

GNSS Solutions® Tutorials

September 20-21, 2010 • Oregon Convention Center • Portland, Oregon, USA

	TRACK 1	TRACK 2	TRACK 3	TRACK 4	TRACK 5
Monday AM 8:30-12:00	CN405: Fundamentals of GNSS I with Emphasis on GPS Chris Bartone, Ohio University	CN425: Future GNSS Signals & Systems with emphasis on Galileo Tony Pratt, Orbstar Consultants	CN431: GNSS Receiver Design I: RF Front-End Theory and Design Sanjeev Gunawardena, Ohio University	CN460: Introduction to Strapdown Inertial Navigation Systems I Kevin Dutton, Honeywell International	CN480: Fundamentals of Kalman Filtering for GPS/INS Integration I Mohinder S. Grewal, California State Univ, Fullerton
Monday PM 1:30-5:00	CN406: Fundamentals of GNSS II with Emphasis on GPS Chris Bartone, Ohio University	CN426: Future GNSS Signal Performance with emphasis on Galileo Tony Pratt, Orbstar Consultants	CN432: GNSS Receiver Design II: Baseband Signal Processing and Implementation Sanjeev Gunawardena, Ohio University	CN461: Introduction to Strapdown Inertial Navigation Systems II Kevin Dutton, Honeywell International	CN 481: Fundamentals of Kalman Filtering for GPS/INS Integration II Mohinder S. Grewal, California State Univ, Fullerton
Monday EVE 6:45-9:30	CN420: GPS Modernization and Relation to other GNSS Thomas Stansell, Stansell Consulting	CN413: GNSS Integrity and RAIM Christophe Macabiau, ENAC	CN435: GNSS Receiver Vector Tracking Theory and Implementation Matthew Lashley, Navigation Technology Associates	CN473: Land Navigation using Integrated Systems David M. Bevy, Auburn University	Open (check www.GNSSolutions.com for updates)
Tuesday AM 8:30-12:00	CN428: Glonass Fundamentals & Modernization Dr. Sergey Revniykh, Central Research Institute of Roscosmos & others	CN433: Receiver Signal Processing for Future GNSS Signals - Introduction Olivier Julien, ENAC	CN441: GNSS Antennas I - Fundamentals Chris Bartone, Ohio University	CN462: Applications of Strapdown Inertial Navigation I Andrey Soloviev, University of Florida	CN 482: Fundamentals of GPS/INS Integration I Mohinder S. Grewal, California State Univ, Fullerton
Tuesday PM 1:30- 5:00	CN360: Intellectual Property and Patents Gary J. Edwards, J.D., Haynes and Boone Steve Levitan, J.D., Haynes and Boone	CN434: Receiver Signal Processing for Future GNSS Signals - Advanced Olivier Julien, ENAC	CN445: GNSS Antennas II - Special Topics Chris Bartone, Ohio University	CN463: Applications of Strapdown Inertial Navigation II - Integrated Inertial Navigation Systems Andrey Soloviev, University of Florida	CN 483: Fundamentals of GPS/INS Integration II Mohinder S. Grewal, California State Univ, Fullerton



Dr. Chris G. Bartone, P.E. is a professor at Ohio University with over 27 years of experience in communications, navigation, and surveillance systems. He received his Ph.D. EE from Ohio University in 1998, a MSEE from the Naval Postgraduate School in 1987, and BSEE from Penn State in 1983. He previously worked for the Naval Air Warfare Center, performing RDT&E on CNS systems. Chris is a recipient of the RTCA William E. Jackson Award for his outstanding contribution to aviation in the area of DGPS. At Ohio University, Dr. Bartone has developed and teaches a number of GPS, wave propagation, radar and antenna classes. His research concentrates on all aspects of navigation. He is a member of the ION, the IEEE, and the ILA. He is very active with the ION; chaired several programs; served on the ION Council as Chair, ION Outreach Committee; Eastern Region VP, Air Representative, and is currently the Editor of the, ION Virtual Navigation Museum. Chris is a licensed professional engineer in the state of Ohio, and President of GNSS Solutions® Ltd.



Thomas A. Stansell is a pioneer of satellite navigation with over 50 years of experience, beginning in 1960 at the Johns Hopkins University Applied Physics Laboratory where he helped develop the Transit Navigation Satellite System, particularly the world's first surface ship satellite navigation receiver and the world's first portable Doppler geodetic survey instrument. Later with Magnavox, Leica, and now as independent consultant he has led many firsts in GPS, and Glonass receiver technology and played a key role and contributed crucial ideas to the design of all modernized GPS signals: L5, L2C, M-code, and L1C, with lead roles for L2C and L1C. He is an ION Fellow and has received multiple awards, including: GPS JPO Navstar, ION Weems, IEEE PLANS Kershner, and ION Kepler. Tom is an influential GPS consultant advising the GPS Wing and other organizations on GNSS modernization issues.



Dr. Sergey G. Revniykh is Deputy Director General of the Central Research Institute of Machine Building, leading institute of Federal Space Agency, head of PNT Analysis and Information Center. He is a member of the management of the Federal GLONASS Program. Graduated Moscow Aviation Institute, flight dynamic engineer in 1978. Received Ph.D. in Moscow Aviation Institute in 2006. Dr. Revniykh will be assisted with a team of Russian technical experts for the CN428 Glonass course.



Dr. Gary J. Edwards is a partner in the Haynes and BooneIP group in San Jose, CA. He has extensive experience in patent, patent litigation, patent prosecution, and IP licensing. Dr. Edwards has a strong background in Physics and Materials Science and broad experience in protecting diverse technologies including semiconductor, telecommunications, nanotechnologies (e.g., MEMS), and remote sensing devices. Dr. Edwards received his Juris Doctor degree from The University of Pittsburgh School of Law, 1997, his Ph.D. and M.S. in Physics from The University of Connecticut, 1989, and 1982, respectively, and a B.S., Physics, from The University of Vermont, cum laude in 1981. Dr. Edwards has co-authored 28 refereed journal publications and holds bar membership with the California Bar Association and the U.S. Patent and Trademark Office.



Steve Levitan, a partner in the IP group in the San Jose, CA office of Haynes and Boone, specializes in IP litigation and licensing. Steve has extensive experience in patent, trademark, copyright, trade secret, antitrust, unfair competition, false advertising, and technology contract disputes. His litigation experience encompasses trial and appellate work in federal courts,

California and Oregon state courts, the ITC, as well as arbitrations. Steve has representative experience with a wide variety of technologies including GPS. Steve received his Juris Doctor degree from The University of Michigan Law School, cum laude, and a B.A. from Stanford University. He is a member of the State Bar of California and the Santa Clara County Bar Associations.



Dr. Tony Pratt has over 40 year of experience with Signal Processing and GPS. He graduated with a B.Sc. and Ph.D. in Electrical Engineering from Birmingham University, UK in 1967. He has held teaching positions at Loughborough University, UK, Yale University, IIT, New Delhi, University of Copenhagen, and holds a full special professorship at University of Nottingham; his teaching is primarily in signal processing, electronics, probability theory, and satellite navigation system design. He has worked for or consulted to industry for Navstar Ltd, Peak, Parthus, QinetiQ Ltd, UK, Cambridge Positioning Systems, now part of the CSR plc group, and European Space Agency. Dr. Pratt is a Consultant to the UK Government in the development of the Galileo Satellite System and has played key roles in the signal design and international negotiations. He runs two companies, OrbStar Consultants and OrbStar Ltd providing various services to the GNSS sector. Dr Pratt has published numerous papers on signal processing, sonar, and satellite navigation. He published more than 50 papers and holds over 40 patents.



Dr. Christophe Macabiau graduated as an electronics engineer in 1992 from the ENAC (Ecole Nationale de l'Aviation Civile) in Toulouse, France. Since 1994, he has been working on the application of satellite navigation techniques to civil aviation. He received his Ph.D. in 1997 and has been in charge of the signal processing lab of the ENAC since 2000. His research now also applies to vehicular, pedestrian and space applications, and includes advanced GNSS signal processing techniques for acquisition, tracking, interference and multipath mitigation, GNSS integrity, as well as integrated GNSS-inertial systems and indoor GNSS techniques.



Dr. Olivier Julien is an assistant professor with the Signal Processing and Telecommunications laboratory of ENAC, Toulouse, France. He received his PhD from the Department of Geomatics Engineering at the University of Calgary, Canada. He is involved in many R&D projects including GNSS receiver design, multipath and interference mitigation techniques, and GNSS interoperability. He is the recipient of the 2006 Bradford W. Parkinson award.



Dr. Sanjeev Gunawardena is a Senior Research Engineer with the Ohio University Avionics Engineering Center (AEC). He is the primary developer of the multi-frequency instrumentation-grade FPGA-based next-generation GNSS receiver used for scientific research at AEC. In 2002, he demonstrated the first-documented real-time continuously-processing implementation of the FFT-based GNSS parallel code correlation algorithm and the first known reconfigurable GPS receiver employing both time and frequency-domain processing in its baseband processor. He was awarded the 2007 RTCA William E. Jackson Award for his outstanding contribution to aviation for the application of transform-domain GNSS receiver technology. Dr. Gunawardena received his B.S. in engineering physics, BSEE, MSEE, and Ph.D. in EE from Ohio University. He has taught courses in ASIC design, VHDL, FPGA design, GNSS signal processing and advanced satellite navigation.



Dr. Matthew Lashley is a research engineer with Navigation Technology Associates, Inc. and a former member of the GPS and Vehicle Dynamics Lab (GAVLAB) at Auburn University. He received his B.S., M.S., and Ph.D. from Auburn University in electrical engineering in 2004, 2006, and 2009, respectively. His research has focused on vector tracking algorithms and deep integration architectures for GPS receivers, and his areas of research interest are navigation, signal processing, radar, and optimal estimation.



Dr. Kevin Dutton received his BS in Aeronautical Engineering from Rensselaer Polytechnic Institute in 1988 and his MS degree in Astronautics from the George Washington University in 1993. In 1989 he began work at NASA Langley Research Center on advanced spacecraft trajectory optimization. In 1993 he worked in the area of GPS to obtain his PhD in EE from Ohio University in 2003, studying various aspects of the GPS and INS, including attitude determination, relative navigation, and tightly coupled GPS/INS Kalman filter design. In 2004, Dr. Dutton accepted a position with Honeywell in Clearwater, Florida as the lead designer of the Sea-Based JPALS GPS/INS relative navigation Kalman filter. He is also involved in the Navy Unmanned Combat Air System (UCAS) ship system design and inertial sensor modeling and simulation for the Joint Strike Fighter program.



Dr. David Bevy received his B.S. from Texas A&M University in 1995, M.S. from Massachusetts Institute of Technology in 1997, and Ph.D. from Stanford University in 2001 in mechanical engineering. He joined the faculty of the Department of Mechanical Engineering at Auburn University in 2001 and is currently an associate professor. Dr. Bevy's research focuses on vehicle dynamics as well as modeling, control, and navigation of ground vehicle systems. Specifically, Dr. Bevy has developed methods for identifying critical vehicle parameters using GPS and inertial sensors as well as algorithms for control of off-road vehicles including participation in the past DARPA Grand Challenges.



Dr. Andrey Soloviev is a Research Assistant Professor at the University of Florida. Previously he served as a Senior Research Engineer at the Ohio University Avionics Engineering Center. He holds B.S. and M.S. in Applied Mathematics and Physics from Moscow University of Physics and Technology and a Ph.D. in Electrical Engineering from Ohio University. His current research focuses on all aspects of multi-sensor integrated navigation and applications of synthetic aperture signal processing techniques for GNSS. Andrey currently serves as the ION Land Representative. He received the RTCA William E. Jackson Award in 2002 for the development of frequency-domain INS algorithms and the ION Early Achievement Award in 2006 for outstanding contributions to deeply integrated Inertial/GPS and advanced GPS signal processing.



Dr. Mohinder S. Grewal, P.E., coauthored Kalman Filtering: Theory & Practice Using MATLAB Third Edition (Wiley & Sons, 2008) and GPS, Inertial Navigation, & Integration Second Edition (Wiley & Sons, 2007). Dr. Grewal has consulted with Raytheon Systems, Geodetics, Boeing Company, Lockheed-Martin, and Northrop on application of Kalman filtering. He has published over 60 papers in IEEE and ION refereed journals and proceedings, including the ION's Redbook. Currently, Dr. Grewal is Professor of EE at California State University, Fullerton, in Fullerton, California, where he received the 2009 Outstanding Professor award. He is an architect of the GEO Uplink Subsystem (GUS) for WAAS, including the GUS clock steering algorithms, and holds two patents in this area. His current research interest is in the area of application of GPS, INS integration to navigation. Dr. Grewal is a member of the ION, Senior Member of IEEE, and a Fellow of the Institute for the Advancement of Engineering.

Images: GPS SV image courtesy Lockheed Martin. Galileo satellite image courtesy ESA - P. Carri

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TRACK 1 MONDAY AM & PM

Updated

MONDAY, 8:30am-12:00 pm, Room C120
CN405 Fundamentals of GNSS I with emphasis on GPS (3.0 CEU)
Dr. Chris Bartone, P.E., Ohio University

This course emphasizes the fundamentals of GNSS with emphasis on GPS. The course begins with a solid overview of GNSS and GPS. The core functions that need to be performed in obtaining a user solution using GPS in an error free environment will be explained. The course concludes with an illustration of a user state calculation, performance metrics (i.e., DOPs) and an error budget for GPS.

The major topics include:

- Introduction to Positioning and GNSS
- GPS Segments: Control, Space, User
- Coordinate frames and datum's used in GNSS
 - ECI, ECEF, LLH, MSL, WGS-84, ITRF, conversions, etc.
- GPS signal structure formats for current and future signals.
 - Basic/Legacy GPS: C/A, P(Y) code formats
- Modernized GPS, Galileo, Glonass (Overview)
- GPS Link Budget
- GPS Navigation Message Data Format Descriptions
- Calculation of the GPS space vehicle (SV) position using the broadcast Kepler parameters (ephemeris and almanac)
- GPS Time Considerations
- Calculation of user state (i.e., position and time)
- Associated performance parameters (i.e., dilution of precision)
- GPS error budget (overview)

Updated

MONDAY, 1:30pm-5:00 pm, Room C120
CN406 Fundamentals of GNSS II with emphasis on GPS (3.0 CEU)
Dr. Chris Bartone, P.E., Ohio University

This course emphasizes the fundamentals of GNSS with emphasis on GPS in the presents of various error sources. The course provided details on the source and nature of various error source in GNSS, their impact, and methods for mitigation. Differential GNSS will be presented to include correction-based, measurement-based, single, double, and triple differencing techniques. The course includes illustrations of an error mitigated user state calculation with real GPS data for stand-alone, correction-based, measurement-based, and triple differenced user solutions.

Major topics include:

- GPS error budget (review)
- Overview of GNSS receiver and antenna technologies and tracking loops
- Atmosphere Errors:
 - Troposphere error sources and characterization, models and mitigation
 - Ionosphere error sources and characterization, models and mitigation
 - Single and dual-frequency mitigation
- Satellite orbit and clock errors, and mitigation methods
- Signal Multipath Error characterization and mitigation techniques
- Smoothing
- Code-minus-Carrier and Code-Carrier-Divergence Analysis
- GNSS Receiver Autonomous Integrity Monitoring (RAIM)-overview
- Precise Point Positioning
- Differential GNSS (DGNSS) and different ways to implement it.
 - Correction-based methods
 - Example systems: NDGPS, WAAS, LAAS.
 - Measurement-based methods
 - Single, Double, and Triple-differencing

TRACK 2 MONDAY AM & PM

Updated

MONDAY 8:30am-12:00pm, Room C121
CN425: Future GNSS Signals and Systems with emphasis on Galileo (3.0 CEU)
Dr. Tony Pratt, Orbstar Consultants

This course provides a solid foundation of GNSS signal formats, basic concepts in signal decoding and emphasizes the new signal and services for Galileo and other providers. Details on GNSS signal formats, spreading codes, and their characteristics are provided. The main topics include:

GNSS System Overview:

Introduction to different GNSS Signals and Providers:

- GPS, Glonass, Galileo, Compass, IRNSS, QZSS
 - Status of Navigation Systems deployment
 - GIOVE A & B – new technology initiatives
- Spread Spectrum Signal Characteristics
- Description of different spreading modulation
 - CDMA, BPSK, BOC, AltBOC, MBOC, TMBOC, CBOC, FDMA
- Basic Concepts in Signal reception, acquisition, tracking & decoding
- Signal Spectra in L1, L2, L5, E1, E5, E6
 - Signal ranging requirements for satellite navigation
- Signal Multiplexing – different ways for hosting many services on a single carrier
 - Phase Plane Plots
 - Quadrature phase, Interplex, Modified Interplex, CASM, Majority Voting
 - Data bearing and pilot signals, data rates
- Navigation Message Overview
- GPS and Galileo

Updated

MONDAY 1:30pm-5:00pm, Room C121
CN426 Future GNSS Signal Performance with emphasis on Galileo (3.0 CEU)
Dr. Tony Pratt, Orbstar Consultants

This course provides a solid foundation for the performance of GNSS signal formats and emphasizes the new signal and services for Galileo. Details on GNSS signal spreading codes and their performance in noise, multipath, and interference are provided. Additionally, the performances of the Galileo signals are characterized with respect to the GPS signal formats. Major topics include:

- Basics of Satellite Measurements
- Code and Carrier Tracking
 - New layers of complexity?
 - Pseudo-range (and the various definitions) and tri-lateration
 - Simple location solutions
 - Measurement ambiguity – a problem solved using new signals?
 - Measurement and solution accuracy
 - User range error
 - Cramer-Rao Lower bound
 - Signal and noise levels
- Noise and Interference Levels for GNSS Signals:
- Interference definitions for GNSS spreading codes
 - Inter & Intra interference between Galileo & GPS
 - Spectral Separation Coefficients (SSC) with lists for SSC values
 - Multipath consideration for Galileo & GPS signals
 - Historic and modern mitigation techniques
 - Gabor bandwidth

TRACK 3 MONDAY AM & PM

Updated

MONDAY, 8:30am-12:00pm, Room C122
CN431 GNSS Receiver Design I: RF Front-End Theory and Design (3.0 CEU)
Dr. Sanjeev Gunawardena, Ohio University

This course is the first of a two-part sequence covering the design and practical implementation of GNSS receivers using the latest developments in RF and digital signal processing technologies. This first course covers the design of single and multiband GNSS RF front-ends. The course material is presented from both a theoretical and practical perspective using case studies.

- GNSS signals overview: Link budget, signal structure, power spectrum, spreading codes, correlation properties, thermal noise, and system noise figure.
- GNSS front-end architectures: Single versus dual conversion, analog versus digital down-conversion, direct RF sampling.
- Frequency planning and control: Image frequencies, bandwidth and filter selection, reference clock types and parameters, PLL synthesizers, phase noise, and cost-performance tradeoffs.
- RF/IF components: Parameters important to GNSS signal processing: component selection guidelines for amplifiers, filters, mixers and oscillators.
- Implementation intricacies: component-induced multipath, crosstalk, etc.
- Sampling subsystem: ADC specifications, impact of sampling resolution and jitter, automatic gain control, dynamic range considerations.
- GNSS front-end design techniques and case studies
 - o Modular design using connectorized components
 - o PCB-level design using discrete RF components
 - o Commercial GNSS MMICs for portable electronics

Updated

MONDAY, 1:30pm-5:00pm, Room C122
CN432 GNSS Receiver Design II: Baseband Signal Processing and Implementation (3.0 CEU)
Dr. Sanjeev Gunawardena, Ohio University

This course is the second of a two-part sequence covering the design and practical implementation of GNSS receivers using the latest developments in RF and digital signal processing technologies. This second course covers digital signal processing techniques. The course material is presented from both a theoretical and practical perspective using case studies.

- GNSS signals overview: Signal structures of GPS and Galileo.
- Signal correlation: Time, frequency, and transform-domain techniques. Coherent versus non-coherent integration. Advanced correlator architectures for multipath mitigation and signal quality monitoring.
- Processing complexity: complexity vs realtime implementation.
- Signal Acquisition: threshold statistics, search algorithms, fast acquisition techniques.
- Acquisition-to-tracking transition: Acquisition verification, bit synchronization, and false-lock detection techniques.
- Tracking: FLL, PLL and DLL, loop tightening/transitioning techniques, noise bandwidth, tracking performance, block (batch) processing and loopless tracking techniques.
- Measurement computation: Navigation datatbit extraction and decoding, TOT and TOR counters, pseudorange and carrier-phase measurements.
- Implementation techniques and platforms (including case studies):
 - o Matlab®-based non-realtime algorithms
 - o Bitwise software algorithms for general-purpose microprocessors
 - o FPGA-based processing engines and design overview
 - o Commercial GPS processor chipsets

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TRACK 1 TUESDAY AM & PM

TUESDAY, 8:30am-1:00pm, Room C120
CN428 Glonass Fundamentals & Modernization (3.0 CEU)
Dr. Sergey Revnivikh, Central Research Institute of Roscosmos & others

Back by Popular Demand

This course will be taught by a team of Russian technical experts that emphasizes the fundamental and modernization of Glonass. The course includes the history, status and state policy of Glonass followed by the details of the system architecture. Glonass system time, signal processing, tools, and user equipment are covered. This is a rare opportunity to have direct hands-on interactions with the technical experts on Glonass. The main topics to be covered by this course are:

- GLONASS history, status and State Policy
- GLONASS system architecture:
 - Space Segment (orbital constellation features, GLONASS satellites)
 - Ground Control Segment
 - Modernization plans
- GLONASS system time architecture, synchronization issues
- GLONASS signals and processing
- Russian national programs and tools of Earth Rotation Parameters determination for GLONASS support
- GLONASS User Segment and Applications

TUESDAY, 1:30pm-5:00pm, Room C120
CN360 Intellectual Property and Patents (3.0 CEU)
Dr. Gary J. Edwards, J.D., Haynes and Boone
Steve Levitan, J.D., Haynes and Boone

NEW

This course emphasizes the fundamentals of intellectual property and patents. The course provides a solid basis for understanding intellectual property, patents, and aspects of protecting intellectual property including patent application, issuance, enforcement, and defense. Major topics include:

Acquisition of Intellectual Property Rights

- Forms of Intellectual Property
- Inventions
- Requirements for a valid patent
- Patent prior art research
- Patent Application Timing
- Types of Patent Applications
- Preparation of the patent application
- After-filing – Patent Prosecution
- After Issuance of the US application
- International Patent Prosecution

Enforcement and Defenses from the Enforcement Actions of Others

- Enforcement of your Patent Rights
- Defending against the assertion of others
- The life of a patent litigation

Images: GPS SV image courtesy Lockheed Martin, Galileo satellite image courtesy ESA - P. Carril

TRACK 2 TUESDAY AM & PM

TUESDAY, 8:30am-12:00pm, Room C121
CN433 Receiver Signal Processing for Future GNSS Signals - Introduction (3.0 CEU)
Dr. Olivier Julien, Ecole Nationale de l'Aviation Civile (ENAC)

Updated

This course concentrates on future GNSS (with emphasis on GPS and Galileo) signal processing and aspects in GNSS receiver design and performance. It also provides an evaluation of the future signals with respect to the current GPS C/A signal in terms of receiver performance and complexity. The main topics:

Reminder on future transmitted civil GNSS signals:

- Binary Offset Carrier (BOC) modulation, pilot channel and secondary code,
- Structure of future GPS and Galileo civil signals on L1/E1 and L5/E5 bands: Components, modulations (BPSK, QPSK, MBOC, TMBOC, CBOC, ALTBOC) and spectral representation

The correlation operation:

- Correlator output model in the presence of thermal noise,
- GPS and Galileo main correlation functions

Acquisition of future GNSS signals:

- Joint data/pilot acquisition detectors,
- Impact of BOC-based modulations on acquisition performance, and
- Secondary code acquisition

Phase tracking architectures and performances of future GNSS signals:

- Use of the pilot channel for phase tracking, and
- Phase tracking performance using future GPS and Galileo signals

Code tracking architectures and performances of future GNSS signals:

- Use of the pilot and secondary code for code tracking,
- Investigation of basic BOC tracking
- Tracking of BOC-based signals and application to future GPS and Galileo signals: (architecture, performance in thermal noise, tracking ambiguity problem)

TUESDAY, 1:30pm-5:00pm, Room C121
CN434 Receiver Signal Processing for Future GNSS Signals - Advanced (3.0 CEU)
Dr. Olivier Julien, Ecole Nationale de l'Aviation Civile (ENAC)

Updated

This course provides an excellent overview of future GNSS signal processing and the many aspects that affect GNSS receiver performance. The course first investigates specific receiver tracking architectures dedicated to future civil GNSS signals, and then characterizes the resistance of these signals towards-multipath and interference environments with respect to GPS C/A.

The main topics to be covered by this course are:

Advanced code tracking architectures:

- Introduction to typical tracking techniques against BOC-related tracking ambiguity,
- MBOC tracking for wide-band and narrow-band receivers, and
- ALTBOC tracking for wide-band and very-wide-band receivers

Multipath effects on tracking:

- Multipath model and impact on code and phase tracking
- Phase tracking multipath envelopes for future GNSS civil signals
- Code tracking multipath envelopes for future GNSS civil signals

Interference effects on tracking:

- Main interference threats and models in L1 and E5 bands
- Impact of future GNSS signals' structure on the receiver capability to mitigate narrow- and wide-band interference
- Introduction to pulsed interference effects and mitigation on GPS L5 and Galileo E5

TRACK 3 TUESDAY AM & PM

TUESDAY, 8:30am-12:00pm, Room C122
CN441 GNSS Antennas I - Fundamentals (CEU: 3.0)
Dr. Chris Bartone, P.E., Ohio University

Updated

This course emphasizes the fundamentals of antenna for GNSS. A solid basis for understanding fundamentals of antennas, antenna types, design, development, tests, and implementation aspects of GNSS antennas will be covered including:

- Fundamentals of Antennas:
 - Antenna pattern and field descriptions
 - Mismatch losses (Γ , SWR, polarization)
 - Wave and antenna polarization
 - Antenna and receiver noise figure considerations
 - Antenna aperture and the Friis transmission equation
- Antenna Types: linear, helix, patches, arrays
- GNSS Antennas & the GPS SV49 Issues
- Common GNSS User Antennas
- Antenna Siting Issues: Mask angle, multipath, etc.
- Antenna Multipath considerations: design, metrics, and technology comparison (patch, survey, integrated multipath limiting antenna (IMLA))
- Test/Design and Evaluation:
 - Computer simulation tools
 - Component level evaluations
 - Antenna test range options
 - Field test characterization
- Phase and group delay calibration (overview)

TUESDAY, 1:30pm-5:00pm, Room C122
CN445 GNSS Antennas II – Special Topics (3.0 CEU)
Dr. Chris Bartone, P.E., Ohio University

Updated

This course present information on special and advanced topics related to GNSS antennas for particular applications, which are important to many users. Antenna measurement effects and specialized antennas to maximize GNSS performance will be presented. Major topics include:

- Multi-band GNSS Antennas for Modernized GPS, Galileo & Glonass :
 - Broadband and Multi-band antennas: Spiral, Helical Antennas, etc.
 - Some Industry Examples (e.g, Pinwheel spiral antenna, Geodetic type antenna, Multi-band stacked patch antennas, etc.)
- Multipath Considerations for GNSS Antennas
- Ground Plane effects on GNSS antennas
- Active GPS Antennas specification of the G/T Ratio
- Antennas for Assisted-GPS
- Adaptive Antenna Arrays:
 - Arrays for Reducing Interference and Jamming,
 - Introduction to Power Inversion
 - Nulling Antenna Arrays
 - Space Time Adaptive Processing (STAP)
 - Space Frequency Adaptive Processing (SFAP)
 - Digital Beam Forming Antenna Arrays
- Antenna Effects on GNSS Observables:
 - Phase Variation and mitigation
 - Group/code variation and mitigation

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TRACK 4 MONDAY AM & PM

Updated

MONDAY, 8:30am-12:00 pm, Room C120
CN460 Introduction to Strapdown Inertial Navigation Systems I (3.0 CEU)

Dr. Kevin Dutton, Honeywell International

This course emphasizes the physics and mathematics of strapdown inertial navigation systems. It provides sufficient information for the user to construct their own free inertial navigation solution. Main topics include:

- Basic inertial navigation with two-dimensional examples
- Vector and matrix notation and mathematics
- Coordinate frames: Inertial, Earth-Centered, Earth-Fixed, Local-Level (East/North/Up, North/East/Down, Wander), Body, transformations
- Attitude Fundamentals and Representations
 - Direction Cosine Matrix (DCM)
 - rotation vector and Euler angles
 - quaternions
- Earth geoid and gravity model
- Strapdown inertial navigation equations
- Vertical channel dynamics
 - inherent instability in vertical channel
 - stabilization of vertical channel using external information
- Coning and sculling
 - Definitions and compensation
- Integration of navigation equations
 - attitude update
 - velocity update
 - position update

MONDAY, 1:30am-5:00 pm, Room C120
CN461 Introduction to Strapdown Inertial Navigation Systems II (3.0 CEU)

Dr. Kevin Dutton, Honeywell International

This course emphasizes the fundamentals of strapdown inertial navigation sensors – the types of sensors and their errors and their behavior. The course also discusses sensor and system specifications. Main topics include:

- Strapdown inertial navigation error equations and performance
- Alignment techniques
 - gyro-compass alignment
 - in-flight alignment
 - at-sea alignment
 - transfer alignment
- Inertial sensors
 - gyroscopes
 - accelerometers
- Sensor errors and error models
 - Gauss-Markov random process
 - bias
 - scale factor
 - misalignment
 - non-orthogonality
 - size effects
- Sensor calibration techniques
- Sensor specifications
- Inertial navigation system performance and specifications

TRACK 5 MONDAY AM & PM

Updated

MONDAY, 8:30am-12:00pm, Room C125
CN480: Fundamentals of Kalman Filtering for GPS/INS Integration I (3.0 CEU)

Dr. Mohinder S. Grewal, P.E., California State University, Fullerton

This course emphasizes the fundamentals of Kalman filtering with application to GPS/INS integration. It addresses subtleties, problems, and limitations of estimation theory as applied to real world situations encountered in GPS, INS, and navigation and provides application examples. Attendees are encouraged to bring their laptop with Matlab® to these courses.

Main topics include:

- What is a Kalman Filter
- Discrete Kalman Filter
- Continuous Kalman Filter
- Relationship Between Discrete and Continuous Process Noise
- Shaping Filters
- Example (1 State)
- Example (6 States) with MATLAB®
- Measurements as Scalars (No Matrix Inversion)

MONDAY, 1:30pm-5:00pm, Room C125

Updated

CN 481: Fundamentals of Kalman Filtering for GPS/INS Integration II (3.0 CEU)

Dr. Mohinder S. Grewal, P.E., California State University, Fullerton

Fundamentals Part II continues topics from Part I. This course discusses fundamentals of Kalman filtering application to non-linear systems and emphasizes implementation issues as applied to GPS and INS. Attendees are encouraged to bring their laptop with Matlab® to these courses.

Main topics include:

- Nonlinear Kalman Filters
- Examples
- Sigma Point Kalman Filter (Unscented)
- Square Root Filtering
- Example with MATLAB®
- Prefiltering and Data Rejection
- Divergence and Effective Cures
- Kalman Filter Engineering
- Nonlinearity Considerations
- Suboptimal Filtering
- Kalman Filter Monitoring
- Monitoring Filter Health

TRACK 1 MONDAY EXTENDED EVENING

Updated

MONDAY, 6:45pm-9:30pm, Room C120
CN420: GPS Modernization and Relation to other GNSS (2.5 CEU)

Thomas Stansell, Stansell Consulting

This course provides information on many aspects of GPS modernization and how these efforts relate to other GNSS systems; the course covers topics on GPS modernization, including signals and satellite capabilities, interoperability with Galileo signal formats and services, QZSS, Glonass, Compass and other GNSS concepts. Major topics include:

- Motivations for modernization
- GPS Modernization:
 - L2C, L5, M-code, and L1C signals
 - Galileo interoperability
 - Improved GPS III functionality
 - Program status, schedule and new capabilities
- Relationship to other GNSS
 - Quasi-Zenith Satellite System (QZSS)
 - Galileo
 - Glonass
 - Chinese Compass and Beidou-2
 - Indian Regional Satellite System
- GNSS Compatibility and Interoperability
- Interoperability improvement opportunities
- Performance improvement opportunities

TRACK 2 MONDAY EXTENDED EVENING

Updated

MONDAY, 6:45pm-9:30pm, Room C121
CN413 GNSS Integrity and RAIM (2.5 CEU)

Dr. Christophe Macabiau, ENAC

This course provides information on obtaining integrity in GNSS applications. The course begins with an overview of the different ways to obtain GNSS integrity for civil aviation, followed by details on receiver autonomous integrity monitoring (RAIM) approach. The course concludes addressing future applications of RAIM with Multi-GNSS constellations and other than aviation applications (i.e., land). Major topics include:

GNSS Integrity for civil aviation:

- Requirements for civil aviation applications
- Integrity monitoring techniques: ABAS, GBAS, SBAS, Galileo GIC
- RAIM Fault detection, Fault Exclusion

RAIM for NPA and APV

- Nominal measurement model (UERE, nominal biases, correlation time)
- Threat model (single or multiple failures, failure probability distribution)
- Internal probabilities (from application specifications and threat model)
- LSR RAIM Detection criterion (fault detection, fault exclusion)
- LSR RAIM Horizontal and Vertical Protection Level (PL) computation
- Assumptions for RAIM performance evaluation

Future of RAIM:

- GPS/Galileo RAIM for civil aviation
- ARAIM (i.e., Absolute RAIM adapted with low-update rate monitoring)
- RAIM for other applications (e.g. land vehicle).

Images: GPS SV image courtesy Lockheed Martin, Galileo satellite image courtesy ESA - P. Carril

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TRACK 4 TUESDAY AM & PM

TUESDAY, 8:30am-12:00pm, Room C120

CN462 Applications of Strapdown Inertial Navigation I (3.0 CEU)

Dr. Andrey Soloviev, University of Florida

Updated

This course focuses on practical applications of the strapdown inertial technology. Types of inertial applications are discussed. Challenges of using strapdown inertial navigation system (INS) for practical application areas are addressed. Specific application examples for stand-alone and integrated INS navigation are considered with the emphasis on INS specification requirements and INS performance characteristics. Main topics include:

- Types of strapdown INS applications:
 - Stand-alone applications
 - INS as a core part of integrated navigation systems
- Inertial sensors:
 - Sensor specifications – what do they mean and how to “read” them
 - Main sensor technologies, their current state and perspectives
- Challenges of using strapdown inertial in practical application areas:
 - Sensor and packaging errors
 - Vibrations
 - Sculling and coning errors
- Example stand-alone INS applications:
 - Long-term inertial coasting for aviation applications
- Example integrated INS applications:
 - GPS/INS integration for weak GPS signal processing

TUESDAY, 1:30am-5:00pm, Room C120

CN463 Applications of Strapdown Inertial Navigation II - Integrated Inertial Navigation Systems (3.0 CEU)

Dr. Andrey Soloviev, University of Florida

Updated

This course considers the use of inertial navigation system (INS) for multi-sensor integrated applications. The emphasis is on the integration of INS with GNSS-alternative navigation aids such as video cameras and laser radars. The course introduces a generic approach for multi-sensor fusion that uses INS as a core navigation sensor. Types of the integrated solution are discussed and specific integration examples are provided. As a particular case study, the multi-sensor fusion approach is applied to integrate the INS with laser radar (Lidar) for navigation in GNSS-denied environments. Main topics include:

- Generic approach for INS-based multi-sensor navigation
- Review of Kalman filter principles
- Types of the multi-sensor integrated solution
 - Loose integration
 - Tight integration
 - Deep integration
- Range domain formulation of the INS-based multi-sensor fusion
- Case study: Lidar/INS integration for GNSS-denied navigation
 - Introduction to lidar-based navigation
 - Two-dimensional INS/lidar mechanization
 - Extension into a three-dimensional case
 - Performance demonstration with actual data

TRACK 5 TUESDAY AM & PM

TUESDAY, 8:30am-12:00pm, Room C125

CN 482: Fundamentals of GPS/INS Integration I (3.0 CEU)
Dr. Mohinder S. Grewal, P.E., California State University, Fullerton

Updated

This course covers the fundamentals of inertial navigation equations in Strapdown systems, GPS/INS configurations, integration and modeling of INS errors. Attendees are encouraged to bring their laptop with Matlab® to these courses.

Main topics include:

- Fundamentals of Inertial Navigation
- Coordinate Transformations (Inertial, ECEF, Tangent, Geographic Frames)
- INS Descriptions
- INS Kinematic Equations
- INS Vertical Channel Instability, Schuler Oscillation, Coriolis Effect, Coning and Sculling, and Gravity Modeling
- Sensor Specifications and Models
- Sensor Error Models (Accelerometer and Gyro Error Modeling)
- Application of Kalman Filtering to Inertial Navigation Systems and GPS with Examples
 - Feed Forward/Feedback Configuration
 - Tightly/Loosely Coupled
 - Deep INS/GPS
- INS Error Models for Strapdown System (23 States)
- Extended Kalman Filter Mechanization and Software Modules

TUESDAY, 1:30pm-5:00pm, Room C125

CN 483: Fundamentals of GPS/INS Integration II (3.0 CEU)
Dr. Mohinder S. Grewal, P.E., California State University, Fullerton

Updated

Building on Part I topics, this course gives examples of tightly and loosely coupled systems to large scale problems, such as 8, 11, 17, 21 and 23 states with GPS and DGPS. Attendees are encouraged to bring their laptop with Matlab® to these courses.

Main topics include:

- Simplified Models for Strapdown System
- INS Error Models and Sensor Parameters
- INS Mechanization Equations
 - INS Error State Dynamic Equation
 - Full Error State Model
 - Augmented State Equation
- Tightly Coupled (4 States by Hand)
- 8 Error State Estimation with 4 Pseudorange and 4 Delta Pseudorange with MATLAB®
- Tightly Coupled (8, 11 States with MATLAB®)
- Tightly and Loosely coupled (17 States with MATLAB®)
- Tightly and Loosely Coupled with DGPS (21 States with MATLAB®)

TRACK 3 MONDAY EXTENDED EVENING

Monday, 6:45pm-9:30pm, Room C122

CN435 Vector Tracking Theory and Implementation (2.5 CEU)
Dr. Matthew Lashley, Navigation Technology Associates

NEW

This course provides an overview of GNSS receiver vector tracking algorithms, their performance, and implementation. The course begins with a review of the standard, scalar tracking loops then introduces vector tracking. The differences between scalar and vector tracking loops are explored. The performance of vector tracking relative to scalar tracking loops is discussed in detail. The course then focuses on the implementation of vector tracking loops addressing: correlator processing, carrier-to-noise power density ratio estimation, and implementation of the vector tracking Kalman filter.

Course Content:

- Traditional receiver architectures (reviewed):
 - principles of GNSS receiver operation
 - tracking loop operation
 - PVT determination from the signal parameters.
- Vector tracking: relation to the traditional receiver: combining signal tracking and PVT estimation into a single algorithm
- Position and pseudorange state formulations of vector tracking: designing the vector tracking Kalman filter
- Performance improvement from vector tracking vs scalar tracking loops
- Predicting the GNSS signals from the vector tracking Kalman filter states
- Correlator processing to produce measurements
- Measurement update of the vector tracking Kalman filter
- Federated vector tracking architectures:
 - Design and operation of federated vector tracking, architectures, optimization.
- Deep integration/ultra tight coupling: discussion of integrating inertial measurement units with vector tracking algorithms.

TRACK 4 MONDAY EXTENDED EVENING

MONDAY, 6:45pm-9:30pm, Room C120

CN473 Land Navigation using Integrated Systems Implementation (2.5 CEU)

Dr. David M. Bevly, Auburn University

Updated

This course emphasizes the fundamentals of integrated navigation systems for land vehicles applications. The course reviews common sensors used in integrated navigation systems such as: GPS, INS, IMU, odometer, vision, and Lidar for navigation in benign and GPS denied environments. The course includes examples of work on a variety of vehicles with illustrations of navigation and estimation results. Major topics include:

- GPS/INS Integration for Vehicle dynamics
- Brief overview of GPS and its errors
- IMU modeling and ground vehicle dead-reckoning errors
- Introduction of the Kalman Filter
- Ground Vehicle Dynamics
- Ground vehicle models
- Estimation of vehicle navigation states and parameters
- Integration of additional navigational signals
- Vision, Lidar, Doppler radar, odometer
- Application Examples
- DARPA Grand Challenge
- John Deere Auto Steer Tractor, and others.

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	TRACK 1	TRACK 2	TRACK 3	TRACK 4	TRACK 5
Monday AM 8:30-12:00	<input type="checkbox"/> CN405: Fundamentals of GNSS I (Chris Bartone)	<input type="checkbox"/> CN425: Future GNSS Signals & Systems with emphasis on Galileo (Tony Pratt)	<input type="checkbox"/> CN431: GNSS Receiver Design I: RF Front-End Theory and Design (Gunawardena)	<input type="checkbox"/> CN460: Intro to Strapdown Inertial Navigation Systems I (Kevin Dutton)	<input type="checkbox"/> CN480: Fundamentals of Kalman Filtering for GPS/INS Integration I (Mohinder Grewal)
Monday PM 1:30-5:00	<input type="checkbox"/> CN406: Fundamentals of GNSS II (Chris Bartone)	<input type="checkbox"/> CN426: Future GNSS Signal Performance with emphasis on Galileo (Tony Pratt)	<input type="checkbox"/> CN432: Receiver Design II: Signal Processing (Sanjeev Gunawardena)	<input type="checkbox"/> CN461: Intro to Strapdown Inertial Navigation Systems II (Kevin Dutton)	<input type="checkbox"/> CN 481: Fundamentals of Kalman Filtering for GPS/INS Integration II (Mohinder Grewal)
Monday EVE 6:45-9:30	<input type="checkbox"/> CN420: GPS Modernization and Relation to other GNSS (Thomas Stansell)	<input type="checkbox"/> CN413: GNSS Integrity and RAIM (Christophe Macabiau)	<input type="checkbox"/> CN435: GNSS Receiver Vector Tracking Theory & Implementation (Matthew Lashley)	<input type="checkbox"/> CN473: Land Navigation using Integrated Systems (David M. Bevy)	<input type="checkbox"/> Open (check www.GNSSolutions.com for updates)
Tuesday AM 8:30- 12:00	<input type="checkbox"/> CN428: Glonass Fundamentals & Modernization (Sergey Revnivkykh)	<input type="checkbox"/> CN433: Receiver Signal Processing for Future GNSS Signals - Introduction (Olivier Julien)	<input type="checkbox"/> CN441: GNSS Antennas I - Fundamentals (Chris Bartone)	<input type="checkbox"/> CN462: Applications of Strapdown Inertial Navigation I (Andrey Soloviev)	<input type="checkbox"/> CN 482: Fundamentals of GPS/INS Integration I (Mohinder Grewal)
Tuesday PM 1:30- 5:00	<input type="checkbox"/> CN360: Intellectual Property and Patents (Gary J. Edwards, J.D. & Steve Levitan, J.D.)	<input type="checkbox"/> CN434: Receiver Signal Processing for Future GNSS Signals - Advanced (Olivier Julien)	<input type="checkbox"/> CN445: GNSS Antennas II - Special Topics (Chris Bartone)	<input type="checkbox"/> CN463: Applications of Strapdown Inertial Navigation II – Integrated (Andrey Soloviev)	<input type="checkbox"/> CN 483: Fundamentals of GPS/INS Integration II (Mohinder Grewal)

Registration Information:

Selection: Choose any time slot. An entire track, or move around to suite your needs, see www.GNSSolutions.com/ION_GNSS_2010_Tutorials_Seminars.html for course syllabi, prerequisites, intended audiences, recommendations and updates.

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Times: 7:00 am Coffee/Sign-in begins
8:30 am-12:00 pm Morning Sessions
1:30 pm-5:00 pm Afternoon Sessions
6:45 pm-9:30 pm Extended Evening Sessions

Coffee/drinks/snacks
throughout the day

Register to win: Every paid tutorial attendee will be entered to win a handheld Garmin GPS Nuvi Receiver; one entry for each tutorial.

Registration/Attendees Information:

Name: _____

Organization: _____

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City: _____

State/Prov./Country: _____

Zip/Postal Code: _____

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Preregister me now,
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Certificate of Completion:
Individualized with name, tutorials
and CEUs listed.

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Card Type (circle one): Visa Master Card American Express
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Number of 1/2 day Sessions	Quality You Can Count On – Competitive Pricing			
	Early Registration (Paid by 31 Aug)		Standard Registration (After 31 Aug)	
	Total Cost for 1/2 Day Sessions	Add an Extended Evening Session	Total Cost for 1/2 Day Sessions	Add an Extended Evening Session
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2	\$789	\$308	\$858	\$338
3	\$1099	\$299	\$1,199	\$325
4	\$1,389	\$289	\$1,487	\$314

Total Payment:

Total 1/2 day fees: _____

Extended evening fee: _____

Track 5: Grewal Book, \$98 _____

Total fee due: _____

Images: GPS SV image courtesy Lockheed Martin. Galileo satellite image courtesy ESA - P. Carril

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