GPS/GNSS Courses for 2019

Unsurpassed GPS/GNSS technical training demands experience, expertise and world-class instructors.

NavtechGPS has been the go-to company for GNSS technical training for 35 years!

GNSS Courses Offered in the Following Areas

- Inertial systems, Kalman filtering and GPS / GNSS integration
- GPS/GNSS operations for engineers and professionals
- GPS/GNSS equipment vulnerability assessment and mitigation (for U.S. military groups only)
- Using advanced GNSS signals and systems
- GPS/GNSS fundamentals
- Differential GPS
About Our On-Site and Public Courses

GPS/GNSS Training
NavtechGPS is a world leader in GPS/GNSS education with more than 35 years of experience and a comprehensive list of course offerings. Our courses are taught by world-class instructors who have trained thousands of GNSS professionals.

Our Courses
Our Public Course Venues. We host our most requested courses each year for individuals to attend. Of course, any of our seminars can be brought directly to your location.

Our On-Site Courses. Many of our clients prefer that we bring our classes to them. Our on-site courses are often more economical because there is no travel involved and the per-person fee is lower. On-site training also allows us to tailor a course to your specific needs. You can request one of the classes listed in this catalog or a combination of any of these classes to be taught at your facility. We make it easy for you. We will guide you through the process and help you with the logistics.

Our Experience
We have been presenting our courses internationally and domestically to civil, military and governmental organizations since 1984. Our instructors are leaders in their specialized GNSS fields. Learn from them at our public venues or let us bring their expertise to your team.

Contact Us
We want to provide you with the best possible experience from beginning to end. Please contact me. I would like to answer your questions, register you, and provide you with information about your training options.

Please Call Me
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cmcdonald@NavtechGPS.com

Carolyn McDonald*
CEO, President and Seminar Director

†NavtechGPS is a Florida approved provider for Courses 122 and 346.
Join Us for GNSS Training in NEW ORLEANS, December 9–13

InterContinental New Orleans
Course Location and Hotel Accommodations, December 2019

About the InterContinental New Orleans Hotel
The InterContinental New Orleans is centrally located within a 5-minute walk of the French Quarter and is on the famous St. Charles Trolley Line.

Rooms. Make yourself at home in one of the 484 air-conditioned rooms with complimentary wireless Internet access to keep you connected.

Amenities. Recreational opportunities include a health club and an outdoor pool. Additional features include concierge services, gift shops/newsstands.

Hotel Dining. Grab a bite to eat at one of the hotel’s two restaurants, or take advantage of the 24-hour room service. Snacks are also available at the coffee shop/café. Need to unwind? Take a break at one of the 2 bars/lounges. Buffet breakfasts are available daily from 6:30 AM to 10 AM for a fee.

Special Sleeping Room Rates: $150 Single-Double Occupancy. (This is at or below the U.S. government rate.) Discount rate runs from December 6 through December 16, subject to availability. Cut-off Date to Book at This Rate: November 18, OR as soon as the discount room block sells out. Details at www.NavtechGPS.com. See also registration form for weblink and more details. Hotel Reservations: 1-504-585-4352. Mention NavtechGPS Seminars. Or: https://book.passkey.com/e/49960492
NavtechGPS has been leading the way in GPS/GNSS training for over 30 years. We hire the world’s leading authorities to teach YOU, so you have the latest information to develop top-level skills to execute your mission.

John Betz, Ph.D., is a fellow of The MITRE Corporation. He has contributed to the design of modernized signals including the GPS M-signal and L1C signal, to aspects of receiver processing for modernized signals, and also to systems engineering for GNSS modernization. He has been a key contributor to ongoing technical discussions between the U.S. and other nations developing their own satellite-based navigation and timing (satnav) systems. He is a fellow of the Institute of Navigation (ION) in 2006 and the IEEE, and was a member of the United States Air Force Scientific Advisory Board for eight years, including three years as its chairman. He has received the ION’s Burka Award, Thurlow Award, and Kepler Award. He also was recognized by the International Institute of Associations of Navigation with its John Harrison Award. He is a member of the U.S. National Space-Based Positioning, Navigation, and Timing Advisory Board. His publications include Engineering Satellite-Based Navigation and Timing: Global Navigation Satellite Systems, Signals, and Receivers, Wiley-IEEE Press, 2015.

Franck Boynton, NavtechGPS VP and CTO, heads the NavtechGPS product division. NavtechGPS sells GPS and GNSS products from over 30 leading manufacturers and offers technical advice on complex precise positioning projects in addition to offering technical GNSS training through its seminar division. Since 1988, Boynton has been involved in the testing and operation of GNSS receivers, antennas, boards, data link products and related equipment. He is certified by several manufacturers for sales, operation and training on high accuracy receiver systems and OEM products. He specializes in custom system development and the design and implementation of high performance GNSS components. Boynton is a member of The Institute of Navigation and won a "Best Paper" award for GPS applications at the ION GNSS 2003 meeting. He has also co-chaired sessions at past ION meetings and co-chaired "New Products and Commercial Services" at ION GNSS+ 2013. He is a NavtechGPS technical board member and a corporate officer.

Michael S. Braasch, Ph.D., P.E., is the Thomas Professor of Electrical Engineering and has served as the director of the Avionics Engineering Center at Ohio University. His research includes GPS receiver design, GPS/INS integration, multipath mitigation, advanced cockpit displays and UAV operational safety analysis. Dr. Braasch has served as a technical advisor both to the FAA and the International Civil Aviation Organization (ICAO) in the area of precision approach and landing systems, and he has received international recognition for his work on characterizing the effects of multipath on GPS/GNSS accuracy. As co-founder of the company GPSoft, Dr. Braasch has been instrumental in the development the Satellite Navigation (SatNav) Toolbox, the Inertial Navigation System (INS) Toolbox, and the Navigation System Integration & Kalman Filter Toolbox for MATLAB. Dr. Braasch is a fellow of the ION, a senior member of the IEEE, is an instrument-rated commercial pilot and is a licensed professional engineer in the State of Ohio.

Christopher Hegarty, D.Sc., is a director with the MITRE Corporation, where he has worked mainly on aviation applications of GNSS since 1992. He is currently the chair of the Program Management Committee of RTCA, Inc., and co-chairs RTCA Special Committee 159 (GNSS). He served as editor of NAVIGATION: The Journal of the Institute of Navigation from 1997–2006, and as president of The Institute of Navigation in 2008. He was a recipient of the ION Early Achievement Award in 1998, the U.S. Department of State Superior Honor Award in 2005, the ION Kepler Award in 2006, the RTCA Achievement Award in 2014, and the GPS World Leadership Award in 2017. He is a fellow of the ION and IEEE, and a co-editor/co-author of the textbook, Understanding GPS/GNSS: Principles and Applications, 3rd edition.

Stephen Heppe, D.Sc., operates Telenergy, Inc., an engineering consulting firm specializing in telecommunications, navigation, spectrum management and product integration. He received his BS/EE/CS from Princeton University in 1977 and his master’s and doctorate from The George Washington University in 1982 and 1989, respectively. Dr. Heppe has been working with GPS and GNSS since 1980. He led SC159/WG6 from 1993 through 1997 (first version of DO-235). Participating in RTCA, ICAO, and the ITU, he has also supported the development of standards for WAAS, SCAT-I and GBAS, as well as ADS-B and VHF Data Link Mode 4. Dr. Heppe was the communications lead on an early DGPS precision approach demonstration for the U.S. Navy. While working at Insitu, Inc., he developed a ship-borne moving-reference RTK system for recovery of the ScanEagle UAV. Dr. Heppe is a member of the IEEE, the RTCA and The Institute of Navigation.

Our Instructors
Alan J. Pue, Ph.D., is the chief scientist of the Air and Missile Defense Sector at The Johns Hopkins University Applied Physics Laboratory (JHU/APL). Since 1974, he has worked at JHU/APL on a wide variety of guidance, control, and navigation projects, including automated ground vehicle control research, space telescope pointing control, and missile guidance, navigation, and control.

He has frequently consulted and served on engineering review boards or has led concept developments for major acquisition programs. He is now a member of the Air Force Scientific Advisory Board.

For over 30 years, Dr. Pue has been a graduate lecturer on Linear Systems Theory and Control System Design Methods for The Johns Hopkins University.

Our Instructors, continued

Some of Our Many Satisfied Clients

- AENA, Madrid, Spain
- ARINC, Phoenix, AZ
- ATK Weapons Division, Plymouth, MN
- AT&T Bell Laboratories, Holmdel, NJ
- Boeing Defense & Space Gp., Seattle, WA
- Broadcom, Irvine, CA
- CAMP (Collision Avoidance Metrics Project), Farmington Hills, MI
- Canadian Marconi Company, Montreal
- Caterpillar, Peoria, IL
- C.S. Draper Laboratory, Cambridge, MA
- Delco Systems Operations, Goleta, CA
- Dynamics Research Corp., Boston, MA
- EPA, Las Vegas, NV
- ESA-ESTEC, Nordwijk, The Netherlands
- European Patent Office, Munich, Germany
- FAA: FAA HQ, Washington, DC
  FAA, Oklahoma City, OK
  FAA, Ft. Worth, TX
  FAA Tech. Center, Atlantic City, NJ
- GM Onstar, Troy, MI
- GPS Ireland at the Cork Institute of Technology, Cork Ireland
- ISN Corporation, Bethesda MD
- Honeywell: Honeywell, Clearwater, FL
  Honeywell, Coon Rapids, MN
- Hughes: Hughes Aircraft & Electro Optical Sys, El Segundo, CA
- Hughes, Fullerton, CA
- IBM, Gaithersburg, MD
- Indra Espacio, Barcelona, Spain
- Industri Pesawat Terband, Jakarta, Indonesia
- Israeli Aircraft Industries (IAI), Ben Gurion International Airport, Israel
- JHU/Applied Physics Lab, Laurel, MD
- Leidos, Columbia, MD
- L-3, Lexington Park, MD
- Loral Fed Systems Corp, Gaithersburg, MD
- Loral Federal Systems, Owego, NY
- Lucent Technologies, Naperville, IL
- McDonnell Douglas, St. Louis, MO
- McQ, Fredericksburg, Virginia
- MITRE, Bedford, MA
- Motorola: Motorola, Chandler, AZ
  Motorola, Harvard, IL
  Motorola, Phoenix, AZ
  Motorola, Sunrise, FL
- NASA: NASA Langley, Langley, VA
  NASA Johnson Space Center, Houston, TX
  NASA Kennedy Space Center, FL
  NASA Dryden at Edwards AFB, CA
  NASA Marshall SFC, AL
  NASA Huntsville, AL
- Nokia: Nokia, Copenhagen, Denmark
  Nokia, Irving, TX
  Nokia, Oulu, Finland
  Nokia, Naperville, Illinois
  Nokia, Tampere, Finland
- Norden Systems/United Technologies, Norwalk, CT
- Northrop Corporation, Los Angeles, CA
- Northrop Grumman, Rome, Italy
- NovAtel, Calgary, Alberta, Canada
- Offshore Navigation, Inc, Harahan, LA
- Panama Canal Commission, Panama
- Raytheon: Raytheon, Boston, MA
  Raytheon, El Segundo, CA
- Resource Management Concepts, Lex. Park, MD
- Rim, Waterloo, Ontario, Canada
- Rockwell, Cedar Rapids, IA
- Saab-Bofors, Linkoping, Sweden
- Samsung, Cedar Rapids
- SIRC, Los Angeles, CA
- SnapTrack/Qualcomm, Campbell, CA
- Sparton Corporation, De Leon Springs, FL
- Spirent, Paington, UK
- Swales Aerospace, Laurel, MD
- Systems Network, Inc., Ottawa, Ontario
- Texas Instruments, Plano, TX
- United Defense, Minneapolis, MN
- USCG: Navigation Center, Alexandria, VA
  USCG C2 Cen, Portsmouth, VA
  Eglin Air Force Base
  Holloman Air Force Base
  47th Test Group
  Peterson Air Force Base
  Randolph AFB/General Dynamics
  Warner Robins Air Force Base
  Wright Patterson Air Force Base
- US Army: Aberdeen Proving Ground, MD
  Charleston, VA
  Fort Belvoir, VA
  Picatinny Arsenal, NJ
  Redstone Arsenal, AL
  White Sands Missile Range (OTD)
- US Navy: NAWCPNS, China Lake, CA
  NAWCAD, Patuxent River, MD
  Naval Surface Weapons Center, Indian Head, MD
  NAVAIR, Patuxent River, MD
  Naval Avionics Center, Indianapolis, IN
  Naval Coastal Systems Station, Panama City, FL
  Naval Electronics Systems Engineering Activity
  Naval Pacific Missile Test Center, Pt. Mugu, CA
  Naval Research Laboratory, Washington DC
  NRd, Warminster, PA
  NRd, San Diego, CA
  Naval Surface Weapons Center, Dahlgren, VA
  Naval Undersea Warfare Center, Newport, RI
  SPAWAR, San Diego, CA
- US DoT, Volpe TSC, Cambridge, MA
- US Forest Service, Salt Lake City, Utah
- UTC Aerospace Systems, Westford, MA

He received his B.S.E.E. from the University of Florida in 1987 and his M.S.E.E. degree from the University of South Florida in 1991. During his 16 years at Honeywell Aerospace, he was awarded five patents in aided navigation.

At the 2010 Institute of Navigation GNSS conference, he was asked to present at a special panel celebrating the 50th anniversary of the invention of the Kalman filter.
About Course 336/337: GPS/GNSS Fundamentals and Enhancements with Emphasis on DGPS (Same course, reconfigured)

"After 20 years in the GNSS domain (with emphasis in SBAS), [the instructor was able to] recap, reinforce knowledge and also deepen my knowledge in some areas where I had less experience. The goals have been met. Dr. Hegarty was very clear, kind and with a very good background and recognition at international level. I was honored to be taught by Dr. Hegarty."
— Jerry Rodriguez Melo, Patuxent, MD, February 2018

"This was a very high-quality course. Much better and more informative than what I was expecting. The subject matter expert [Dr. Hegarty] had incredible knowledge and was entertaining to listen to. Also great reference materials."
— Felix Taran, ESTEC, November 2018

"As a non-tech/non-engineer, I was concerned about attending a class of engineers and technical professionals. Dr. Hegarty was able to take some difficult subject material and help me stay connected to the material. He was able to go deeper when answering deeper questions. He also drew us in with questions—not just lecture but asking us about what he said. Had a calm excitement about GPS/GNSS."
— Name withheld upon request, May 2018

"My main objective was to solidify the on the job training I've had thus far as a navigation engineer with my company. The instructor under Course 346 met that main objective and exceeded it by expanding my knowledge of global positioning systems, DGPS, and Kalman filtering. For aviation and military applications, especially being a new engineer in the field, this class formed a base from which to learn more in-depth knowledge as well as to contribute to aircraft design improvement as GPS continues to evolve and advance."
— Margaret Alfafara, Northrop Grumman, December 2014

About Course 346: GPS Operations for Engineers and Technical Professionals

"As a non-tech/non-engineer, I was concerned about attending a class of engineers and technical professionals, Dr. Hegarty was able to take some difficult subject material and help me stay connected to the material. He was able to go deeper when answering deeper questions. He also drew us in with questions—not just lecture but asking us about what he said. Had a calm excitement about GPS/GNSS."
— Dennis Shrink, May 2018, Dayton, Ohio

Dr. Hegarty was excellent. His wealth of knowledge and experience was very apparent. He did a great job breaking down complex concepts and ensuring the class had a good understanding before moving on. Also, his humor helped lighten the class material and kept everyone engaged!
— Military attendee. Name withheld upon request, May 2018, Falls Church, VA

"My objective was two-fold. (1) Refresh my knowledge of communication systems and (2) Learn how communications technology is used within GPS. Dr. Hegarty's course gave an excellent in-depth overview of communication systems and provided all the details to understand how GPS works. I loved this course and believe it met all my objectives. Thank you!"
— Alexander DeRieux, Naval Research Laboratory, Washington, DC, December 2017

"I wanted to learn more about the GPS message format, signals, receivers and how the data from the Sats [satellites] allowed GPS receivers to acquire and track. This course met my expectations. I learned a great deal about the ephemeris data and how the receiver uses this data."
— Daniel Friedman, JHU/APL, March 2016

"My main objective was to solidify the on the job training I've had thus far as a navigation engineer with my company. The instructor under Course 346 met that main objective and exceeded it by expanding my knowledge of global positioning systems, DGPS, and Kalman filtering. For aviation and military applications, especially being a new engineer in the field, this class formed a base from which to learn more in-depth knowledge as well as to contribute to aircraft design improvement as GPS continues to evolve and advance."
— Margaret Alfafara, Northrop Grumman, December 2014

About Course 557/556/546: Inertial Systems, Kalman Filtering and GPS/INS Integration (Same course, reconfigured)

"As a practicing engineer in integrated navigation, I came to the class to explore the boundaries of my knowledge. The course greatly exceeded my expectations. Mr. Vaujin's mastery of each topic helped me to synthesize prior knowledge and attain new fundamental understanding of the psi and phi navigators."
— Andrew Harmon, Signal Quest, May 2018

"I really like the instructor's teaching style. [Mr. Vaujin] is giving a very good understanding of the subject. The fact that he actually worked on real projects helps a lot because he emphasises critical points and of course he is really experienced."
— Name withheld upon request, May 2018

"I found Mr. Vaujin's lecture style to be concise and efficient without being overly terse. He was able to relay a great deal of information, clearly, in a relatively short period of time. I definitely felt that I got my money's worth from this course."
— Henry McCabe, USAF, November 2016

I found the lecturer [Dr. Pue] to have struck just the right blend of informality and academic rigor. I came into the course with a basic background in GPS and a "black box" knowledge of IMUs and Kalman filtration. I can confidently say that my knowledge of these subjects has been markedly increased.
— Henry McCabe, USAF, November 2016

"As he [Mr. Vaujin] highlighted the first day, the combination of lecture and MATLAB® examples provide a great vehicle to teach this complex subject."

"My main objective was to familiarize myself with the basic concepts of inertial navigation and learn the challenges of integration of INS and GPS. The course has met them. I feel empowered by the material and the knowledge that the instructor transferred to us."
— Dmitri Baraban, The MITRE Corporation; April 2015

"This course would be almost impossible to replicate at a university without taking several courses that would only comment on the subject. Having it all in one place over two days is well worth the money."
— Ed May, H2 International, LLC, April 2015

About Course 551/541: Using Advanced GPS/GNSS Signals and Systems (Same course, reconfigured)

"I acquired lots of understanding for engineering trades when implementing new signals that will be useful when implementing them. I just want to reiterate how impressed I was with the content and delivery of this class. The notes are also good enough to be a valuable stand-alone resource."
— Jeff Melville, MITRE, April 2018

"I wanted to have a greater understanding of detailed performance characteristics/tradeoffs. I also wanted to see more detail about the modernized/foreign signals. [I acquired] lots of understanding for engineering trades when implementing new signals that will be useful. I just want to reiterate how impressed I was with the content and delivery of this class. The notes are also good enough to be a valuable stand-alone resource."
— Jeff Melville, MITRE, February 2018

"He [Dr. John Betz] had a very methodical and logical way to present the material and build on it. It was very effective. He took questions well and answered them thoroughly and encouraged questions. Understanding the trade-offs that Dr. Betz presented in an elegant way helps us decipher when and how to use the different parameters for receiver design and signal processing and which techniques to use."
— Gina Guiducci, U.S. Army, Aberdeen Proving Grounds, January 2017

Read more at NavtechGPS.com/events/testimonials
### PUBLIC VENUE OR ON-SITE COURSE

**Course 346: GPS/GNSS Operations for Engineers & Technical Professionals:** Principles, Technology, Applications and an Introduction to Basic DGPS (2.7 CEUs)

<table>
<thead>
<tr>
<th>DAYS 1 AND 2 MAY BE TAKEN AS COURSE 122. SEE REGISTRATION FORM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAY 1</strong></td>
</tr>
<tr>
<td>GPS Principles and Technologies</td>
</tr>
<tr>
<td>Clocks and Timing</td>
</tr>
<tr>
<td>Importance for GPS</td>
</tr>
<tr>
<td>Geodesy and Satellite Orbits</td>
</tr>
<tr>
<td>Coordinate frames and geodesy</td>
</tr>
<tr>
<td>Satellites and Control Segment</td>
</tr>
<tr>
<td>GPS satellite blocks</td>
</tr>
<tr>
<td>Ground control modernization</td>
</tr>
<tr>
<td>Differential GPS Overview</td>
</tr>
<tr>
<td>Local- and wide-area architectures</td>
</tr>
<tr>
<td>Differential error sources</td>
</tr>
<tr>
<td>DGPS Standards and Systems</td>
</tr>
<tr>
<td>RTCM SC104 message format</td>
</tr>
<tr>
<td>RINEX format, CORS, and IGS networks</td>
</tr>
<tr>
<td>GPS Signal Processing</td>
</tr>
<tr>
<td>In-phase and quadra-phase signal paths</td>
</tr>
<tr>
<td>Code processing strategies</td>
</tr>
<tr>
<td>Code Tracking, Carrier Tracking &amp; Data Demodulation</td>
</tr>
<tr>
<td>Delay locked loop (DLL) implementations, performance</td>
</tr>
<tr>
<td>Receiver impairments and Enhancements</td>
</tr>
<tr>
<td>Impairments - bandlimiting, oscillators, multipath, interference</td>
</tr>
</tbody>
</table>

#### Course Description

Take this 4-day course to gain a comprehensive understanding of GPS/GNSS system concepts, design and operation, including information on GPS signal processing by the receiver, techniques by which GPS obtains position, velocity and time, and a brief introduction to differential GPS (DGPS) and Kalman filtering. This course is similar to Course 356 (5 days), but with less emphasis on DGPS and Kalman filtering.

#### Objectives

- A comprehensive introduction to GPS, system concepts, an introduction to DGPS, design, operation, implementation and applications.
- Detailed information on the GPS signal, its processing by the receiver, and the techniques by which GPS obtains position, velocity and time.
- Current information on the status, plans, schedule and capabilities of GPS, as well as of other satellite-based systems with position velocity and time determination applications.
- Information to fill the technical gaps for those working in the GPS/GNSS fields.

#### Who Should Attend?

Excellent for engineering staff who need to be rapidly brought up to speed on GNSS, and for those already working in GPS who need exposure to the system as a whole in order to work more effectively.

#### Prerequisites

Familiarity with engineering terms and analysis techniques. General familiarity with matrix operations and familiarity with signal processing techniques is desirable.
PUBLIC VENUE OR ON-SITE COURSE

Course 122: GPS/GNSS Fundamentals & Enhancements (1.2 CEUs)
(Days 1 and 2 of Course 346)

SAME AS DAYS 1 AND 2 OF COURSE 346

DAY 1

- GPS System Description
  - Overview and terminology
  - Principles of operation
  - Augmentations
  - Trilateration
  - Performance overview
  - Modernization
- GPS Policy and Context
  - Condensed navigation system history
  - GPS policy and governance
  - Modernization program
  - Ground segment
  - Other satellite navigation systems
- GPS Applications
  - Land
  - Marine
  - Aviation
  - Science
  - Personal navigation
  - Accuracy measures
  - Error sources
- Legacy GPS Signals
  - Signal structure and characteristics
  - Modulations: BPSK, DSSS, BOC
  - Signal generation
  - Navigation data
- Measurements and Positioning
  - Pseudorange and carrier phase measurements
  - Least squares solution
  - Dilution of precision
  - Types of positioning solutions
- GPS Receiver Basics
  - Types of receivers
  - Functional overview
  - Antennas

DAY 2

- GPS Principles and Technologies
  - Clocks and Timing
    - Importance for GPS
    - Timescales
    - Clock types
    - Stability measures
    - Relativistic effects
- Geodesy and Satellite Orbits
  - Coordinate frames and geodesy
  - Satellite orbits
  - GPS constellation
  - Constellation maintenance
- Satellites and Control Segment
  - GPS satellite blocks
  - Control segment components and operation
  - Monitor stations, MCS, and ground antennas
  - Upload operations
  - Ground control modernization
- Error Sources and Models
  - Sources of error and correction models
  - GPS signals in space performance
  - Ionospheric and tropospheric effects
  - Multipath
  - Error budget
- Augmentations and Other Constellations
  - Augmentations: local-area, satellite-based, and regional
  - Russia’s GLONASS
  - Europe’s Galileo
  - China’s Compass (Beidou)
- Precise Positioning
  - Precise positioning concepts
  - Reference station networks
  - RINEX data format

Objectives
- To give an comprehensive introduction to GPS technology, system concepts, design, operation, implementation and applications.
- To provide detailed information on the GPS signal, its processing by the receiver, and the techniques by which GPS obtains position, velocity and time

Prerequisites
- Some familiarity with engineering terms is helpful but not essential.

Who Should Attend?
- Engineers and technical professionals seeking conceptual explanations of GPS / GNSS technology, operation, capabilities, applications, and development trends
- Professionals in navigation, positioning, and related fields who are concerned with the capabilities, operation and principles of GPS and related GNSS systems.
- System analysts and specialists who need general information on position data and its use.
- Managers concerned with GPS, GNSS activities, or the positioning field.

Materials You Will Keep
- A color electronic copy of all course notes will be provided on a USB Drive or CD-ROM. Bringing a laptop to this class is highly recommended for taking notes using the Adobe® Acrobat® sticky notes feature; power access will be provided.
- A black and white hard copy of the course notes will also be provided.

What Attendees Have Said
- I liked the overall flow and design of the course, especially because I was trying to take the full 4-day [course]. I feel we touched pretty much all major points.
  — Devashish Chandekar, Spirient, San Jose, 2018
- “I came into the course with only basic GPS knowledge. The course provided a wealth of information and appreciation of GPS technology. The course exceeded expectations.”
  — Rex Roebuck, USCG, 2016
- “My main objective was to gain a better understanding about the GPS system as a whole. The course met my objective and having the course content in hard/soft copy is a great bonus!”
  — Military Attendee, Name withheld upon request, 2016

Course Fee Entitles You to the Following Books
GPS Basics for Technical Professionals, Pratap Misra, Ganga-Jamuna Press, 2016. (Note: This arrangement does not apply to on-site contracts. Any books for on-site group contracts are negotiated on a case by case basis.)

Instructors
Dr. Chris Hegarty

JUST NEED THE FUNDAMENTALS?
Take Course 122, which covers all the major areas of GPS. It is the same as days 1 and 2 of Course 346. (Course 346 drills deeper on days 3 and 4.)

To REGISTER or for MORE INFORMATION, Contact Carolyn McDonald at (703) 256-8900 or cmcdonald@navtechgps.com.
Course 557: Inertial Systems, Kalman Filtering and GPS/INS Integration (3.0 CEUs)

**Introduction**

This course on GNSS-aided navigation will immerse the student in the fundamental concepts and practical implementations of the various types of Kalman filters that optimally fuse GPS receiver measurements with a strapdown inertial navigation solution. The course includes the fundamentals of inertial navigation, inertial instrument technologies, technology surveys and trends, integration architectures, practical Kalman filter design techniques, case studies, and illustrative demonstrations using MATLAB®. The full five days allow for a fuller, detailed development of the design of an aided navigation system, including a detailed discussion of the use of lower quality IMUs, and advanced filtering techniques.

**Who Should Attend?**

- GPS/GNSS engineers, scientists, systems analysts, program specialists and others concerned with the integration of inertial sensors and systems.
- Those needing a working knowledge of Kalman filtering, or those who work in the fields of either navigation or target tracking.

**Prerequisites**

- Familiarity with principles of engineering analysis, including matrix algebra and linear systems.
- A basic understanding of probability, random variables, and stochastic processes.
- An understanding of GPS operational principles in Course 346, or equivalent experience.

**Equipment Recommendation**

- A laptop (PC or Mac) with full version of MATLAB® 5.0 (or later) installed. This will allow you to work the problems in class and do the practice “homework” problems. Problems will be worked in class by the instructor, so this equipment is not required, but is recommended.

**Materials You Will Keep**

- A CD-ROM or USB drive with a color copy of all course notes.
- A black and white hard copy of the course notes, printed 3 slides to a page.

**What Attendees Have Said**

"As he [Mr. Vaujin] highlighted the first day, the combination of lecture and MATLAB® examples provide a great vehicle to teach this complex subject.


“My main objective was to familiarize myself with the basic concepts of inertial navigation and learn the challenges of integration of INS and GPS. The course has met them, I feel empowered by the material and the knowledge that the instructor transferred to us.”

— Dmitri Baraban, The MITRE Corporation

**Course Objectives**

This course is designed to provide a comprehensive understanding of Kalman filtering and GPS/INS integration. The course objectives include:

- **Inertial Navigation:** Understanding the principles of inertial navigation and its applications.
- **Kalman Filtering:** Learning the fundamentals of Kalman filtering and its implementation.
- **GPS/INS Integration:** Mastering the integration of GPS and INS systems.

**Course Notes**

- Introduction to INS/GPS integration
- Inertial navigation
- Integration architectures
- Practical Kalman filter design techniques
- Case studies
- Illustrative inertial instrument technologies, technology surveys and trends, integration architectures, practical Kalman filter design techniques, case studies, and illustrative demonstrations using MATLAB®.

**Course Notes (Day 1)**

- **Introduction to INS/GPS Integration**
- **Inertial Navigation**
- **Mechanization**
- **Gravity model**
- **Navigation equations**
- **Implementation options**

**Course Notes (Day 2)**

- **Inertial Sensor Technologies**
- **Accelerometer technologies**
- **Optical gyroscopes**
- **MEMS technologies**
- **Technology survey**

**Course Notes (Day 3)**

- **Strapdown Systems**
- **Quaternions**
- **Orientation vector**
- **Coning and sculling compensation**

**Course Notes (Day 4)**

- **Aided Receiver Tracking**
- **Track loop design trades**
- **Inference suppression**
- **Deep integration**

**Course Notes (Day 5)**

- **Tightly-Coupled INS/GPS Design**
- **Measurement processing**
- **Filter parameter selection**
- **Pseudo-range and delta pseudo-range measurement models**

**Lunch**

**Instructors**

- Dr. Alan Pue, Johns Hopkins, Navigation & Defense Consultant
- Mr. Michael Vaujin, Aerospace, Navigation & Defense Consultant

**What Attendees Have Said**

"My main objective was to familiarize myself with the basic concepts of inertial navigation and learn the challenges of integration of INS and GPS. The course has met them, I feel empowered by the material and the knowledge that the instructor transferred to us.”

— Dmitri Baraban, The MITRE Corporation

**To REGISTER or for MORE INFORMATION, Contact Carolyn McDonald at (703) 256-8900 or cmcdonald@navtechgps.com.**
PUBLIC VENUE OR ON-SITE COURSE
Course 336: GPS/GNSS Fundamentals and Enhancements with Emphasis on DGPS (1.8 CEUs)

DAY 1 | DAY 2 | DAY 3
---|---|---
Dr. Chris Hegarty

**Description/Objectives**
This 3-day public or on-site course offers a comprehensive introduction to GPS/GNSS technology, system concepts, design, operation, implementation and applications, and a full day of differential GPS. Detailed information on the GPS signal, its processing by the receiver, and the techniques by which GPS obtains position, velocity and time will be covered.

**Prerequisites**
Some familiarity with engineering terms is helpful but not essential.

**Who Should Attend?**
- Engineers and technical professionals seeking conceptual and detailed explanations of GNSS technology, operation, capabilities, applications, and development trends
- Professionals in navigation, positioning, and related fields who are concerned with the capabilities, operation and principles of GPS, DGPS, and related GNSS systems.
- System analysts and specialists concerned with position data and its use.
- Managers concerned with GPS, GNSS activities, or the positioning field.

**Public Course Fee Entitles You to the Following Books**
Introduction to GPS: The Global Positioning System, 2nd ed., Ahmed El-Rabbany, Artech House, 2006., or book of your choice from our website (Note: This arrangement does not apply to on-site contracts. Any books for on-site group contracts are negotiated as part of the contract.)

**FOR THOSE WHO NEED GPS/GNSS BASICS AND A FULL DAY OF DIFFERENTIAL GNSS**

**Instructor**
Dr. Chris Hegarty

**For those who need GPS/GNSS basics and a full day of differential GNSS**

**Legacy GPS Signals**
- Signal structure and characteristics
- Modulations: BPSK, OQPSK, BOC
- Signal generation
- Navigation data

**Measurements and Positioning**
- Pseudorange and carrier phase measurements
- Least squares solution
- Dilution of precision
- Types of positioning solutions

**GPS Receiver Basics**
- Types of receivers
- Functional overview
- Antennas

**GPS Principles and Technologies**
- Differential GPS Overview
  - Local-area, regional-area, wide-area architectures
  - Code vs. carrier-phase based systems
  - Pseudolites
  - Performance overview
- Differential Error Sources
  - Satellite ephemerides errors
  - Satellite clock errors
  - Selective availability
  - Ionospheric, tropospheric delay
  - Multipath
  - Receiver internal noise, biases
- Observables Modeling
  - Code pseudorange and carrier-phase outputs
  - Code-minus-carrier observables
  - Carrier-smoothed code operation
  - Double difference operation
  - System error budgets

**Error Sources and Models**
- Sources of error and correction models
- GPS signals in space performance
- Ionospheric and tropospheric effects
- Multipath
- Error budget

**Augmentations and Other Constellations**
- Augmentations: local-area, satellite-based, and regional
- Russia’s GLONASS
- Europe’s Galileo
- China’s Compass (Beidou)

**Precise Positioning**
- Precise positioning concepts
- Reference station networks
- RINEX data format

**Differential GPS Design Considerations**
- Range vs. navigation domain corrections
- Data links
- Pseudolites
- Reducing major error components
- Ambiguity resolution

**DGPS Case Studies I**
- RTCM SC104 message format
- USCG maritime DGPS and National DGPS (NDGPS)
- Commercial satellite-based systems

**DGPS Case Studies II**
- Wide Area Augmentation System (WAAS)
- Local Area Augmentation System (LAAS)
- RINEX format
- CORS&AGS network for precise positioning (survey)
- Precise time transfer

**What Attendees Have Said**
- "Especially useful were the aspects related to how the user receivers make use of the GNSS signals and all the steps involved in the process, from receiving the raw RF signal to the computation of the user position."
  — Marc Garcia Mateos, Course 336, ESA/ESTEC, September 2016
- "Dr. Hegarty is extremely knowledgeable and well versed in the material. Well prepared and well designed course and course material! Course material was well organized with accompanying slides — Nice notebook!"
  — David Wright, Course 346, June 2015.
- "(Course 336 is a subset of Courses 346 and 356)"
- "There are many bright scientists and engineers, but very few are bright and gifted in teaching. Even fewer could explain each part of a very complex equation in simple layman’s terms. Dr. Hegarty got my full attention."
  — Sigong Ho, NovAtel, Course 346, February 2014 (Course 336 is a subset of Courses 346 and 356)
ON-SITE COURSE

Courses 356: GPS / GNSS and DGPS Operations for Engineers & Technical Professionals: Principles, Technology, Applications and DGPS Concepts (3.0 CEUs)

(Similar to Course 346, but with three additional hours of Differential GPS and two additional hours of Kalman filtering.)

<table>
<thead>
<tr>
<th>DAY 1</th>
<th>DAY 2</th>
<th>DAY 3</th>
<th>DAY 4</th>
<th>DAY 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Chris Hegarty, MITRE</td>
<td></td>
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<tr>
<td>Fundamentals of GPS operation. Overview of how the system works, U.S. policy and current status.</td>
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<tr>
<td>GPS System Description</td>
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<tr>
<td>○ Overview and terminology</td>
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<td>○ Principles of operation</td>
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<td>○ Augmentations</td>
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<td>○ Termination</td>
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<tr>
<td>○ Performance overview</td>
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<tr>
<td>○ Modernization</td>
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<tr>
<td>GPS Policy and Context</td>
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<tr>
<td>○ Condensed navigation system history</td>
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<tr>
<td>○ GPS policy and governance</td>
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<td>○ Modernization program</td>
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<td>○ Ground segment</td>
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<tr>
<td>○ Other satellite navigation systems</td>
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<tr>
<td>GPS Applications</td>
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<td>○ Land</td>
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<td>○ Accuracy measures</td>
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<td>○ Error sources</td>
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<td>GPS Principles and Technologies</td>
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<td>○ Clocks and Timing</td>
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<td>○ Importance for GPS</td>
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<td>○ Stability measures</td>
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<td>○ Relativistic effects</td>
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<td>Geodesy and Satellite Orbits</td>
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<td>○ Coordinate frames and geodesy</td>
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<td>Satellites and Control Segment</td>
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<td>○ Control segment components and operation</td>
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<td>○ Monitor stations, MCS, and ground antennas</td>
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<td>○ Upload operations</td>
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<td>Differential GPS Overview</td>
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<td>○ Pseudolites</td>
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<td>○ Performance overview</td>
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<td>Differential Error Sources</td>
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<td>○ Satellite ephemeris errors</td>
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<td>○ Receiver internal noise, biases</td>
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<td>Observable Modeling</td>
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<td>○ Code pseudorange and carrier-phase outputs</td>
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<td>○ Code-minus-carrier observables</td>
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<td>○ System error budgets</td>
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<td>GPS Signal Structure and Message Content</td>
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<td>○ Signal structures</td>
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<td>○ Signal properties</td>
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<td>○ Navigation message</td>
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<td>○ Code-phase estimate</td>
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<td>○ Carrier-phase estimate</td>
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<td>○ Data demodulation</td>
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<td>GPS Navigation Alorithms: Point Sources</td>
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<td>○ Pseudorange measurement models</td>
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<td>○ Point solution method and example</td>
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<td>Basics of Kalman Filtering</td>
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<td>○ Introduction to Kalman filtering</td>
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<td>○ Filter structure</td>
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<td>○ Simulation results</td>
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<td>Lunch is On Your Own</td>
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Course Objectives
- To give you a comprehensive introduction to GPS and DGPS technology, system concepts, design, operation, implementation, and applications, including critical information on DGPS and Kalman filtering concepts.
- To provide detailed information on the GPS signal, its processing by the receiver, and the techniques by which GPS obtains position, velocity and time.
- To present current information on the status, plans, schedule and capabilities of GPS, as well as of other satellite-based systems with position velocity and time determination applications.
- To fill in technical information gaps for those working in the GPS and GNSS fields.
- This course has two highly respected instructors who bring their unique experiences and professional expertise to the class.

Who Should Attend?
Excellent for engineering staff who need to be rapidly brought up to speed on GPS, and for those already working in GPS who need exposure to the system as a whole in order to work more effectively.

Prerequisites
Familiarity with engineering terms and analysis techniques. General familiarity with matrix operations is desirable for Thursday and Friday, and familiarity with signal processing techniques is desirable for Wednesday through Friday. (The materials for days 3, 4 and 5 of Course 356 are more intensive than what is taught in Course 346.)

Materials You Will Keep
- A color electronic copy of all course notes will be provided on a USB Drive or CD-ROM. Bringing a laptop to this class is highly recommended for taking notes using the Adobe® Acrobat® sticky notes feature; power access will be provided.
- A black and white hard copy of the course notes will also be provided.

Course Fee Entitles Your Group to a Book Allowance
Any book allowances for on-site group contracts are negotiated as part of the contract.

What Attendees Have Said
"[My objective was to] gain a better understanding of GPS operating principles with a focus on error sources and differential GPS. I thought [Dr. Hegarty’s] teaching style was excellent. He specifically tailored his approach to the small classroom environment with significant student interaction: True teaching versus lecturing. I would recommend this course to system engineers requiring more than a black box knowledge of GPS." – Jim Sabin (Organization withheld upon request), March 2011, San Diego, California

To REGISTER or for MORE INFORMATION, Contact Carolyn McDonald at (703) 256-8900 or cmcdonald@navtechgps.com.
## ON-SITE COURSE

**Course 356B: GPS/GNSS Operations, DGPS, GPS Signals & Processing (1.8 CEUs)**

<table>
<thead>
<tr>
<th>DAY 1</th>
<th>DAY 2</th>
<th>DAY 3</th>
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</thead>
<tbody>
<tr>
<td><strong>Dr. Chris Hegarty, MITRE</strong></td>
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</tr>
<tr>
<td><strong>Differential GPS Overview</strong></td>
<td><strong>GPS Signal Structure and Message Content</strong></td>
<td><strong>Case Study: Tracing a GPS Signal Through a Receiver</strong></td>
</tr>
<tr>
<td>Local-area, regional-area, wide-area architectures</td>
<td>Signal structures</td>
<td>Received signal</td>
</tr>
<tr>
<td>Code vs. carrier-phase based systems</td>
<td>Signal properties</td>
<td>Digitized signal</td>
</tr>
<tr>
<td>Pseudolites</td>
<td>Navigation message</td>
<td>Correlator outputs</td>
</tr>
<tr>
<td>Performance overview</td>
<td></td>
<td>Code-phase estimate</td>
</tr>
<tr>
<td><strong>Differential Error Sources</strong></td>
<td><strong>GPS Receiver Overview</strong></td>
<td><strong>Carrier-phase estimate</strong></td>
</tr>
<tr>
<td>Satellite ephemeris errors</td>
<td>Functional overview</td>
<td>Data demodulation</td>
</tr>
<tr>
<td>Satellite clock errors</td>
<td>Synchronization concepts</td>
<td><strong>GPS Navigation Algorithms: Point Solutions</strong></td>
</tr>
<tr>
<td>Selective availability</td>
<td>Acquisition</td>
<td>Precision pseudorange measurement models</td>
</tr>
<tr>
<td>Ionospheric, tropospheric delay</td>
<td>Code tracking</td>
<td>Point solution method and example</td>
</tr>
<tr>
<td>Multipath</td>
<td>Carrier tracking</td>
<td></td>
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<tr>
<td>Receiver internal noise, biases</td>
<td>Data demodulation</td>
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<tr>
<td><strong>Observable Modeling</strong></td>
<td><strong>GPS Antennas</strong></td>
<td><strong>Basics of Kalman Filtering</strong></td>
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<tr>
<td>Code pseudorange and carrier-phase outputs</td>
<td>Antenna types</td>
<td>Introduction to Kalman filtering</td>
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<tr>
<td>Code-minus-carrier observables</td>
<td>Antenna performance characteristics</td>
<td>Filter structure</td>
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<tr>
<td>Carrier-smoothed code operation</td>
<td>Prefilters</td>
<td>Simulation results</td>
</tr>
<tr>
<td>Double difference operation</td>
<td>Low-noise amplifiers (LNAs)</td>
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<tr>
<td>System error budgets</td>
<td>Noise figure</td>
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</tbody>
</table>

### LUNCH IS ON YOUR OWN

<table>
<thead>
<tr>
<th><strong>Differential GPS Design Considerations</strong></th>
<th><strong>GPS Signal Processing</strong></th>
<th><strong>Kalman Filtering for GPS Navigation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Data links</td>
<td>In-phase and quadra-phase signal paths</td>
<td>Clock models and dynamic models</td>
</tr>
<tr>
<td>Pseudolites</td>
<td>Analog-to-digital (A/D) conversion</td>
<td>Integration with INS</td>
</tr>
<tr>
<td>Reducing major error components</td>
<td>Automatic gain control (AGC)</td>
<td>Measurement and dynamic mismodeling</td>
</tr>
<tr>
<td>Ambiguity resolution</td>
<td>Correlation channels</td>
<td>Practical Aspects I</td>
</tr>
<tr>
<td><strong>DGPS Case Studies I</strong></td>
<td><strong>Code Tracking, Carrier Tracking &amp; Data Demodulation</strong></td>
<td>Types of GPS and DGPS receivers</td>
</tr>
<tr>
<td>ATOM E104 message format</td>
<td>Delay locked loop (DLL) implementations; performance</td>
<td>Understanding specification sheets</td>
</tr>
<tr>
<td>USCG maritime DGPS and National DGPS (NDGPS)</td>
<td>Frequency locked loops (PLLs)</td>
<td>Data links</td>
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<tr>
<td>Commercial satellite-based systems</td>
<td>Phase locked loops (PLLs)</td>
<td>Antennas</td>
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<tr>
<td><strong>DGPS Case Studies II</strong></td>
<td>Carrier-aiding of DLLs</td>
<td>Practical Aspects II</td>
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<tr>
<td>Wide Area Augmentation System (WAAS)</td>
<td>Data demodulation</td>
<td>Receiver and interface standards</td>
</tr>
<tr>
<td>Local Area Augmentation System (LAAS)</td>
<td><strong>Repeater Impairments and Enhancements</strong></td>
<td>Connectors</td>
</tr>
<tr>
<td>RINEX format</td>
<td>Impairments - bandlimiting, oscillators, multipath, interference</td>
<td>Accessories</td>
</tr>
<tr>
<td>CORS/IGS network for precise position- ing (survey)</td>
<td>Enhancements - carrier smoothing, narrow correlator, codeless/semicodeless tracking, vector tracking, external aiding</td>
<td>Test, evaluation, and signal performance</td>
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<td>Precise time transfer</td>
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### Description

This 3-day course begins with a discussion of differential GPS, which continues through the rest of the week together with an in-depth look at GPS signal processing, navigation message content, code tracking, receivers and concludes with a discussion on the basics of Kalman filtering. (Note: This course is the same as the last 3 days of Course 356.)

### Objectives

- To give a comprehensive introduction to GPS and DGPS technology, system concepts, design, operation, implementation and applications.
- To provide detailed information on the GPS signal, its processing by the receiver, and the techniques by which GPS obtains position, velocity and time.
- To present current information on the status, plans, schedule and capabilities of GPS, as well as other satellite-based systems with position velocity and time determination applications.
- To fill in technical information gaps for those working in the GPS and GNSS fields.

### Prerequisites

Familiarly with the subject matter covered in days 1 and 2 of Course 356.

### Who Should Attend?

Excellent for those engineers and technical professionals who know the basics of GPS but need more detail on DGPS, signals, receivers, antennas, navigation algorithms, Kalman filtering and practical aspects of GPS.

### Materials You Will Keep

- A color electronic copy of all course notes will be provided on a USB Drive or CD-ROM. Bringing a laptop to this class is highly recommended for taking notes using the Adobe® Acrobat® sticky notes feature; power access will be provided.
- A black and white hard copy of the course notes will also be provided.

### Course Fee Entitles Your Group to a Book Allowance

Book allowances for on-site group contracts are negotiated as part of the contract.

### What Attendees Have Said

*"Dr. Hegarty is very knowledgeable and he is a great communicator. He explained conceptual and theoretical topics clearly. He was very accessible in answering questions. He did an excellent job engaging the students in the learning experience."
— Carol Chen, March 2011; San Diego, California*

*I thought [Dr. Hegarty] had a great teaching style, was funny and had just the right amount of slides. [Dr. Hegarty] was very good at explaining very technical things in a way that made sense to someone with very little signals / communications background."
— A. Muscat, July 2011; Annapolis, Maryland*
ON-SITE COURSE

Course 551: Using Advanced GPS/GNSS Signals and Systems (3.0 CEUs)

<table>
<thead>
<tr>
<th>DAY 1</th>
<th>DAY 2</th>
<th>DAY 3</th>
<th>DAY 4</th>
<th>DAY 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dr. John Betz, MITRE</strong></td>
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</tbody>
</table>

Day 1 Morning
Objectives: Review basics of satellite-based positioning and timing, establish common terminology and notation, explore satellite orbits and constellations, understand satnav signal fundamentals

Day 2 Morning
Objectives: Review Day 1 material, begin to explore details of GPS and its signals, both original and modernized

Day 1 Review Questions and Answers

GPS and SBAS Overview
- GPS Signals
  - C/A signal
  - P(Y) signal
  - L2C signal
  - M signal
  - L5 signal

Day 2 Morning
Objectives: Review Day 2 material, address details of analog-to-digital conversion, introduce initial synchronization

Day 2 Review Questions and Answers

Analog to Digital Conversion
- Fundamentals
- Linear ADC
- ADC for the digitizing correlator
- Replica aliasing

Initial Synchronization Overview
- Receiver states
- Time-frequency search and the crossambiguity function
- Widening BOC correlation functions

Day 3 Morning
Objectives: Review Day 3 material, address details of code tracking and data message demodulation

Day 3 Review Questions and Answers

Code Tracking
- RMS bandwidth and its influence on code tracking performance
- Signal processing and discriminators for code tracking
- Implementation and tradeoffs
- Performance prediction
- False lock points

Day 4 Morning
Objectives: Review Day 4 material, complete description of Galileo signals, describe Galileo receiver processing

Day 4 Review Questions and Answers

Galileo System and Signals
- E5a, E5b
- E1 OS receiver processing
- E6 receiver processing

Day 5 Morning
Objectives: Summarize other satnav systems and signals (GLONASS, BDS, QZSS), provide overviews of differential satnav, assisted satnav, and multipath considerations, wrap up course

Other Satnav Systems and Signals
- GLONASS
- BDS
- QZSS

Instructor
Dr. John Betz, Ph.D.,

What Attendees Have Said

"He [Dr. John Betz] had a very methodical and logical way to present the material and build on it. It was very effective. He took questions well and answered them thoroughly and encouraged questions. Understanding the trade-offs that Dr. Betz presented in an elegant way helps us decipher when and how to use the different parameters for receiver design and signal processing and which techniques to use."

— Gina Guiducci, U.S. Army, Aberdeen Proving Grounds, January 2017

"Main objectives: To learn more about GPS/GNSS receiver algorithms. To learn more about GNSS signals. The course met and exceeded my objectives. I especially like the review questions. I also like the real-world examples and anecdotes from Dr. Betz’s experience developing real systems."

— Patrick Pitoscia, U.S. Army

Description
This 5-day course enables attendees to achieve proficiency, not merely familiarity, with the essential aspects of using GPS/GNSS signals. Not only does it thoroughly address current and future GPS signals, but it also drifts deeply into available details of signals from other satellite-based positioning and timing systems. As attendees understand similarities and distinctions among different systems and signals, they will become equipped to take advantage of signals from multiple systems.

Receiver processing techniques are described along with ways to characterize the performance of receiver processing. These processing techniques are customized to specific characteristics of signals from GPS and other satnav systems. Specialized topics, including dealing with interference and multipath, differential satnav, and assisted satnav, are also addressed.

Attendees will be given review questions each day that will be reviewed in class the following morning. These review problems and solutions help attendees understand and apply key concepts.

Course Objectives
To develop proficiency with advanced receiver processing of modernized and new signals from GPS, GLONASS, Galileo, BeiDou, and QZSS, supplemented by systems engineering skills, integrated with techniques for assessing performance and performing design trades concerning receiver processing.

Prerequisites
Attendees should have a solid background in GPS and be ready to develop advanced skills. Prior exposure to basic signal processing techniques and terminology as well as familiarity with engineering mathematics is needed.

To REGISTER or for MORE INFORMATION, Contact Carolyn McDonald at (703) 256-8900 or cmcdonald@navtechgps.com.

Materials You Will Keep
- A color electronic copy of all course notes will be provided on a USB Drive or CD-ROM.
- A black and white hard copy of the course notes will also be provided.

Book Allowance
Book allowances for on-site group contracts, if any, are negotiated as part of the contract. For your allowance, we encourage you to consider the book by John Betz, Ph.D., Engineering Satellite-Based Navigation & Timing: GNSS, Signals, & Receivers, Betz. Wiley-IEEE Press, 2015.

To REGISTER or for MORE INFORMATION, Contact Carolyn McDonald at (703) 256-8900 or cmcdonald@navtechgps.com.
GNSS Courses in New Orleans, Louisiana, December 9 – 13
InterContinental New Orleans Hotel, 444 Saint Charles Ave, New Orleans, LA, 70130
(Hotel Rate: $150/night: U.S. government and commercial attendees. See www.NavtechGPS.com for details.)

ATTN: Please download and save this form BEFORE completing. Email to cmcdonald@navtechgps.com or fax to 703-256-8988.

Please use a separate form for EACH attendee. Questions? Call Carolyn McDonald 703-256-8900.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Dates</th>
<th>Choose Media</th>
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</thead>
<tbody>
<tr>
<td>346:</td>
<td>GPS/GNSS Operations for Engineers and Technical Professionals. (4 days)†</td>
<td>December 9–12 8:00 AM to 4:30 PM</td>
<td>$2899</td>
<td>2.4</td>
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<tr>
<td>122:</td>
<td>GPS Fundamentals and Enhancements (Days 1 and 2 of Course 346) (2 days) †</td>
<td>December 9–10 8:00 AM to 4:30 PM</td>
<td>$1499</td>
<td>1.2</td>
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<td>557A:</td>
<td>Inertial Systems, Kalman Filtering, and GPS/INS Integration (This is the FULL enhanced 5-day course. See our website for details.)</td>
<td>December 9–13 8:00 AM to 4:30 PM</td>
<td>$3299</td>
<td>3.0</td>
</tr>
<tr>
<td>557B:</td>
<td>Inertial Systems, Kalman Filtering, and GPS/INS Integration (No Review). I want to opt out of the morning of Course 557; I do not need the review, which reduces my fee. (4.5 Days) Monday start time is 1PM for 557B.</td>
<td>December 9–13 1 PM to 4:30 PM</td>
<td>$3099</td>
<td>2.7</td>
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</tbody>
</table>

Course notes are provided on CD-ROM or USB drive (as well as on paper in black and white). Please CHECK preference!

**Courtesy U.S. federal government/U.S. military discount. †NavtechGPS is a Florida approved provider for Courses 122 and 346.

掇 Billing Office

Contact (If Any): *Title First Name* ___________ *Middle Initial* ___________ *Last (Family Name)* ___________
Billing Office Email (If Any): *Cell Phone:* ___________ *Fax:* ___________

Attendee Name:*Title First Name* ___________ *Middle Initial* ___________ *Last (Family Name)* ___________
Attendee Organization:*Internal Mail Stop:* ___________ *Fax:* ___________

Attendee Address:*City:* ___________ *State/Province:* ___________ *Zip/Postal Code:* ___________ *Country:* ___________

Attendee Email:*Attendee Cell Phone:* ___________ *Office Phone:* ___________

Required Information

Proposed Payment Method:

___ I wish to pay by check. Please write check payable to NavtechGPS. *Note: NavtechGPS does NOT charge a processing fee for wire transfers.*
___ I would like to pay by credit card. We will call you to obtain your credit card information and billing address, or you may call us at the number listed above.

‡ Still not sure? Need processing time? Let us know. We will hold a seat for you (no obligation) AND honor any discounts if you tentatively registered by an early bird deadline. (A minimum enrollment is needed for most courses.)

Questions? Call or email Carolyn McDonald. cmcdonald@navtechgps.com or 703-256-8900
NavtechGPS ◆ 5500 Cherokee Avenue ◆ Suite 440 ◆ Alexandria, VA 22312-2321 USA +1-703-256-8900
Products from 20+ Manufacturers
NavtechGPS offers in-house expertise on a wide range of components and systems from more than 20 manufacturers. We deliver expert GNSS+INS system design, COTS equipment solutions and more for your GPS needs, including unmanned systems positioning.

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- GPS RF network components, design and installation
- GNSS heading and attitude
- Differential subscription services
- Signal distribution products
- GPS development software
- Post-processing software
- GPS Inertial Navigation
- OEM receiver boards
- Customized cables
- GIS equipment
- GPS/GNSS Simulators
- GNSS Antennas
- RTK systems
- PPP systems
- SBAS

Expertise and Experience
NavtechGPS has over 35 years of experience in GPS, GNSS and precise positioning technology. We deliver innovative solutions for military, commercial and research COTS (commercial off-the-shelf) integration projects. NavtechGPS® has been a critical team member on hundreds of complex projects, for:

- Unmanned air/ground/maritime vehicles
- Precise recovery/docking systems
- Reconnaissance for geolocation applications
- Mobile surveillance vehicles
- Precise attitude/heading system applications
- PNT (position, navigation and timing) applications
- RF networking system design and installation, also known as distributed antenna systems (DAS).

Contact Us!
+1-703-256-8900 +1-703-256-8988, fax

Did You Know that NavtechGPS® Is Also a Distributor of Precision GPS/GNSS Hardware?

Trimble BD940 INS GNSS Receiver
Septentrio AsteRx-iV GNSS with IMU
NovAtel OMEM Family of GNSS Receivers
LabSat 3 Wideband GNSS Simulator
Hemisphere Vector V500 GNSS SMART Antenna
NavCom SF-5050 StarFire™ GNSS Receiver
Hemisphere GNSS Crescent Vector H220 OEM (heading, position, attitude)
VectorNav Industrial Series, MEMS-based INS
VectorNav Industrial Series, MEMS-based INS (surface mount and rugged)