His recent focus is on radio-navigation robustness and security. His awards include the NSF CAREER award, the ION Thurlow award, and the Presidential Early Career Award. He is an ION Fellow.

Dr. John Raquet is currently the Director of IS4S-Dayton. Previously, he was the Founding Director of the Autonomy and Navigation Technology (ANT) Center at the Air Force Institute of Technology (AFIT). Dr. Raquet has a PhD in Geomatics Engineering from the University of Calgary, an MS in Aero/Astro Engineering from the Massachusetts Institute of Technology, and a BS in Astronautical Engineering from the US Air Force Academy. He has published over 170 navigation-related conference and journal papers and taught 60 navigation-related short courses to over 3600 students in many different organizations. He is the immediate past president of the Institute of Navigation and is an ION Fellow.

Dr. Sanjeev Gunawardena is a research assistant professor with the Air Force Institute of Technology (AFIT). He leads robust GNSS technology development - one of three R&D thrusts of the Autonomy and Navigation Technology Center at AFIT. Sanjeev has been an active member of ION since 2000. He served as a GNSS+ track chair and co-chaired numerous technical sessions at GNSS+, ITM, and PLANs conferences. He was Eastern Council Member-at-Large during 2014-2015 and Satellite Division Treasurer during 2016-2018. Dr. Gunawardena was also the instigator and co-chair of the ION GNSS SDR Metadata Standard Working Group (ratified in 2020). He earned his PhD in Electrical Engineering from Ohio University.

Mark Carroll is an Electronics Engineer at the Air Force Research Laboratory Sensors Directorate. He received his BS in Computer Engineering and MS in Computational Science and Engineering from Miami University. His research interests include GNSS, Software Defined Radios (SDRs), and machine learning.

Terrance Nelson works for Booz Allen Hamilton where he has supported the Army Product Manager (PM) Positioning, Navigation, and Timing (PNT) and SMC Production Corps organizations for over 15 years in the area of Interface Control document (ICD) and Interface Specification (IS) development, GPS receiver specification development, platform integration support, and risk mitigation assessment. He functions as the primary CTS-153 SME and ICD-GPS-153 serial interface compliance test engineer and has functional experience in the areas of hardware and software design and analysis, including techniques for solving problems involving complex electronic systems. He holds a BS in Electrical Engineering from California State and is a licensed Professional Engineer.
Pre-Conference Tutorials
10:30 a.m. - 12:00 p.m.

Tutorials will be held Tuesday, August 24, in a FEDCON U.S. ONLY environment. Tutorials are included in a Full Conference or Tuesday registration.

**Integrity/Assurance of Navigation Systems - Ballroom E**

In critical navigation systems that involve large risks to financial or human life, the design process of such systems needs to be at high levels of reliability in order to limits such risks. This course introduces the concept of integrity and assurance of navigation systems. The course will start by defining assurance and integrity and how system requirements are derived. The concept of integrity risk tree will then be introduced by using the derived requirements, identifying the system components, fault nodes and fault modes, and allocating the risks among these system components and faults. The tutorial will also present different methods and techniques to address the requirements and allocations, and how to evaluate the system performance during the design process. In addition, validation and verification techniques will be discussed. The course will use different examples from aviation and ground applications for illustration purposes at each step of the navigation system design process.

**An Introduction to Cryptography with Attention to Navigation - Ballroom C**

This tutorial offers a brief, broad and benign overview of cryptography. The first half of the course will explain the three main cryptographic methods: symmetric ciphers, hashes and public key cryptography. We will illustrate these methods using a variety of non-navigation examples. We will then segue to the second part of the course, which shows where cryptography is used for navigation.

**Introduction to SatNav SDRs using Python: Part 2 - Ballroom D**

This two-part course aims to provide attendees with a solid understanding of the fundamentals of satellite timing and navigation (satnav) software receivers and associated signal processing. The course is divided into multiple modules, each comprised of a short lecture followed by a python code demonstration that reinforces the topics covered. By the end of this course, attendees will have an understanding of how the provided satnav software receiver works which includes capabilities such as processing of multiband live-sky sampled data files, acquisition and tracking of visible open GNSS signals, and outputting signal observables. This open-source receiver may be further developed to yield a functional satnav SDR that is ideal for research.

Part 2: Acquisition engines; signal tracking techniques and control state machines; inter-frequency aiding; measurement computation; introduction and demonstration of provided python SDR architecture and code.

---

Dr. Samer Khanafseh is currently a research assistant professor at the Illinois Institute of Technology and the cofounder and manager of TruNav LLC. Dr. Khanafseh is an associate editor of IEEE Transactions on Aerospace and Electronic Systems and was the recipient of ION’s Early Achievement Award (2011) for his outstanding contributions to the integrity of carrier phase navigation systems. He has served ION as a session chair several times and as a reviewer for NAVIGATION and conference papers. Dr. Khanafseh received his PhD degree in Aerospace Engineering at IIT in 2008. Technical expertise and interests include high accuracy and high integrity navigation systems, cycle ambiguity resolution, fault monitoring and robust estimation techniques, high precision aviation applications such as Autonomous Airborne Refuelling (AAR) of unmanned air vehicles, autonomous shipboard landing for the UCAS and JPALS programs, and Ground Based Augmentation System (GBAS).

Dr. Joe J. Rushanan is a principal mathematician in the Communications, SIGINT, & PNT department of The MITRE Corporation. He was part of the M-code signal design team and the L1C signal design team. He was the 2019 recipient of ION’s Capt. P.V.H. Weems award for his sustained contributions to the design on GPS. Additionally, he currently teaches cryptography for Northeastern University’s Khoury College Cybersecurity graduate program. He received his MS and PhD in mathematics from The Ohio State University and the California Institute of Technology, respectively. Technical expertise and interests include signal design (especially binary sequences and spreading code generation), cryptography, signal authentication, and innovative methods to secure PNT. His latest research is in applying inference methods to reasoning about PNT assurance.

Dr. Sanjeev Gunawardena is a research assistant professor with the Air Force Institute of Technology (AFIT). He leads robust GNSS technology development - one of three R&D thrusts of the Autonomy and Navigation Technology Center at AFIT. Sanjeev has been an active member of ION since 2000. He served as a GNSS+ track chair and co-chaired numerous technical sessions at GNSS+, ITM, and PLANS conferences. He was Eastern Council Member-at-Large during 2014-2015 and Satellite Division Treasurer during 2016-2018. Dr. Gunawardena was also the instigator and co-chair of the ION GNSS SDR Metadata Standard Working Group (ratified in 2020). He earned his PhD in Electrical Engineering from Ohio University.

Dr. Mark Carroll is an electronics engineer at the Air Force Research Laboratory Sensors Directorate. He received his BS in Computer Engineering and MS in Computational Science and Engineering from Miami University. His research interests include GNSS, Software Defined Radios (SDRs), and machine learning.
Session D1a: NAVWAR: Counter PNT
Ballroom B


10:55 Jammer Airborne Wavefront Simulator (JAWS): George Lee, Steven Fuller, Paul Osadchy, Dan Drescher, Northrop Grumman; William Deike, Dana Howell and Denice Jacobs, Air Force Research Laboratory/RYWN; Eddy Emile, SMC/GPUT

11:15 Blue Force Electronic Attack (BFEA) Jammer Aided Navigation - BFJAN: Taehwan Kim, Khiem Cai, Jarret Perry, James Landon, Raytheon Intelligence and Space

11:35 The Future of GNSS Field Testing – Get it Done: Greg Gerten and Steve Billman, KBR

Alternates
2. Raytheon Modeling and Simulation in the Threat Environment and Associated Performance against Threat Characterization: Ryan Jackson, Jarrett Perry, Matt Dusard, Raytheon Intelligence and Space

Lunch in Event Center I (First Floor): 12:00 - 1:00 p.m.
Tuesday Technical Sessions  
1:45 p.m. - 3:15 p.m.

Session A1: Space and Satellite Applications, NTS-3 Overview  
Ballroom E

1:50 NTS-3 Signals Experiments - Overview: Jon Anderson, Canyon Consulting; Philip Dafesh, James Gillis, The Aerospace Corporation; Joanna Hinks, Air Force Research Laboratory; Shawn Miller, Brady O’Hanlon, Joseph C. Rushanan, The MITRE Corporation


2:30 NTS-3 Experiments with a New SatNav Payload Architecture: Joanna Hinks, Air Force Research Labs; James Lake, Canyon Consulting; Val A. Loretii, MEI Company; Shah Nejadi, Canyon Consulting; Gary Okerson, The MITRE Corporation; Nathan Pax, University of Dayton Research Institute; Steven Stoyanov, L3Harris; Renee A. Yazdi, Canyon Consulting

2:50 Profiling Embedded Performance of Generating Chimera Authentication: Jared Kresge, Samuel Wamsley, CAL Analytics; Sanjeev Gunawardena, Air Force Institute of Technology

Alternates
1. Assessment of NTS-3 Acquisition Aiding Signals: Benefits to Military GPS Receiver Performance, Spectrum Compatibility, and use Cases: Philip Dafesh and Alex Eapen, The Aerospace Corporation
3. GNSSTRA as a Receiver for NTS-3 Experimentation: Shawn Miller, The MITRE Corporation

Session B1: Collaborative Navigation Techniques  
Ballroom C

1:50 PANAVO Team Employing Cooperative Navigation Technologies and Techniques in GNSS Denied Environments: Luke Rinard, T2S Solutions; Yoonkee Kim, CSISR Center; Mikel Miller, IS4S

2:10 Collaborative Navigation with Warfighters Transitioning to and from Mounted Platforms: Jordan Britt and Kevin Betts, Leidos

2:30 Raytheon HiPRNAV-T and 2-Way Time Transfer: Matthew Dusard, Jarrett Perry and Paul Quinn, Raytheon Intelligence and Space

2:50 Resilience for Multi-Filter All-source Navigation Framework: Johnathan S. Gipson and Robert C. Leishman, ANT Center, AFIT

Alternates
2. The PNT Chain: A Collaborative Navigation Architecture for Projecting Accurate PNT Information Across Vast GPS-denied Areas: Samuel Shapero, Daniel Levy, Matthew Lashley, and Mark Smith, Georgia Tech Research Institute
3. Cooperative PNT in a Relative Reference Frame using two-way Time and Range, Barometric Pressure and Inertial Measurements: William Kirchner, Ramachandra Sattigeri, Vladislav Gavrilets, and James Doty, Collins Aerospace

Session C1: Complementary PNT 1: Vision Aided Air  
Ballroom D

1:50 Image Positioning System for PNT AgilePod: Donald Venable, Michael Veth, Veth Research Associates; Mark Smearcheck, AFRL


2:30 Honeywell Vision-Aided Navigation for GPS-Denied Environments: Kevin Sweeney, Justin Syrstad, Annis Nusseibeh, Tim Kukowski, Sally Ann Keyes, Honeywell International


Alternates
1. Boeing Vision Based Navigation Design & Flight Demo Results: R. (Ken) Li, Boeing Research & Technology; Tom Tsao, BDS; Andrey Tolstov, Kevin Davis, Paul Haug, Boeing Research & Technology
2. Using Motion Capture and Augmented Reality to Test AAR with Boom Occlusion: Xiaoyang Wu, Vincent Bownes, and Scott Nykl, AFIT

Session D1b: NAVWAR: Situational Awareness  
Ballroom B

1:50 NAVWAR Situation Awareness Framework: Luke Rinard, T2S Solutions; Robert Beckinger, Fritz Newcomer, CSISR Center; William Travis, Josh Starling, Travis Keller, Jeremy Shepherd, IS4S; Scott Parsons, Andy Keckler, SRC Inc.

2:10 Spoofing Detection in NavAtel’s OEM7 Receivers: Sandy Kennedy, Ali Bouamandan, Thomas Taylor, NavAtel America, Inc.

2:30 Improved Jamming Situational Awareness Using Array Data: John Wegner, BAE Systems/NSS


Alternates
2. Orienting the Warfighting OODA Loop: Renee A. Yazdi, Canyon Consulting; Joseph P. Lortie, Jr, Defense Aerospace Consultant; L. Kevin Slimak, Brian Zufelt, COSMIC UNM; Madeleine Naudaud, Air Force Research Labs

Free Time in Exhibit Hall/Hosted Break in Event Center I: 3:15 p.m. - 4:00 p.m., Sponsored by GPS Networking
Tuesday Technical Sessions

Session A2: Space and Satellite Applications
Ballroom E

4:05 An Experiment in Interstellar Navigation: Gregory S. Hennessy and George H. Kaplan, US Naval Observatory

4:25 Analysis of GPS III Concentric Array Based Antenna (CABA) Satellite Payload Configuration for Enhanced PNT Performance: Erik Liei, Mark Crews, Chuck Frey, Lockheed Martin Space; Madeleine Naudeau, AFRL

4:45 Options for Expanded Space Service Volume: James Lake, Laura Duffy, Canyon Consulting, LLC, and Jason Guarnieri, AFRL/RV

5:05 Space-based GPS Interference Monitoring and Detection with Proliferated LEO: Steven W. Lewis, Blair F. Thompson, Tanner Stevens, Rebecca Bishop, The Aerospace Corporation

Alternate


Session B2: PANEL: MGUE Integration
Ballroom B

This panel will feature representatives from weapon systems conducting some of the initial integration of MGUE receivers. Panelists will share experience and lessons learned working with the first generation of M-Code receivers.

Panel Members:
1. Terrance Nelson, Systems Engineer, Booz Allen Hamilton
2. Glen Collins, GPNTS Technical Lead, Booz Allen Hamilton
3. Dr. John Janeski, The Aerospace Corporation
4. Eric Hillen, TBS
5. Paul White, Engineer, U.S. Army DEVCOM Aviation & Missile Center
6. Dr. Sultan Mahmood, WBB Inc.

Session C2: Complementary PNT 2: LiDAR and Vision Aided Ground
Ballroom D


4:45 LiDAR-Aided INS System for GPS-Denied Navigation in Dense Forestry Area: Andrey Soloviev, Ananth Vadlamani, JD Sharon, QuNav; Michael Caporellie, US Army CSISR

5:05 Sensor-fused Doppler Lidar/IMU for Terrestrial Navigation: Jason Hull, Diego Pierrottiet, Stephen Sandford, Donald Erbschloe, Kenneth Morrison, Psionic LLC

Alternate


Session D2: Weapon Applications
Ballroom C


4:25 Image-Based Navigation and Seeking in GPS Denied and Contested Environments: Matthew Jamula, Draper

4:45 MIM-104 Patriot Missile Launcher Incorporates M-Code based MAPS GenI: Paul White, U.S. Army DEVCOM - Missiles & Aviation; Greg Graham, NTA-INC; Dave Jones, Gentry Gardner, GPS Source

5:05 eLoran Based Navigation System for GPS Denied Environments: Christopher Zarowski, Jeffrey Anderson, Mayflower Communications Company, Inc.; Stephen Bartlett, UrsaNav, Inc.; Joseph Hewlett, Scott Salazar, Naval Air Warfare Center Weapons Division, US Navy

Alternate

1. Modernized GPS for Precision Guidance Kit (PGK): Steve Phillips, Justin Miller, Randall Jaffe, and Justin Yakura, L3Harris
2. Stellar Aiding to Improve Long Range Missile Performance: Kyle Miller, John Mastrangelo, Joseph Ho, Thomas Vaughan, James Hardaway, Ball Aerospace & Technology Corp.; Scott David, Michael Payne, NTA-INC; Patrick Renfroe, US Army CCDC/AVMC
Session A3: Applications of Atomic Standards in DoD Time Transfer and Dissemination

Ballroom E

8:35 Exploring the Chip Scale Atomic Clock (CSAC) for On Demand Position Navigation & Time (OD-PNT) Applications: Luke Littleton-Strand, Jade A. Babcock-Chi, Penina Axelrad, Dennis M. Akos, University of Colorado at Boulder


9:15 Position Determination and Timing with Laser Pulses: Nathan Barnwell, Kari Moran, Jonathan Itschner, Kevin Stanzione, and LaChelle McMahan, NIWC Pacific

9:35 Realizing Satellite Time Transfer Through S&T: McLaina Oum, William Joo, and Joe Schnecker, NIWC Pacific

Alternate


Session B3: Military GPS User Equipment

Ballroom C

8:35 BAE Systems MGUE Status, M-Code is Here: Charles A. Popeck and Shawn Ryan, BAE Systems/NSS

8:55 L3Harris Military GPS User Equipment (MGUE): Rick Bieniak, L3Harris

9:15 Raytheon MGUE Program Status: Mike Delanty, Mark Martinez, and Jarrett Perry, Raytheon Intelligence and Space

9:35 First Flight Test of EGI with M-Code: Scott Leavy, Paisley Rowe, Michael Nelson, Honeywell

Alternate

1. Improvements to MAPS Gen 1 and Fielding Status: David Jones and Gentry Gardner, GPS Source


Session C3: Complementary PNT 3: Vision Aided Optical and RF/Stellar

Ballroom D

8:35 All-Weather Absolute Visual Navigation with Advanced Radar: Scott Jenkins, Tim Bielek, Doug Bickel, R. Derek West, Tucker Haydon, Sandia National Laboratories

8:55 Boeing Modern Celestial Navigation Design: R. (Ken) Li, Tom Tsoa, C.J. Yoo, Paul Haug, Boeing Research & Technology

9:15 Celestial-Based Position Algorithm for GPS-Denied Environments with SkyPASS Gen3 Simulation and Implementation Test Results: Laura Eshelman, Adam Smith, Art Lompado, Katie McCann, and David Chenault, Polaris Sensor Technologies, Inc.


Session D3: Navigating in Challenged Environments (e.g., Urban, Indoor and Sub-Surface Navigation)

Ballroom B


9:35 Direction of Motion Pedestrian Dead Reckoning Efficacy in a Non-Foot-Mounted, Body Worn Measurement Unit: George Hsu, PNI Sensor Corporation

Alternate


Free Time in Exhibit Hall/Hosted Break in Event Center I: 10:00 a.m. - 10:45 a.m., Sponsored by EMCORE
Session A4: Novel Timing Technologies and Applications
Ballroom E
10:50 Clock Resiliency Test Results with GPS Prototype Hardware: Michael R. Jones, John P. Janis, Nicholas Quackenbush, Amy Caprioni, Robert Montana, L3 Harris Technologies
11:30 Militarized Chip-Scale Atomic Clock: Peter Cash, Igor Kosvin, Paul Machado, Michael Silveira, and Gary Wernsing, Microchip Technologies
11:50 Distributed Network Time Synchronization: Social Learning versus Consensus: Hyuck M. Kwon and Ian Ellis L. Hulede, Wichita State University, EECS
Alternate
1. Novel Algorithm for Precision Time Synchronization of Distributed Defense Systems: James P. Vogel, Evan D. Walsh, and David A. Friedman, Systems & Technology Research

Session B4: Multi-GNSS Receivers for Military Applications
Ballroom C
11:10 A Software Defined implementation of Time-differenced Carrier Phase Solution with Random Sample Consensus: Zhen Zhu and Sanjeev Gunawardena, East Carolina University
11:30 Multi-GNSS Applications of Codeless Processing of Binary Offset Carrier Signals: Alan Choy, John Langer, Andrew Lin, Mark Kubiak, Herwin Chan, John Janeski, The Aerospace Corporation
Alternates
1. Multi-GNSS Risks and Rewards – Applying RMF and Cyber Hygiene to GNSS: Greg Gerten and Steven Billman, KBR; Ray Hitt, AFRL/RYWN
2. Analysis of Direct Conversion Front-End Distortion on Satnav Signal Deformation Monitoring Applications: Mark Carroll, Air Force Research Labs, RYW/N; Sanjeev Gunawardena, Air Force Institute of Technology; Eric Vinande, Air Force Research Labs, RYW/N

Session C4: Complementary PNT 4: Naturally Occurring Sources – Including Gravity, Magnetic Fields, Lightning
Ballroom D
10:50 Advancing the State of the Art for Magnetometer Calibration on an F16 Magnetic Navigation System: Aaron Canciani, AFIT
11:30 Magnetic Anomaly Aided Navigation Results from Airborne Flight Test Including Edwards AFB and PNTAX 2020: Paul Samanant, Trevor Stephens, Rob Compton, Blaise Morton, Honeywell; Aaron Canciani, NRO; Aaron Nielsen, AFIT

Session D4: PANEL: Rapid Agile Development and Manufacturing
Ballroom B
Representatives from all three services will address their plans to respond to urgent PNT requirements from the field in a rapid manner. Panelists will present current plans to quickly allocate requirements to an open system architecture (OSA), cooperate with industry to demonstrate prototypes, where OSA promotes the ability to plug and play new sensors with flexible interfaces from a diverse set of providers, adaptive software development to support the fusion of PNT sensor information, iterative prototyping in a cooperative manner with industry conducting demonstrations/test in government laboratories, and move forward to conduct operational tests to ensure all requirements have been satisfied. Using this methodology manufacturing can begin in a very quick turnaround in comparison to current DoD acquisition.
Panel Members:
1. Mr. Chris Garrett, Senior Leader (SL) for System Engineering, USAF
2. CAPT Andrew Gibbons, Program Manager, Communications and GPS Navigation Program Office, USN
3. COL Nick Koutas, Program Manager for Positioning, Navigation and Timing, US Army
4. Dr. Mikel Miller, Industry Perspective, IS4S

Lunch Served in Event Center I: 12:15 p.m. – 1:30 p.m.
Wednesday Plenary Session -  Ballroom B  1:45 p.m. - 3:15 p.m.

Mr. William B. Nelson  
Director, Assured Positioning  
Navigation & Timing (APNT) Cross  
Functional Team (CFT), U.S. Army  
Futures Command

Dr. Nikki Markiel  
Senior Geospatial Authority for Geomatics, National  
Geospatial Intelligence Agency

Free Time in Exhibit Hall/Hosted Break in Event Center I: 3:15 p.m. – 4:00 p.m., Sponsored by LinQuest

Wednesday Technical Sessions  4:00 p.m. - 5:30 p.m.

Session A5: Integrity and Assurance  
Ballroom E


4:25 A Novel Fault Correlator Architecture for GNSS Spoofing Survivability: Charles A. Givhan, Auburn University; Michael R. Walker and Connor L. Brashar, Sandia National Laboratories

4:45 Detection and Localization of Adversarial GPS Interference Source Based on Clock Signatures: Joseph B. Smith, Joshua M. Wood, Scott M. Martin, Auburn University; Connor Brashar, Sandia Nation Laboratories

5:05 Testing of Low SWAP-C Dismount GNSS Threat Detection: John Karvounis, Benjamin Funk, Jeff Kunst, Carole Teolis, Carol Politi, TRX Systems; Nhut Vo, CSISR Center CP&B/ID PNT DIV

Alternate

1. A Bit Sequential Method for Proof of Life over Low-Rate Channels: Peter Hokanson and Johnathan York, ARL, Univ. of Texas at Austin

Session B5: GPS Modernization

Ballroom C

4:05 Evaluating Interference from GPS Regional Military Protection to Reception of GPS Signals: John W. Betz, The MITRE Corporation

4:25 GPS Next Generation Operational Control Segment (OCX) Performance Analyses of Key Navigation Metrics: Michael Vlابoıy, Qun Shi, L3Harris Corporation; Yoaz Bar-Sever, Willy Bertiger, Bela Szilagy, Jet Propulsion Laboratory; Michael Coleman, Naval Research Laboratory

4:45 An Exchange Format for M-code Navigation Message Data: Brent Renfro, John Knutson, Emery Reed, ARL, The University of Texas at Austin; Cliff Harris, The Aerospace Corporation; Trevor Garner, National Geospatial-Intelligence Agency

5:05 GPS III, IIF, and Operational Control Segment Modernization: Tonya Ladwig, Dave Hatch, and Mark Crews, Lockheed Martin Space

Alternate

1. GPS Satellite Autonomous Operations Accuracy: Charles H. Frey, Lockheed Martin Corporation/Space Systems

Session C5: Complementary PNT 5: RF Aided/SDR (Non-GPS)

Ballroom D

4:05 SDR-Based PNT Solution Using Signals of Opportunity: John Carlson, Martin Alles, Joe Kennedy, Echo Ridge, LLC; Mark Smearcheck, Air Force Research Laboratory; Luke Steelman, Naval Surface Warfare Center


4:45 An Agile RF Broadcast & SDR-enabled Closed Loop PNT System: Gary Green, KBR; Joe Kennedy, Echo Ridge; Zac Hester, Braxton

5:05 One Satellite Receiver for Localization of Radio Emitter: Hyuck M. Kwon, Andrew Rankin, Ian Ellis L. Huleed, Wichita State University

Alternates


Session D5: NAVWAR: User Technologies

Ballroom B

4:05 Modernized GPS and Digital Anti-Jam Contributions to the Range and Lethality Challenge of Multi-Domain / Maritime Distributed Operations (MDO): Justin R. Wymore Sr., BAE Systems/NSS


4:45 Optimal Filtering for Jamming Suppression: John W. Betz, The MITRE Corporation

5:05 Consumer Reports - NAVWAR Battery Side by Side Scoring and Assessment: Mitchel Kromer, KBR; Ray Hitt, AFRL/RVWE

Alternates

1. Eroding the Jamming Threat to Military GPS: Alex Cerruti, Daniel Shultz, John W. Betz, The MITRE Corporation

2. Protected RF Mode for M-Code Receiver Interoperability with Anti-Jam Electronics: Greg Farley, BAE Systems/NSS

3. LCDR Joseph Haynsworth  
C5ISC
**Thursday Technical Sessions**

**Ballroom E**

**Session A6: Reconfigurable SatNav**

**8:35 On Demand PNT (OD-PNT):** P. Axelrad, D. Akos, J. Morton, S. Palo, R. Kingsbury, University of Colorado Boulder; L. Scott, Logan Scott Consulting

**8:55 Adaptive and Learned Transmit Technologies to Defeat Jamming:** Michael Tinston, Enrico Mattei, AfSahy Saqib, Michael Person, Brent Marin, Dan Weigand, Expedition Technology, Inc.

**9:15 Noise Reduction Technique in Radio Astronomy Band for GPS Satellite Payload Applications:** J. Johana Yan, Donald E. Cowles III, Hourman Ghajari, MaXentric Technologies LLC; Aly E. Fathy, University of Tennessee Knoxville


**Alternates**

1. Developing the GNSS Waveform Prototyping Platform (GWPP) for End-to-End CHIMERA Tests: Andrew Cochrane, Jim Aarestad, COSMIC Research Center, The University of New Mexico; Greg Myer, Canyon Consulting; Luis Hernandez, COSMIC Research Center, The University of New Mexico; Sanjeev Gunawardena, Air Force Institute of Technology

2. Rapid-OODA with GNSS Machine Learning Toolset (MLT): Brian Zufelt, COSMIC University of New Mexico; Renee A. Yazdi, Canyon Consulting; Andrew Cochrane, Jim Aarestad, COSMIC University of New Mexico; David Choi, Caleb Sapp, Madeleine Naudeau, Air Force Research Laboratory

**Ballroom C**

**Session B6: PNT Open Systems Architecture**

**8:35 ASPN Upgrade: Progress and Way Forward:** Adam Schofield, Meghan Bentz, CCDC CSISR; Ken Fisher, Kyle Kauffman, and John Raquet, IS4S

**8:55 Department of the Air Force PNT Reference Architecture Development:** Delbert Champ, Headquarters Air Force A5/7; Matthew Kascak, Justin Malek, Armin Kudrian, Boz Allen Hamilton


**9:35 Challenges to Creating a Resilient-EGI (R-EGI):** Jacob Campbell, Morgan Raymond, AFLCMC/WNY; Barb Frantom, AFLR/RWNN; John Bowling, AFLCMC/EZ; Geneva West, Ray Simons, AFLCMC/WNY

**Alternates**

1. PNT Open System Architecture: David Selim, Honeywell Engineering & Technology

2. Continuous Competition Design Agent (CCDA) for Acquisition of Resilient-EGI (R-EGI) Design: Mikel M. Miller, John Larson, D. Bruce Simpson, James Moore, IS4S; Raymond Morgan, Jacob Campbell, Barb Frantom, John Rohde, USAF

**Ballroom D**

**Session C6: Modeling and Simulation**

**8:35 Closing the Loop on Model Based Design:** The Baro-Inertial Vertical Channel as a Case Study: N. Datta, M. Braasch, Ohio University; C. P. Bruner, L. Murphy, M. Moecl, Northrop Grumman Mission Systems

**8:55 Modeling Tightly-coupled Receivers with GIANT:** Jacob Jost and Jim Fitch, LinQuest Corporation

**9:15 Tracking Phase Through the Polarization Efficiency Factor with Application to Precision Guided Munitions:** A. Tetovsky, J. Lazow, Draper; R. Scott Boughton, The Aerospace Corporation; G. Panas, D. Smith, Army; J. Fitch, LinQuest

**9:35 Navigation Warfare M&S Geolocation Algorithm Evaluation:** Robert Beckinger, Nora Lenhardt, Song Huang, and Liam Dobbins, CSISR PNT

**Alternates**

1. Performance Analysis of an Attitude-Based GPS Vector Tracking Loop: Tanner Watts, Scott Martin, and David Bevly, Auburn University


3. Real-Time Phase Alignment Enables Next Generation GNSS Wavefront Simulation: Tim Erbes, Orolia Defense and Security

**Ballroom B**

**Session D6: Application/Impact of PNT Technologies in the Homeland Critical Infrastructure**

**8:35 AA Resilient National Timing Architecture:** Marc Weiss, Consultant; Patrick Diamond, RNT Foundation; Dana A. Goward, RNT Foundation

**8:55 A Multi-Level Approach for Integrating GNSS Integrity into Critical Timing Applications:** Josh Clanton, David Hodo, IS4S; John David Martin, and Scott Martin, Auburn University


**9:35 Resilient PNT Reference Architecture for Critical Infrastructure:** Patricia Larkoski, William Young, Bradley Moran, Fei Sun, Arthur Scholz, DHS HSSEDI FFRDC, operated by The MITRE Corporation; Ernest Wong, DHS Science and Technology Directorate

**Alternates**

1. How the West is Losing the Navigation and Timing War, and Risking Everything: Dana A. Goward, Resilient Navigation and Timing Foundation

2. How to (Easily) Ignore Geofencing of Protected Areas: Threat, Demonstration, and Mitigation: Jonathan Taylor, Orolia Defense & Security

3. PNT Assessments of Critical Infrastructure — Find, Fix and Fortify: Greg Gerten and Geoffrey Hella, KBR
Thursday Technical Sessions

Session A7: Operational System Demonstrations 1
Ballroom E

10:45  IS-1500® Motion Tracker for Dismounted, GPS-Optional PNT: Richard Madison and Brian Haight, Thales Defense and Security, Inc.

Session B7: PNT Open Systems Architecture 2
Ballroom C

10:50  PNT AgilePod Flight Test Experimentation: Mark Smearcheck, Branden McNally, Andrew Cottle, Air Force Research Laboratory, Jacob Hoehler, Adriel Fillippini, University of Dayton Research Institute
11:30  Navy’s Next Generation, GPNTS Hull Optimized System – Tactical (GHOST) for Smaller Maritime Platforms: Eric Shuey, PEO C4I - PMW/A 170 GPS Navigation Division; Aaron Nascimento, NAVWAR; Chad Pinkelman, NIWC Pacific GPNTS; Glen Collins, Booz Allen Hamilton; Phong Bach, Hahng Nguyen, Brett Balazs, Steve Ouellette, Raytheon IDS
11:50  Open Architecture GPS Inertial Simulator for Assured-PNT Development and Testing: Dien Nguyen and Alison Brown, NAVSYS Corporation

Alternates
1. Learning Sensor Models for Robust PNT: Clark Taylor, ANT Center, AFIT
2. R-EGI-A Peek Under the Hood of the DDPs (Detailed Design Prototypes): Jacob Campbell, Morgan Raymond, AFLCMC/ACS; Mikel Miller, John Larson, IS4S

Session C7: Inertial Measurement Unit (IMU)
Ballroom D

10:50  Compact Short-Term Navigation Grade Quartz MEMS IMU: Sergey Zotov and David Hoyh, EMCORE Corp. - Systron Donner Inertial
11:10  Dual-Use Navigation-Grade MEMS IMU: Burgess R. Johnson, John Reinke, Markus Gnerlich, Curt Albrecht, Todd Braman, Patrick Duffy, Daniel Endean, Honeywell International
11:30  Fibernetics Inertial Measurement Unit: Ralph Bergh, Fibernetics LLC
11:50  Miniature, Precision Inertial Navigator: Zenon Melnyk and William J. Tortora, Collins Aerospace

Alternates
1. mHRG IMU for Improved Navigation in GPS Denied Environments: Phil Bruner, Albert Choi, Philip Clark, Michael Chavez, Farzin Dinyarian, Lawrence Linick, Daniel Rampacek, William Schellhorn, Alex Trusov, Cole Umemura, Northrop Grumman; Scott David, Michael Payne, Stephen Pethel, NTA; Patrick Renfroe, US Army CCDC AvMC
2. Toward GPS Denied Inertial Navigation Using Hollow Core Fiber Based Resonator Fiber Optic Gyro (RFOG) Technology: Marc Smiciklas, Glen Sanders, Wes Williams Honeywell Inc.; Jeff Williams NTA Inc.; Patrick Renfroe, US Army DEVCOM/AvMC
3. LN200HP (Compacted High Performance IMU) with High Gyro Bandwidth, Low Quantization Noise, ARW, and Gyro Bias Error: Steven Kim, Daniel Tazartes, Greg Zimmerman, Northrop Grumman
4. Benefits of Quadratically Tapered Flexures for Silicon MEMS Gyroscopes and Resonators: Brian E. Grantham, Technology Development Directorate; US Army CCDC, AMC; Redstone Arsenal; Jennifer M. English, University of Alabama in Huntsville

Session D7: PANEL: National Critical Infrastructure Threat
Ballroom B

This panel will focus on PNT threats to the national critical infrastructure. Discussion topics may include threats to the electrical grid, communication, transportation, finance, and domestic DoD support infrastructure as well as emerging infrastructure for domestic employment of UAV systems that create a challenge for safeguarding national assets and maintaining homeland security.

Panel Members:
1. Mr. Ken Alexander, Chief Scientific and Technical Advisor for Satellite Navigation, Federal Aviation Administration
2. Dr. Andrew Hansen, Principal, Aviation Modeling & System Design, OST-R/Volpe Center, U.S. Department of Transportation
4. Ms. Misty Finical, Deputy Principal Advisor, Enterprise Protection, National Aeronautics and Space Administration

Lunch in Event Center I: 12:15 p.m. - 1:30 p.m.
Thursday Plenary Session - Ballroom B 1:45 p.m. - 3:15 p.m.

Brig. Gen. Steven Whitney
Director, Space Programs
– Assistant Secretary for Acquisitions, United States Air Force

Dr. Bradford Parkinson
Stanford Center for PNT

The JNC is grateful for the support of:

JNC Conference Patrons

JNC Conference Contributors

JNC Media Partners
Thursday Technical Sessions

**Session A8: Operational System Demonstrations 2**

*Ballroom E*

- **4:00** GPS Jamming Training: SPACE JAM Update and Roadmap
  - William Deike, Jeffrey Hebert, and Dan Drescher, AFRL/RYWN
- **4:45** Using a GNSS Simulator to Output Inertial Sensor Data, via an Open-Source Plug-In Interface
  - Jaemin Powell, Orolia Defense & Security

**Room: Ballroom C**

- **4:05** Real-time SDR Implementation of a Deeply Coupled, High Integrity GNSS Receiver with pntOS Integration
  - Luke Edwards, David Hodo, I54S; Tanner Watts, Scott Martin, Auburn University; Greg Reynolds, Army DEVCOM AvMC
- **4:25** Demonstration of Standalone Direct Acquisition of M-Code Capability
  - Chun Yang, Andrey Soloviev, Ananth Vadlamani, QuNav; Joung C. Ha, AFRL/RYWN; Mathew Cosgrove, Taylor Schluter, Bo Halamandaris, Jeff Dickman, Northrop Grumman Mission Systems
- **4:45** Performance Metrics and Advanced Capabilities of PyChips
  - An Easily Configurable Satnav SDR for Rapid Prototyping and Deployment
  - Sanjeev Gunawardena, Air Force Institute of Technology
- **5:05** Design and Test Results of a System-of-systems Open Architecture PNT (SOAP) Software Defined Radio
  - Alison Brown, Jarrett Redd, Dien Nguyen, and Tom Silva, NAVSYS Corporation

**Alternates**

1. Software Radio Prototype of a Frequency Hop Acquisition Using Secure Transec (FAST) Receiver
2. Software Defined Radio Realization of Anti-jamming, Anti-spoofing and Situational Awareness
3. Plug and Play FPGA Implementation of a GPS Threat Detection, Mitigation, and Geolocating Unit

**Session B8: Software Defined Radios (SDRs) for PNT**

*Room: Ballroom E*

- **4:00** GPS Jamming Training: SPACE JAM Update and Roadmap
  - William Deike, Jeffrey Hebert, and Dan Drescher, AFRL/RYWN
- **4:45** Using a GNSS Simulator to Output Inertial Sensor Data, via an Open-Source Plug-In Interface
  - Jaemin Powell, Orolia Defense & Security

**Room: Ballroom C**

- **4:05** Real-time SDR Implementation of a Deeply Coupled, High Integrity GNSS Receiver with pntOS Integration
  - Luke Edwards, David Hodo, I54S; Tanner Watts, Scott Martin, Auburn University; Greg Reynolds, Army DEVCOM AvMC
- **4:25** Demonstration of Standalone Direct Acquisition of M-Code Capability
  - Chun Yang, Andrey Soloviev, Ananth Vadlamani, QuNav; Joung C. Ha, AFRL/RYWN; Mathew Cosgrove, Taylor Schluter, Bo Halamandaris, Jeff Dickman, Northrop Grumman Mission Systems
- **4:45** Performance Metrics and Advanced Capabilities of PyChips
  - An Easily Configurable Satnav SDR for Rapid Prototyping and Deployment
  - Sanjeev Gunawardena, Air Force Institute of Technology
- **5:05** Design and Test Results of a System-of-systems Open Architecture PNT (SOAP) Software Defined Radio
  - Alison Brown, Jarrett Redd, Dien Nguyen, and Tom Silva, NAVSYS Corporation

**Alternates**

1. Software Radio Prototype of a Frequency Hop Acquisition Using Secure Transec (FAST) Receiver
2. Software Defined Radio Realization of Anti-jamming, Anti-spoofing and Situational Awareness
3. Plug and Play FPGA Implementation of a GPS Threat Detection, Mitigation, and Geolocating Unit

**Session C8: Autonomous Systems and PNT**

*Ballroom D*

- **4:05** Intelligent Virtual Sensor Modeling for Assured PNT System
  - Shahram Moafipoor, Brad Despres, Jeff A. Fayman, Lydia Bock, Bob Stadel Geodetics Inc., Geodetics Inc., An AEVEX Aerospace Company
- **4:25** Accelerating Point Set Registration for Automated Aerial Refueling
  - Ryan Raettig, Joel Miller, and Scott Nykl, AFIT
- **4:45** Towards More Robust Vision-based Map Matching Through Machine Learning
  - Tyler Hussey and Robert C. Leishman, AFIT/ANT Center

**5:05** Stereo Camera Calibrations with CNN-Based Optical Flow
- Joshua Larson, James Lynch, Scott Nykl, AFIT

**Alternates**

1. Electromagnetic Interference Estimation via Conditional Neural Processing
2. Sensor Component Noise Parameter Extraction
3. Recurrent Neural Networks to Mitigate Visual Occlusion in Automated Aerial Refueling
4. Protecting Drones from GPS Jamming: Enabling Robust BVLOS Operations

**Session D8: Antenna Technologies & Interference Mitigation for Robust PNT**

*Room: Ballroom B*

- **4:05** Machine-learning Anti-Jam Interference Cancellation “MAJIC”
  - Phil Hess, Donna Branchevsky, Nathan Whitehair, Anson Lam, Adam Belhouchat, Alex Eapen, Terry Ferretti III, The Aerospace Corporation
- **4:25** Miniature Multi-Band GNSS Antenna for SWaP-Constrained Applications and CRPAs
  - Kathleen Fasenfest, Mike Taing, Edison Kuo, and Tam Nguyen, Antcom Corporation
- **4:45** Multi-Array Panel Testing Results for a Dynamic Constellation Simulation System for Anechoic Chambers
  - Josh Clanton and Josh Starling, I54S; Lloyd Riggs, Auburn University

**5:05** Prototype and Demo of a GPS Interference Mitigation Module
- Chun Yang, Andrey Soloviev, QuNav; Mat Cosgrove, Nathan Duescher, Northrop Grumman; Gregory Reynolds, CCDC Aviation & Missile Center

**Alternates**

1. Simultaneous Exploitation of Time, Spatial, and Polarization Domain Techniques to Mitigate Multipath and Inauthentic Signals for Civilian Satnav Applications
2. Six Degrees of Freedom GNSS Antenna Attitude Determination
3. Small SWaP 4-Channel GPS AJ System

**Morning Coffee, 7:30 a.m. - 8:30 a.m., Sponsored by NAL Research**
Friday Technical Sessions - Ballroom B

8:30 a.m. - 5:10 p.m.

Morning Coffee, 7:30 a.m. - 8:30 a.m., Sponsored by NAL Research

Session E9: JNWC FACILITATED PROGRAM (FEDCON U.S. ONLY):
8:30 a.m. – 10:10 a.m.
8:30 a.m. Welcome

Keynote:
8:45 a.m. - 9:30 a.m.

Major General DeAnna M. Burt
Commander, Combined Force Space Component Command, U.S. Space Command; and Deputy Commander, Space Operations Command, U.S. Space Force, Vandenberg Air Force Base, California

9:30 JNWC Joint Assessment Program and Strategy: Amanda Humphrey, DAF, JNWC

Break, 10:10 a.m. - 10:50 a.m., Sponsored by Lockheed Martin

Session E10: PANEL: Combatant Command Joint Urgent Operational Need (JUON): Warfighter Requirement and Solutions (FEDCON U.S. Only)
10:50 a.m. – 12:20 p.m.

This panel will present highlights of a current JUON to include requirements/funding, mission analysis, fielding, and effectiveness assessment. Discussion will also include use of modular capabilities to accommodate future expansion and modifications to address other combatant command needs and evolving threats.

Panel Members:
1. Seth M. Anderson, MSGt, USAF, Manager, Jt SOF Threat Warning Sys Integration, USAF/645 AESS/361 ISRG OL-E
2. Brandon S. Shultz, SMSGT, USAF, Superintendent, Special Projects, USAF/645 AESS
3. Mark Phillips, Resonant Sciences
4. Benjamin Johnis, MSGT USAF USSOCOM SOCCENT

Lunch in Event Center 1 (First Floor), 12:20 p.m. - 1:30 p.m.

Session E11: PANEL: Warfighters (FEDCON-U.S. Only)
1:50 p.m. – 3:20 p.m.

An interactive discussion between the audience and a panel of warfighters who have had recent operational experience that informs the community on how to better formulate military PNT systems. Warfighters who have had operational “in theater” experience in the past year will be solicited from all services.

Panel Members:
- LCDR Harold J. Kiffer, NIS & GPS Division Chief, USCG Navigation Center
- CAPT Elizabeth Higgins, USN
- MAJ Gabe Wood, SF, Innovation Director, 7th Special Forces Group (Airborne)
- SGM Joshua Gendron, V Corps, US Army
- Lt Col Jonathan Ard, US Air Force

Session E12: JNWC FACILITATED PROGRAM (FEDCON U.S. ONLY)
3:20 p.m. – 5:10 p.m.

3:20 Civil Aviation Low Cost GPS Spoofing Threats: Ken Alexander, Federal Aviation Administration
3:30 Break: 3:40 p.m. - 4:10 p.m., Sponsored by Northrop Grumman


4:30 NAVWAR Sensor – Test Results, Maturation and Tech Transition: Dana Howell and Denice Jacobs, Air Force Research Laboratory (AFRL/RYWN)

4:50 Spectral Compression for Remote Signal Monitoring of GPS M-code: Jordan Cameron, Russell Friesenhahn, Benjamin Glass, Peter Hokanson, Scott Jones, Andrew Joplin, Aaron Kerkhoff, Brian Mechler, Christopher Nail, Adam Williamson, and Johnathan York, ARL, The Univ. of Texas at Austin

NOTICE:
Friday Program to be Held at FEDCON Level. SECRET Materials Distributed via SIPRNet

Due to capacity restrictions and time restraints as a result of the COVID environment, JNC’s Friday technical program, previously planned to be held at the SECRET level, will now be held at FEDCON US-only at the Northern Kentucky Convention Center. Presentation briefing materials and oral remarks will be delivered in a FEDCON US-only environment.

The Joint Navigation Warfare Center (JNWC), the JNC’s DOD sponsor, will be hosting the classified/SECRET materials associated with the briefings on the DOD’s Secret Internet Protocol Router Network (SIPRNet) on the JNWC’s home page for eligible attendees to access through authorized protocols.
Get 10X the Performance!
EMCORE Fiber Optic & Quartz MEMS IMUs

THE EMCORE IMU ADVANTAGE

- Suitable for wide variety of high-precision Defense, Industrial, Marine, and Commercial applications
- Industry’s performance and CSWaP leading tactical grade FOG & MEMS IMUs:
  - EN-300 - 0.04°/hr in-run gyro bias, Ultra-low 0.015°/√hr ARW
  - SDI170 & SDI500 - 1°/hr gyro & 1 mg accel bias, Low 0.02°/√hr ARW
- Ruggedized, compact package designs suitable for shock and vibration environments
- Form, Fit and Function compatible upgrades for legacy FOG & RLG IMUs for easy integration and re-qualification (LN-200, HG1700-AG58)

FOR MORE INFORMATION
navigation-sales@emcore.com
+1 866 234 4976
www.emcore.com/nav