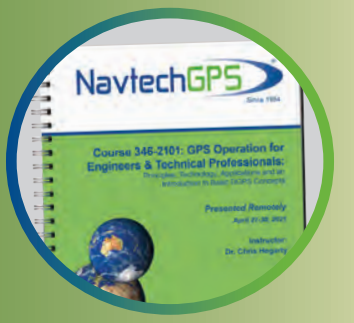
NavtechGPS®

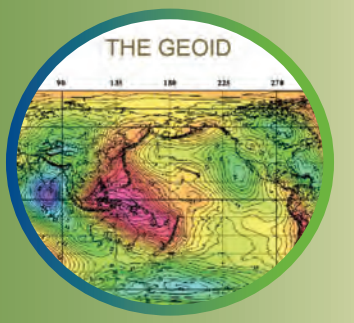
GPS/GNSS Courses for 2025!

GNSS Courses Offered in the Following Areas

- Inertial systems, Kalman filtering and GPS / GNSS integration
- GPS/GNSS operations for engineers and professionals
- Using advanced GNSS signals and systems
- GPS/GNSS fundamentals
- Differential GPS



NavtechGPS is celebrating over 40 years of serving the PNT community as the go-to company for GPS, GNSS, and inertial navigation training. We offer unsurpassed GPS/GNSS technical training from experienced, world-class instructors.



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About Our Public Courses and Private Group Courses

GPS/GNSS Training

NavtechGPS is a world leader in GPS/GNSS education with 40 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 present our most popular courses either remotely or at choice locations a few times each year for the GPS/GNSS community to attend (*for the forseeable future, public courses will be presented remotely*).

Private Group Courses. Our private group courses are often more desireable because your group learns in a secure setting and the per person fee is lower. Private group training also allows us to tailor a course to your organization's needs. You can choose one of the classes listed in the catalog or a combination to be customized for your group. Private courses are available both remotely and on-site

.

Our Experience

We have been presenting our courses internationally and domestically to civil, military and governmental organizations since 1984. See sampling of the organizations in this catalog and numerous attendee testimonials on our website. https://www.navtechgps.com/gps-gnss-training/testimonials/

Contact Us

We will provide you with information about your training options and happily address all your questions.

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*Recipient of The Institute of Navigation 2015 Norman P. Hays Award for the development and production of over 35 years of engineering tutorials in the field of satellite navigation, timing and inertial navigation; and for development and sustained support of The ION's conference programs.

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†*NavtechGPS is a Florida approved provider for Courses 122 and 346.*

Spring Remote Public Courses

April 7-10, 2025 Course 346 and 122 , 9AM-4:30PM, Eastern Standard Time

MONDAY April 7	TUESDAY April 8	WEDNESDAY April 9	THURSDAY April 10	
Course 346: GPS/GNSS Operation for Engineers and Technical Professionals (4 Days) Instructor: Dr. Chris Hegarty, MITRE				
Course 122: GPS/GNSS Fundamentals and Enhancements (Days 1 and 2 of Course 346) Instructor: Dr. Chris Hegarty, MITRE				

April 14-18, 2025, Course 557, 9AM-4:30PM, Eastern Standard Time

MONDAY April 14	TUESDAY April 15	WEDNESDAY April 16	THURSDAY April 17	FRIDAY April 18
Course 557: Inertial Systems, Kalman Filtering and GPS/INS Integration (5 Days) Instructor: Dr. Alan Pue, JHU/APL and Mr. Michael Vaujin, Aerospace, Navigation & Defense Consultant				

Fall Remote Public Courses

November 17-20, 2025, Course 346 and 122 , 9AM-4:30PM, Eastern Standard Time

MONDAY November 17	TUESDAY November 18	WENDESDAY November 19	THURSDAY November 20	
Course 346: GPS/GNSS Operation for Engineers and Technical Professionals (4 Days) Instructor: Dr. Chris Hegarty, MITRE				
Course 122: GPS/GNSS Fundamentals and Enhancements (Days 1 and 2 of Course 346) Instructor: Dr. Chris Hegarty, MITRE				

December 8-12, 2025, Course 557, 9AM-4:30PM, Eastern Standard Time

MONDAY **December** 8	TUESDAY **December** 9	WEDNESDAY **December** 10	THURSDAY **December** 11	FRIDAY **December** 12
Course 557: Inertial Systems, Kalman Filtering and GPS/INS Integration (5 Days) Instructor: Dr. Alan Pue, JHU/APL and Mr. Michael Vaujin, Aerospace, Navigation & Defense Consultant				

NavtechGPS has been leading the way in GPS/GNSS training for over 40 years. Our world-class instructors will have you develop top-level skills.

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 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.

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 2005, the Worcester Polytechnic Institute Hobart Newell 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.

Alan J. Pue, Ph.D., (Retired) was the chief scientist of the Air and Missile Defense Sector at The Johns Hopkins University Applied Physics Laboratory (JHU/APL). Since 1974, he had 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.

Michael Vaujin is an aerospace, navigation and defense consultant currently working for an aerospace engineering firm in Tucson, Arizona. He has over 35 years of experience in the fields of navigation and data fusion, and has designed aided strapdown solutions for land, sea, and airborne platforms using munition, tactical and navigation grade IMUs. 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.

Jade Morton, Ph.D.is Helen and Hubert Croft Professor in the Aerospace Engineering Sciences Department at the University of Colorado Boulder. Her research interests lie at the intersection of satellite navigation technologies and remote sensing of Earth's ionosphere, atmosphere, and surface. She received her PhD in electrical engineering (EE) from Penn State. Dr. Morton was a president and Satellite Division Chair of the US Institute of Navigation (ION), and a recipient of ION Thurlow, Burka, Kepler, IEEE PLANS Kershner, and AGU SPARC award. She is a fellow of IEEE, ION, and RIN.

Read What Our Attendees Have Said!

About Course 336/356: 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."
— *Felix Toran, ESTEC, November 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."
— *Jerry Rodriquez Melo, Patuxent, MD, February 2018*

"Mr. Hegarty went above and beyond in teaching the subject matter. I can't think of anything needing improvement." —Million Araya, US Navy, China Lake, October 2024

About Course 346: GPS Operations for Engineers and Technical Professionals

"I was very pleased with the instructor's teaching style. Dr. Hegarty was very organized and handled all questions completely. The class was only four days and it covered everything I was interested in to the appropriate detail. If anything, slightly more coverage of non-GPS constellations as our work at Samsung involves.

There were not technical "hiccups" or anything like that over the course of four days. Mr. Boynton moderated and helped keep things perfectly on schedule.
— William Schintler, Samsung Semiconductor, 2022 (Remote Course)

"Chris has some really great analogies for complex parts of GNSS. I also appreciated him asking questions that facilitate engagement. I have been working with GNSS receivers for several months now, but the course really helped me gain a deeper understanding of code-based vs carrier-based measurements. I also found the analysis of how different aspects of a GNSS receiver influence accuracy to be especially useful.
— David Ashbrook, ST Microelectronics, 2022 (Remote Course)

"The teaching style was very good. Dr. Hegarty was very effective at taking a massive amount of information and presenting it in a clear and well-paced manner even with the challenge of the virtual format."
— *Ryan Burgess, November 2021*

"The scheduling was perfect, very nice that we could join from Europe. Also the amount of material and number and interval of breaks was well thought of. Thank you for the useful and interesting course!"
— *Heiko Engwerda, NLR, July 2020 (Remote Course*

"The video quality was excellent; I am very pleased with the Webex platform. I don't feel as though going through the course remotely had any negative impact. It was still very personal, easy to ask questions, and I enjoyed the banter over coffee in the morning even if we were all scattered across the world. Mr. Boynton, Ms. McDonald, and Dr. Hegarty were so friendly and welcoming. This was such a great experience."
— *Shealyn Greer, Trident Research, July 2020*

"This course went above and beyond my expectations and I was able to learn a lot from Dr. Hegarty. I was astounded with how much math goes on behind GNSS since I only do environmental testing, so that was a very good deep dive into all the algorithms."
— *Cheryl Du, Joby Sero, May 2024*

The teaching style was excellent! Well presented from an engineering perspective, also high enough level for a non-engineer who is math knowledgable. Really liked how Chris introduced live scenarios and how theory is applied to actual equipment.
— *Eric Velez, US Navy, February 2022*

"Dr. Hegarty is awesome. He went out of his way to explain complex subjects and review material throughout his lectures, which allow complex subjects to be 'hammered in' my brain."
— *Fernando Nelson, US Navy, Patuxent River, MD, May 2023*

"I enjoyed the teaching style. The instructor was knowledgeable but made an effort to explain more complex topics. The instructor often asked the audience questions to keep up engagement. The instructor was willing to and often re-explained topics during breaks for those that requested."
— *Jonathan Yu, US Navy, Patuxent River, MD, May 2023*

About Course 557: Inertial Systems, Kalman Filtering and GPS/INS Integration

"Alan's teaching style was exceptionally good. He obviously knows the material thoroughly. He starts with simple concepts and simple mathematical equations and then builds on them in a very systematic manner time and time again using the same notation and the same variables all along the way. He really pulled everything together in a very cohesive and understandable way.
"
— *Vern Knowles, Multitronix, November 2024*

"I really enjoyed Mike's teaching style, he did a great job with making complex topics digestible and was very knowledgeable about practical estimation. He did a great job fielding questions and giving well-reasoned and understandable answers. I've been working with Extended Kalman Filters for a few years now and feel like I have a solid understanding of what they do and how they work, and even so I found I deepened that foundation with the way he explained things."

— Mike Pasquarelli, JHU/APL, 2024

"Vaujin is a great instructor and very engaging. I could take an entire semester course from him. I really enjoyed going through the Matlab with him, and the hands-on was where I was able to pick up the most knowledge."

— US Military, Name Withheld Upon Request, 2024

Both instructors were very knowledgeable and had great presence. The excitement on the topics of each instructor was very evident and made it easier for me to stay engaged.
— *Cameron Little, US Navy, July 2022*

It is easy to tell that this course is taught by passionate instructors, and that comes through both in their mastery of the subject material, and enthusiasm in presenting the subject matter in a concise and easy-to-follow manner. Despite the difficulty of the material, this course is one of the most well-taught courses I've had the pleasure of taking. I urge both of the instructors to keep teaching, as an instructor's passion is instrumental in a student's absorption of material. Needless to say, they both have passion in spades.
— Aaron Bruinsma, L3 Harris Wescam, December 2021

"It was very engaging and helped me learn topics that could have been tough to understand otherwise…Everything seemed relevant to our line of work.

— US Military, Name Withheld Upon Request, 2022

"I would strongly recommend this course to all GNC and Avionics colleagues at any level. Even for those with a background or experience in navigation systems, like myself, it will be incredibly insightful.

— João Paulo Vieira, SIATT, 2024

Read more at
https://www.navtechgps.com/gps-gnss-training/testimonials/

PUBLIC REMOTE COURSE: APRIL 7-10 & NOVEMBER 17-20, 2025 9:00-4:30 EST

Course 346: GPS/GNSS Operation for Engineers & Technical Professionals:

Principles, Technology, Applications and an Introduction to Basic DGPS (2.4 CEUs)

DAYS 1 AND 2 MAY BE TAKEN AS COURSE 122. SEE REGISTRATION FORM

DAY 1	DAY 2	DAY 3	DAY 4
Dr. Chris Hegarty			
Fundamentals of GPS operation. Overview of how the system works. U.S. policy and current status. **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	**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	**Differential GPS Overview** • Local- and wide-area architectures • Code vs. carrier-phase based systems • Data links; pseudolites • Performance overview **Differential Concepts** • Differential error sources • Measurement processing • Ambiguity resolution • Error budgets **DGPS Standards and Systems** • RTCM SC104 message format • USCG maritime DGPS and National DGPS (NDGPS) • Commercial satellite-based systems • Aviation systems: satellite-based and ground-based (SBAS/GBAS) • RINEX format, CORS and IGS networks • Precise time transfer	**GPS Signal Processing** • In-phase and quadra-phase signal paths • Analog-to-digital (A/D) conversion • Automatic gain control (AGC) • Correlation channels • Acquisition strategies **Code Tracking, Carrier Tracking & Data Demodulation** • Delay locked loop (DLL) implementations; performance • Frequency locked loops (FLLs) • Phase locked loops (PLLs) • Carrier-aiding of DLLs • Data demodulation **Receiver Impairments and Enhancements** • Impairments - bandlimiting, oscillators, multipath, interference • Enhancements - carrier smoothing, narrow correlator, codeless/semicodeless tracking, vector tracking, external aiding
Lunch			
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	**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	**GPS Signal Structure and Message Content** • Signal structure • Signal properties • Navigation message **GPS Receiver Overview** • Functional overview • Synchronization concepts • Acquisition • Code tracking • Carrier tracking • Data demodulation **GPS Antennas** • Antenna types • Antenna performance characteristics • Prefilters • Low-noise amplifiers (LNAs) • Noise figure	**GPS Navigation Algorithms: Point Solutions** • Pseudorange measurement models • Point solution method and example **Introduction to Kalman Filtering** • Algorithm overview • Process and measurement models for navigation • Simulation examples **Practical Aspects** • Types of GPS and DGPS receivers • Understanding specification sheets • Data links • Antennas • Receiver and interface standards • Accessories • Supplemental notes: Tracing a GPS signal through a receiver

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. (Note: The first two days are the same as Course 122. Course 346 expands on the concepts introduced in 122.)

Objectives

This course is designed to give you

- 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.

Materials You Will Keep

- A color electronic copy of all course notes provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- A textbook from the list below.

Course Fee Entitles You to One of the Following Books

Understanding GPS: Principles and Applications, 3rd ed., Elliott Kaplan & Chris Hegarty, Eds., Artech House, 2017, OR

- *Global Positioning System: Signals, Measurement and Performance, P. Misra and P. Enge, 2nd ed., 2011, OR*
- *Engineering Satellite-Based Navigation & Timing: GNSS, Signals and Receivers, John Betz, Ph.D.*
- *GPS Basics for Technical Professionls, P. Misra, 2019.*
- *Introduction to GPS: the Global Positioning System, 2nd Ed., A. El-Rabbany, 2006.*

What Attendees Have Said

"I enjoyed the teaching style. The instructor was knowledgeable but made an effort to explain more complex topics. The instructor often asked the audience questions to keep up engagement. (Dr. Hegarty) was willing to and often re-explained topics during breaks for those that requested."
— Jonathan Yu, US Navy, Patuxent River, MD, May 2023

Instructor

Dr. Chris Hegarty

"The teaching style was excellent! Well presented from an engineering perspective, also high enough level for a non-engineer who is math knowledgable. Really liked how Chris introduced live scenarios and how theory is applied to actual equipment."
— Eric Velez, United States Navy, March, 2022

PUBLIC REMOTE COURSE: APRIL 14-18 & DECEMBER 8-12 2025, 9:00-4:30 EST

Course 557: Inertial Systems, Kalman Filtering and GPS/INS Integration (3.0 CEUs)

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Dr. Alan Pue, Johns Hopkins, Navigation & Defense Consultant			Mr. Michael Vaujin, Aerospace, Navigation & Defense Consultant	
Introduction to INS/GPS integration • Inertial navigation • Integration architectures • Example applications **Vectors, Matrices, and State Space** • Vectors and matrices • State-space description • Examples **Random Processes** • Random variables • Covariance matrices • Random process descriptions	**Inertial Navigation Mechanization** • Gravity model • Navigation equations • Implementation options **Inertial Sensor Technologies** • Accelerometer technologies • Optical gyros • MEMS technologies • Technology survey **Strapdown Systems** • Quaternions • Orientation vector • Coning and sculling compensation	**INS Aiding of Receiver Tracking** • Code and carrier tracking • Track loop design trades • Interference suppression • Deep integration • **Tightly-Coupled INS/GPS Design** • Measurement processing • Filter parameter selection • Pseudo-range and delta pseudo-range measurement models **Multi-Sensor Integration** • Terrain aiding and relative GPS • Carrier phase differential integration • GPS interferometer/INS integration	**Aided Psi-Angle Navigator** • Description and demonstration of an aided Psi-angle wander azimuth navigator flying an aircraft type trajectory **Aided Phi-Angle Navigator** • Description and demonstration of an aided Phi-angle north-slaved navigator flying and aircraft type trajectory • Modeling position error as latitude/longitude error • Modeling position error as navigation frame tilt error • Comparison of popular state dynamics matrix elements **Partials of Measurement Equations** • Techniques and tricks for taking partials, examples • Psi-angle and Phi-angle feedback to strapdown • Pros and cons of the 3 different navigator types	**Square Root Filtering** • Square root covariance filtering and smoothing • Information filter derivation • Square root information filters • UD factorization & filtering **Suboptimal Covariance Analysis** • Effects of mis-modeling errors • Optimal and sub-optimal (two pass) covariance analysis • Error budget and reduced state analysis **Unscented Kalman Filters** • Sigma points and the Unscented Transform • Performance against the EKF • Augmentation and application to navigation • Spherical Simplex Sigma Points • Square Root UKFs
Lunch				
Kalman Filter • Filtering principles • Least squares estimation • Kalman filter derivation **Filter Implementation** • Filter processing example • Off-line analysis • Filter tuning **Navigation Coordinate Systems** • Earth model • Navigation coordinates • Earth relative kinematics	**Navigation System Errors** • Tilt angle definitions • Navigation error dynamics • Simplified error characteristics **System Initialization** • INS static alignment • Transfer alignment • Simplified error analysis **Loosely-Coupled INS/GPS Design** • Measurement processing • Filter design and tuning • Navigation system update	**Mr. Michael Vaujin, Aerospace, Navigation & Defense Consultant** **Building Extended Kalman Filter** • Linearized & Extended Kalman Filters • Radar tracking of vertical body motion with non-linear dynamics • Radar tracking of an accelerating body with non-linear measurements **Numerical Preliminaries & Considerations** • Keeping a covariance matrix well-conditioned, symmetric, & positive definite • Sequential vs batch measurement processing • Methods of measurement de-correlation **Discreet Time Strapdown Implementation** • Attitude updates and TOV of the acceleration • Propagating the position DCM • High rate vs low rate routines • Effects of errors in initialization & IMU data	**Initialization & Process Noise** • Strapdown and covariance matrix initialization • Process noise for gravity and random walk • Common sensor error models: random constant, random walk and Gauss Markov **Measurement Editing & Adaptive Filters** • Online and offline residual analysis • Advanced methods of outlier detection and rejection • Multiple Model Adaptive Estimation • Application to carrier phase integer ambiguity resolution **Methods of Smoothing** • Optimal prediction and fixed interval smoothing • Fixed point and fixed lag smoothing • Applications to navigation testing	**Ground Alignment & Integrated Velocity** • Gyro-Compassing, zero velocity and zero earth rate observations • Large azimuth static alignment, advanced methods • Small azimuth static alignment & leveling • Ground alignment observability examples • Integrated true velocity error, mapping into delta-range **Attitude Matching & Use of Inexpensive IMUs** • Attitude matching & boresight error states • Considerations for use of very inexpensive IMUs • Non-holonomic motion constraints • Magnetometer aiding • In class measurement equation exercise • Matrix partitioning for computational efficiency **Particle Filtering** • Bootstrap particle filter (PF) • Multi-modal position solutions • Particle filter example • Applications to navigation

Course Objectives

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

- Recommended, but not required: A computer (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. However, ALL of the problems will also be worked in class by the instructor.
- These course notes are searchable and you can take electronic notes with the Adobe Acrobat Reader we will provide you.

Materials You Will Keep

- A color electronic copy of all course notes provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- Textbook: I*ntroduction to Random Signals and Applied Kalman Filtering,* 3rd edition, by R. Grover Brown and Patrick Hwang, John Wiley & Sons, Inc., 1996.)

What Attendees Have Said

"I really enjoyed the teaching style. I learn better with examples and implementation so I thought the material was very well laid out. I had a few gaps in my knowledge and going through these implementations really helped it."
—Johnny Wang, Amazon

"Both instructors were very knowledgeable and had great presence. The excitement on the topics of each instructor was very evident and made it easier for me to stay engaged." — Cameron Little, US Navy

Instructors

Dr. Alan Pue, JHU/APL (Retired)

Mr. Michael Vaujin, Consultant

PRESENTED AS A PRIVATE GROUP COURSE ONLY

Course 338: Ionospheric Effects, Monitoring, and Mitigation Techniques (1.8 CEUs)

DAY 1	DAY 2	DAY 3
Introduction to Ionospheric Effects • Fundamental properties of ionosphere impacting satellite navigation • Ionospheric refraction effects in GNSS measurements: code delay, carrier advance, and total electron content (TEC) • TEC broadcast models for single-frequency receivers • TEC estimation using dual-frequency receiver measurements • TEC estimation using multi-frequency receiver measurements • TEC estimation using single-frequency receiver measurements	**Ionospheric Scintillation – Concepts, Theory, Modeling, and Monitoring** • Distinctions between refraction and diffraction effects • Scintillation theory: phase screen models • GNSS signal scintillation indicators • Scintillation model for GPS-like signals transmitted from LEO satellites • Scintillation model for VHF, UHF, L, C, and S band signals transmitted from LEO satellites	**Recent advances in ionospheric effects monitoring and forecasting** • GNSS radio occultation • GNSS reflectometry • Ionospheric effects on signals transmitted from LEO satellites • Machine learning (ML) for ionospheric disturbance detection, classification, and forecasting.
Ionospheric Effects Correction Method • Vertical TEC (VTEC) and mapping function • IGS VTEC products • Network-based VTEC mapping methods • TEC estimation using low-cost receivers • TEC estimation using cell phone measurements • Higher-order ionospheric errors	**Ionospheric scintillation effects and mitigation techniques** • Scintillation effects • Scintillation signal tracking algorithms: architecture, implementations, and performance assessment	A detailed version of the outline for this course can be found at navtechgpscom/338-outline

Instructor

Dr. Jade Morton,

Dr. Jade Morton is Helen and Hubert Croft Professor in the Aerospace Engineering Sciences Department at the University of Colorado Boulder. Her research interests lie at the intersection of satellite navigation technologies and remote sensing of Earth's ionosphere, atmosphere, and surface. She received her PhD in electrical engineering (EE) from Penn State. Dr. Morton was a president and Satellite Division Chair of the US Institute of Navigation (ION), and a recipient of ION Thurlow, Burka, Kepler, IEEE PLANS Kershner, and AGU SPARC award. She is a fellow of IEEE, ION, and RIN.

Note that this course is scheduled to be presented over three days. The start of each lecture is expected to begin later than outlined based on the time added by attendee questions

Course Objectives

- To provide a comprehensive review of fundamentals of ionospheric effects on GNSS
- To present ionospheric correction techniques to improve GNSS measurement accuracy
- To showcase the latest receiver signal processing techniques to mitigate ionospheric scintillation effects
- To highlight recent advances in ground and spaceborne ionospheric monitoring systems, machine learning algorithms, and simulation models to improve current and future navigation systems performance.

Who Should Attend?

This course is designed for students, engineers, researchers, and managers interested in satellite navigation and remote sensing technologies and applications.

Materials You Will Keep

- A color electronic copy of all course notes provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- A GNSS textbook of your choosing from our list of recommended companion texts

Course Description:

Ionospheric effects are major threats to the availability, continuity, and accuracy of GNSS solutions and other satellite-based radio systems. Models, global networks of GNSS stations, and LEO satellite-based radio occultation constellations have been established to monitor and predict the ionospheric effects. This course will present the current state-of-art understanding of the various ionospheric effects on GNSS-based navigation systems and their mitigation techniques. The course consists of five lectures. The first lecture introduces the fundamental properties of the ionosphere that impact satellite navigation signals and PVT solutions, discusses the ionospheric refractive effects, broadcast models from various GNSS service provides, and the Total Electron Content (TEC) estimation techniques for single, dual-, and multi-frequency GNSS receivers. The second lecture focuses on ionospheric error correction methods, including IGS TEC products, network-based TEC mapping techniques, low-cost ionospheric monitoring system, and the latest developing in using cell phone measurements to map ionosphere. Higher order refraction errors and correction techniques will also be covered. Lecture 3 covers ionospheric scintillation effect, with a focus on the concepts, theory, modeling, and indicators for monitoring. Scintillation signal models for current GNSS L-band signals and potential future LEO satellite-based navigation systems at multiple bands ranging from VHF to S band will be discussed. Lecture 4 takes a deeper look into GNSS receiver signal processing algorithms designed to combat ionospheric scintillation effects. Part 5 will provide an update on the latest development in ionospheric effects monitoring and forecasting using machine learning algorithms, worldwide ground-based and space-based GNSS observations, the ionospheric effects on signals transmitted from LEO satellites. We will finish the course with an outlook for outstanding challenges in the field.

PRESENTED AS A PRIVATE GROUP COURSE ONLY

Course 336: GPS/GNSS Fundamentals and Enhancements with Emphasis on DGPS (1.8 CEUs)

Day 1	Day 2	Day 3
Dr. Chris Hegarty		
Fundamentals of GPS operation. Overview of how the system works. U.S. policy and current status. **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	**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	**Differential GPS Overview** • Local-area, regional-area, wide-area architectures • Code vs. carrier-phase based systems • Pseudolites • Performance overview **Differential Error Sources** • Satellite ephemeris errors • Satellite clock errors • Selective availability • Ionospheric, tropospheric delay • Multipath • Receiver internal noise, biases **Observable Modeling** • Code pseudorange and carrier-phase outputs • Code-minus-carrier observables • Carrier-smoothed code operation • Double difference operation • System error budgets
LUNCH IS ON YOUR OWN		
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	**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&IGS network for precise positioning (survey) • Precise time transfer

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

Instructor

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. (Note: the first two days are the same as Course 122. Day 3 is dedicated to differential GPS.)

Prerequisites

Familiarity with engineering terms is very helpful but not essential. Non-engineers will benefit from the conceptual explanations..

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.

Materials You Will Keep

- A color electronic copy of all course notes provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- *GPS Basics for Technical Professionals*, P. Misra, 2019.

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

"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
(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 term. Dr. Hegarty got my full attention."
— Sigong Ho, NovAtel; Course 346,
(Course 336 is a subset of Courses 346 and 356)

"The instructor's [Dr. Hegarty] knowledge of the subject is very impressive. He gave a lot of interesting information on top of what was posted on the slides. I would consider this extra information very helpful. I now have quite an in-depth knowledge of how GPS works. I can definitely relate the working concepts to the technology I handle at work and to make better decisions."
— Jerry Rodriquez Melo, Patuxent, Maryland

PRESENTED AS A PRIVATE GROUP COURSE ONLY

Couses 356: GPS/GNSS and DGPS Operation 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.)

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Dr. Chris Hegaty, MITRE				
Fundamentals of GPS operation. Overview of how the system works. U.S. policy and current status. **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	**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	**Differential GPS Overview** • Local-area, regional-area, wide-area architectures • Code vs. carrier-phase based systems • Pseudolites • Performance overview **Differential Error Sources** • Satellite ephemeris errors • Satellite clock errors • Selective availability • Ionospheric, tropospheric delay • Multipath • Receiver internal noise, biases **Observable Modeling** • Code pseudorange and carrier-phase outputs • Code-minus-carrier observables • Carrier-smoothed code operation • Double difference operation • System error budgets	**GPS Signal Structure and Message Content** • Signal structures • Signal properties • Navigation message **GPS Receiver Overview** • Functional overview • Synchronization concepts • Acquisition • Code tracking • Carrier tracking • Data demodulation **GPS Antennas** • Antenna types • Antenna performance characteristics • Prefilters • Low-noise amplifiers (LNAs) • Noise figure	**Case Study: Tracing a GPS Signal Through a Receiver** • Received signal • Digitized signal • Correlator outputs • Code-phase estimate • Carrier-phase estimate • Data demodulation **GPS Navigation Algorithms: Point Solutions** • Pseudorange measurement models • Point solution method and example **Basics of Kalman Filtering** • Introduction to Kalman filtering • Filter structure • Simulation results
Lunch is On Your Own				
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	**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&IGS network for precise positioning (survey) • Precise time transfer	**GPS Signal Processing** • In-phase and quadra-phase signal paths • Analog-to-digital (A/D) conversion • Automatic gain control (AGC) • Correlation channels • Acquisition strategies **Code Tracking, Carrier Tracking & Data Demodulation** • Delay locked loop (DLL) implementations; performance • Frequency locked loops (FLLs) • Phase locked loops (PLLs) • Carrier-aiding of DLLs • Data demodulation **Receiver Impairments and Enhancements** • Impairments - bandlimiting, oscillators, multipath, interference • Enhancements - carrier smoothing, narrow correlator, codeless/semicodeless tracking, vector tracking, external aiding	**Kalman Filtering for GPS Navigation** • Clock models and dynamic models • Integration with INS • Measurement and dynamic mismodeling **Practical Aspects I** • Types of GPS and DGPS receivers • Understanding specification sheets • Data links • Antennas **Practical Aspects II** • Receiver and interface standards • Connectors • Accessories • Test, evaluation, and signal performance

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 technical information gaps for those working in the GPS and GNSS fields.
- Note: This course encompasses Courses 122, 336 and 356B. If you have selected this course, do not separately select any of these course numbers.

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 in-depth than what is taught in Course 346.)

Materials You Will Keep

- A color electronic copy of all course notes provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- A textbook from the list below.

Course Fee Entitles You to One of the Following Books

- *Understanding GPS: Principles and Applications,* 2nd ed., Elliott Kaplan & Chris Hegarty, Eds., Artech House, 2006, OR
- *Global Positioning System: Signals, Measurement and Performance,* P. Misra and P. Enge, 2nd ed., 2011.
- *GPS Basics for Technical Professionls,* P. Misra, 2019.
- *Introduction to GPS: the Global Positioning System,* 2nd Ed., A. El-Rabbany, 2006. .

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.
— Name withheld upon request

Instructor:

Dr. Chris Hegarty

PRESENTED AS A PRIVATE GROUP COURSE ONLY

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

Day 1	Day 2	DAy 3
Dr. Chris Hegarty, MITRE		
Differential GPS Overview • Local-area, regional-area, wide-area architectures • Code vs. carrier-phase based systems • Pseudolites • Performance overview **Differential Error Sources** • Satellite ephemeris errors • Satellite clock errors • Selective availability • Ionospheric, tropospheric delay • Multipath • Receiver internal noise, biases **Observable Modeling** • Code pseudorange and carrier-phase outputs • Code-minus-carrier observables • Carrier-smoothed code operation • Double difference operation • System error budgets	**GPS Signal Structure and Message Content** • Signal structures • Signal properties • Navigation message **GPS Receiver Overview** • Functional overview • Synchronization concepts • Acquisition • Code tracking • Carrier tracking • Data demodulation **GPS Antennas** • Antenna types • Antenna performance characteristics • Prefilters • Low-noise amplifiers (LNAs) • Noise figure	**Case Study: Tracing a GPS Signal Through a Receiver** • Received signal • Digitized signal • Correlator outputs • Code-phase estimate • Carrier-phase estimate • Data demodulation **GPS Navigation Algorithms: Point Solutions** • Pseudorange measurement models • Point solution method and example **Basics of Kalman Filtering** • Introduction to Kalman filtering • Filter structure • Simulation results
Lunch is on your own		
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&IGS network for precise positioning (survey) • Precise time transfer	**GPS Signal Processing** • In-phase and quadra-phase signal paths • Analog-to-digital (A/D) conversion • Automatic gain control (AGC) • Correlation channels • Acquisition strategies **Code Tracking, Carrier Tracking & Data Demodulation** • Delay locked loop (DLL) implementations; performance • Frequency locked loops (FLLs) • Phase locked loops (PLLs) • Carrier-aiding of DLLs • Data demodulation **Receiver Impairments and Enhancements** • Impairments - bandlimiting, oscillators, multipath, interference • Enhancements - carrier smoothing, narrow correlator, codeless/semicodeless tracking, vector tracking, external aiding	**Kalman Filtering for GPS Navigation** • Clock models and dynamic models • Integration with INS • Measurement and dynamic mismodeling **Practical Aspects I** • Types of GPS and DGPS receivers • Understanding specification sheets • Data links • Antennas **Practical Aspects II** • Receiver and interface standards • Connectors • Accessories • Test, evaluation, and signal performance

FOR GROUPS WHO ALREADY KNOW GPS/GNSS BASICS, BUT NEED TO LEARN DIFFERENTIAL GPS AND KALMAN FILTERING BASICS

Instructor

Dr. Chris Hegarty

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 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.

Prerequisites

Knowledge of GPS fundamentals, as presented in Course 122 is assumed.

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 provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- A textbook .

Course Fee Entitles You to One of the Following Books

- *Introduction to GPS: The Global Positioning System*, 2nd ed., Ahmed El-Rabbany, Artech House, 2006, OR
- *Global Positioning System: Signals, Measurement and Performance,* P. Misra and P. Enge, 2nd ed., 2011, OR
- *GPS Basics for Technical Professionals,* P. Misra, 2019, OR
- *Understanding GPS: Principles and Applications, 3rd Edition,* E. Kaplan and C. Hegarty, 2017

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, 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, Annapolis, Maryland*

"[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."

— Name withheld upon request.,

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GNSS Courses for Engineers and Technical Professionals

April 7-10, 2025 9:00-4:30 EST ◆ Taught Remotely

"The teaching style was excellent! Well presented from an engineering perspective, also high enough level for a non-engineer who is math knowledgable. Really liked how Chris introduced live scenarios and how theory is applied to actual equipment." — Eric Velez, United States Navy

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Select Your Course				Choose Media		Individual Attendee Fees		
SELECT COURSE		Course Name	Dates	USB	CD-ROM	Public	CEUs	US Govt*
☐		**346: GPS/GNSS Operation for Engineers and Technical Professionals.** (4 days)† **(Select Book Choice Below)**	Apr 7-10 9 AM to 4:30 PM EDT	◯	◯	$2899	2.4	$2699**
☐		**122: GPS Fundamentals and Enhancements (Days 1 and 2 of Course 346)** (2 days)† (Book: *GPS Basics for Technical Professionals*, Pratap Misra, Ph.D.)	Apr 7-8 9 AM to 4:30 PM EDT	◯	◯	$1899	1.2	$1749**

Course notes are provided on CD-ROM or USB drive (as well as on paper in black and white). PLEASE SELECT MEDIA

For group discounts, contact Trevor Boynton at +1-571-226-0649, or tboynton@navtechgps.com

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

Reset Selections

☐ Are you a student? Check your year for a 25% discount! ◯ 2025 ◯ 2026 ◯ 2027+ *(Discount will be reflected on the invoice we send you.)*

Course 346 Attendees: CHOOSE ONE

	☐	***Understanding GPS: Principles and Applications, 3rd ed.,*** Elliott Kaplan & Chris Hegarty, Eds., Artech House, 2017. *Note: This book is print to order and may arrive after the start of the course.*
	☐	***Global Positioning System: Signals, Measurement and Performance,*** P. Misra and P. Enge, 2nd ed., 2011
	☐	***Engineering Satellite-Based Navigation & Timing: GNSS, Signals and Receivers,*** John Betz, Ph.D., 2015
	☐	***Introduction to GPS: the Global Positioning System, 2nd Ed.,*** A. El-Rabbany, 2006
		Check out our other GNSS titles at https://www.navtechgps.com/departments/books/all-books/

We can accept registrations the day before the course starts, but cannot guarantee timely arrival of materials unless payment and registration is received three weeks before the course starts.

Billing Office Contact (If Any): * _____ (Title/Pronouns) _____ (First Name) _____ (Middle Initial) * _____ (Last (Family Name))

Billing Office Email (If Any): * _____ Cell Phone: * _____ Fax: : * _____

Attendee Name: * _____ (Title/Pronouns) * _____ (First Name) _____ (Middle Initial) * _____ (Last (Family Name))

Attendee Organization:* _____ Internal Mail Stop:* _____ Fax:* _____

Attendee Address:* _____ City: * _____

Attendee State/Province:* _____ Zip/Postal Code: * _____ Country: : * _____

Attendee Email: * _____ **Attendee** Cell Phone: * _____ Office Phone:* _____

Where or From Whom did You Hear About This Course? _____

**Required Information*

Check here ☐ if you require a formal invoice.

Payment method:

☐ **Credit card** (We will send you a credit card link for payment after the the minimum course attendance is confirmed. A 2.75% processing fee will be added.)

☐ **Wire Transfer** (Please send me wire transfer instructions. **Note:** NavtechGPS does NOT charge a processing fee for wire transfers.)

☐ **A purchase order or training form** will be sent to the attention of Trevor Boynton at the address below.

☐ **Check** to be made payable to NavtechGPS and mailed to the address below.

Questions? Call or email Trevor Boynton, tboynton@navtechgps.com

NavtechGPS ◆ 5500 Cherokee Avenue ◆ Suite 440 ◆ Alexandria, VA 22312-2321 USA ◆ +1-703-256-8900

COURSE CODE: 2501

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557: Inertial Systems, Kalman Filtering, and GPS/INS Integration

April 14-18, 2025 9:00-4:30 EST ◆ Taught Remotely

"It is easy to tell that this course is taught by passionate instructors, and that comes through both in their mastery of the subject material, and enthusiasm in presenting the subject matter in a concise and easy-to-follow manner. Despite the difficulty of the material, this course is one of the most well-taught courses I've had the pleasure of taking. I urge both of the instructors to keep teaching, as an instructor's passion is instrumental in a student's absorption of material. Needless to say, they both have passion in spades."— *Aaron Bruinsma, L3 Harris Wescam*




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Check One	Select Your Course		Choose Media		Individual Attendee Fee		
Sellect Course	Course Name	Dates	USB	CD-ROM	Fee Public	CEUs	Fee US Govt*
☐	557A: Inertial Systems, Kalman Filtering, and GPS/INS Integration (This is the **FULL enhanced course, taught over 5 sessions.** See our website for details.)	APR 14-18	◯	◯	$3299	3.0	$2999**
☐	557B: Inertial Systems, Kalman Filtering, and GPS/INS Integration (No Review). **I want to opt out of the morning of Apr 14; I do not need the review, which reduces my fee.**	APR 14-18	◯	◯	$3249	2.7	$2984**

Course notes are provided on CD-ROM or USB drive (as well as on paper in black and white). **PLEASE SELECT MEDIA**

For group discounts, contact Trevor Boynton at +1-571-226-0649, or tboynton@navtechgps.com

Reset Selections

**Courtesy U.S. federal government/U.S. military discount.

☐ Are you a student? Check your year for a 25% discount! ◯2025 ◯2026 ◯2027+ *(Discount will be reflected on the invoice we send you.)*

We can accept registrations the day before the course starts, but cannot guarantee timely arrival of materials unless payment and registration is received three weeks before the course starts.

Billing Office Contact (If Any): * _____ (Title/Pronouns) _____ (First Name) _____ (Middle Initial) * _____ (Last (Family Name))

Billing Office Email (If Any): * _____ Cell Phone: * _____ Fax: : * _____

Attendee Name: * _____ (Title/Pronouns) * _____ (First Name) _____ (Middle Initial) * _____ (Last (Family Name))

Attendee Organization:* _____ Internal Mail Stop:* _____ Fax:* _____

Attendee Address:* _____ City: * _____

Attendee State/Province:* _____ Zip/Postal Code: * _____ Country: : * _____

Attendee Email: * _____ **Attendee** Cell Phone: * _____ Office Phone:* _____

Where or From Whom did You Hear About This Course? _____

**Required Information*

Check here ☐ if you require a formal invoice.

Payment method:

☐ **Credit card** (We will send you a credit card link for payment after the the minimum course attendance is confirmed. A 2.75% processing fee will be added.)

☐ **Wire Transfer** (Please send me wire transfer instructions. **Note:** NavtechGPS does NOT charge a processing fee for wire transfers.)

☐ **A purchase order or training form** will be sent to the attention of Trevor Boynton at the address below.

☐ **Check** to be made payable to NavtechGPS and mailed to the address below.

Questions? Call or email Trevor Boynton, tboynton@navtechgps.com
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COURSE CODE: 2502

NavtechGPS **REGISTER TODAY! (Tentative Registrations Accepted)**

GNSS Courses for Engineers and Technical Professionals

November 17-20 ,2025 9:00-4:30 EST ◆ Taught Remotely

"The teaching style was excellent! Well presented from an engineering perspective, also high enough level for a non-engineer who is math knowledgeable. Really liked how Chris introduced live scenarios and how theory is applied to actual equipment." — Eric Velez, United States Navy

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Select Your Course				Choose Media		Individual Attendee Fees		
SELECT COURSE		Course Name	Dates	USB	CD-ROM	Public	CEUs	US Govt*
☐		**346: GPS/GNSS Operation for Engineers and Technical Professionals.** (4 days)† **(Select Book Choice Below)**	November 17-20 9 AM to 4:30 PM EDT	◯	◯	$2899	2.4	$2699**
☐		**122: GPS Fundamentals and Enhancements (Days 1 and 2 of Course 346)** (2 days)† (Book: *GPS Basics for Technical Professionals*, Pratap Misra, Ph.D.)	November 17-18 9 AM to 4:30 PM EDT	◯	◯	$1899	1.2	$1749**

Course notes are provided on CD-ROM or USB drive (as well as on paper in black and white). PLEASE SELECT MEDIA

For group discounts, contact Trevor Boynton at +1-571-226-0649, or tboynton@navtechgps.com

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

Reset Selections

☐ Are you a student? Check your year for a 25% discount! ◯ 2025 ◯ 2026 ◯ 2027+ *(Discount will be reflected on the invoice we send you.)*

Course 346 Attendees: CHOOSE ONE

	☐	***Understanding GPS: Principles and Applications, 3rd ed.,*** Elliott Kaplan & Chris Hegarty, Eds., Artech House, 2017. *Note: This book is print to order and may arrive after the start of the course.*
	☐	***Global Positioning System: Signals, Measurement and Performance,*** P. Misra and P. Enge, 2nd ed., 2011
	☐	***Engineering Satellite-Based Navigation & Timing: GNSS, Signals and Receivers,*** John Betz, Ph.D., 2015
	☐	***Introduction to GPS: the Global Positioning System, 2nd Ed.,*** A. El-Rabbany, 2006
		Check out our other GNSS titles at https://www.navtechgps.com/departments/books/all-books/

We can accept registrations the day before the course starts, but cannot guarantee timely arrival of materials unless payment and registration is received three weeks before the course starts.

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Billing Office Email (If Any): * _____ Cell Phone: * _____ Fax: : * _____

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Attendee Organization:* _____ Internal Mail Stop:* _____ Fax:* _____

Attendee Address:* _____ City: * _____

Attendee State/Province:* _____ Zip/Postal Code: * _____ Country: : * _____

Attendee Email: * _____ **Attendee** Cell Phone: * _____ Office Phone:* _____

Where or From Whom did You Hear About This Course? _____

**Required Information*

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Course notes are provided on CD-ROM or USB drive (as well as on paper in black and white). **PLEASE SELECT MEDIA**

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Attendee Name: * _____ (Title/Pronouns) * _____ (First Name) _____ (Middle Initial) * _____ (Last (Family Name))

Attendee Organization:* _____ Internal Mail Stop:* _____ Fax:* _____

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