December 4-7, 2018
Hyatt House Falls Church/ Merrifield
8296 Glass Alley
Fairfax, Virginia, USA, 22031

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

— Margaret Alfafara, Northrop Grumman; December 2014, San Diego

COURSE 346

GPS / GNSS Operations for Engineers & Technical Professionals:

Principles, Technology, Applications and an Introduction to Basic DGPS Concepts

DAYS 1 AND 2 MAY BE TAKEN AS A SEPARATE COURSE (COURSE 122/123). SEE REGISTRATION FORM

	DAY 1	DAY 2	DAY 3	DAY 4
	Dr. Chris Hegarty			
8:30	**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 is on your own			
5:00	**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.

Objectives

This course is designed to give you

- A comprehensive introduction to GPS, system concepts, an introduction to differential GPS (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 and 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 on a USB Drive or CD-ROM. Bringing a laptop to this class is highly recommended for taking notes using the Adobe® Acrobat® sticky notes feature; power access will be provided.
- A black and white hard copy of the course notes will also be provided.

Course Fee Entitles You to the Following Books

Understanding GPS: Principles and Applications, 3rd 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.

What Attendees Have Said

"I have been working with GPS since 1976 and still learned a lot from this course."
— John Barry, FAA, November 2016

"[Dr. Hegarty] is absolutely a wonderful instructor. Very knowledgeable in all areas of GPS. No matter what questions anyone had, he was perfectly able to confidently answer those questions."
— Hamid R. Tabanro, John Deere (Course 346, April 2014)

Instructor

Dr. Chris Hegarty