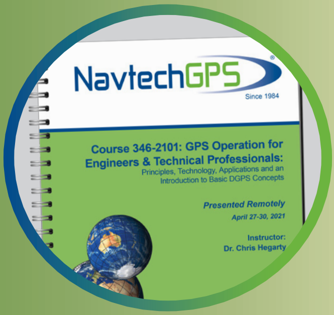
GPS/GNSS Courses for 2024!

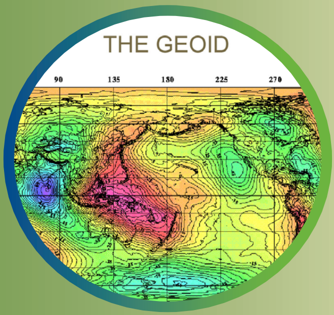
GNSS Courses Offered in the Following Areas

- 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 40 years of serving the PNT community as the go-to company for GPS, GNSS, and inertial navigation training.

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



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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

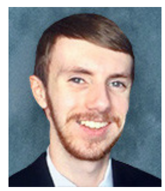
.

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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CONTENTS

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

Spring Remote Public Courses

April 29-May 2, 2024, Course 346 and 122 , 9AM-4:30PM, Eastern Standard Time

MONDAY April 29	TUESDAY April 30	WEDNESDAY May 1	THURSDAY May 2	
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				

May 13-17, 2024, Course 557, 9AM-4:30PM, Eastern Standard Time

MONDAY May 13	TUESDAY May 14	WEDNESDAY May 15	THURSDAY May 16	FRIDAY May 17
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 18-21, 2024, Course 346 and 122 , 9AM-4:30PM, Eastern Standard Time

MONDAY November 18	TUESDAY November 19	WENDESDAY November 20	THURSDAY November 21	
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 9-13, 2024, Course 557, 9AM-4:30PM, Eastern Standard Time

MONDAY December 9	TUESDAY December 10	WEDNESDAY December 11	THURSDAY December 12	FRIDAY December 13
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 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 inv ention of the Kalman filter.

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*

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 (Remote Course)*

"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*

"I was most excited to learn about GPS receivers and antennas. I really didn't know much about GPS hardware before this course. Dr. Hegarty walked us through each component of a receiver and antenna, and I feel it was very beneficial to understand the GPS algorithm as it relates to physical components."
— *Shealyn Greer, Trident Research, July 2020*

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 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 witheld upon request, May 2018, Falls Church, VA*

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

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

"I have recently become interested in learning about strapdown navigation. My objective was to increase my exposure to the topic and gain a more solid overview.
This course met and exceeded my objectives."
— *Kenneth Bentley, United States Air Force, July 2020 (Remote Course))*

"My goal for the course taught by Dr. Alan Pue was to understand how IMUs were integrated into the Kalman filter. The second day's lecture way very helpful for that purpose."
— *Paul Massatt, Aerospace, July 2020 (Remote Course)*

"My main objectives were to learn the aspects of and how to implement modern navigation algorithms. The course definitely met those objectives."
— *Travis Noffke, EXB Solutions, July 2020 (Remote Course)*

"Can't speak highly enough. Mr. Vaujin was engaging and taught the course like a veteran IMU designer teaching novices what to do when they design their own IMU. Do this trick of the trade. Watch out for that pitfall. Be explicit with your vector notation. All of those things Vaujin did and I felt were immensely helpful."
— *Cody Carter, USAF, July 2020 Remote Course)*

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

"

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

PUBLIC REMOTE COURSE: APRIL 29-MAY 2, 2024 9:00-4:30 EST (PRIVATE GROUP OPTION AVAILABLE)

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*

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Instructor

Dr. Chris Hegarty

 FOR MORE: Contact Trevor Boynton, tboynton@navtechgps.com or Carolyn McDonald, cmcdonald@navtechgps.com. (703) 256-8900

PUBLIC REMOTE COURSE: NOVEMBER 18-21, 2024 9:00-4:30 EDT (PRIVATE GROUP OPTION AVAILABLE)

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

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— Eric Velez, United States Navy (March, 2022)

Instructor

Dr. Chris Hegarty

PUBLIC REMOTE COURSE: MAY 13-17, 2024, 9:00-4:30 EST (PRIVATE GROUP OPTION AVAILABLE)

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 naviga-tor 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

PUBLIC REMOTE COURSE: DECEMBER 9-13, 2024, 9:00-4:30 EDT (PRIVATE GROUP OPTION AVAILABLE)

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

PRIVATE GROUP COURSE

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

PRIVATE GROUP COURSE

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

PRIVATE GROUP COURSE

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 from the list below.

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

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

GNSS Courses for Engineers and Technical Professionals

April 29-May 2, 2024 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

ATTN: Download and save form BEFORE completing. Email to: tboynton@navtechgps.com; Fax : +1-703-256-8988. Questions: +1-703-256-8900

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)**	April 29-May 2 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.)	April 29-30 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 year for a 25% discount!** ○ 2024 ○ 2025 ○ 2026+ *(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)

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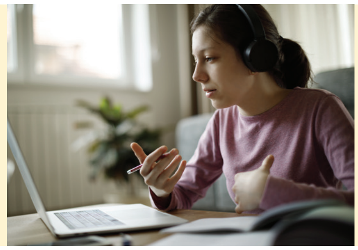


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☐	557B: Inertial Systems, Kalman Filtering, and GPS/INS Integration (No Review). I want to opt out of the morning of Dec 11; I do not need the review, which reduces my fee.	MAY 13-17	○	○	$3249	2.7	$2984**

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