e-KnoT Professional Training Program

PRESENTATION OF THE E-KNOT PROJECT:

- The e-Knot project aims at building strong links between universities, research institutes and industry, and leveraging on past activities already undertaken in this field. It provides direct benefits to industry by implementing measures to strengthen GNSS education and fostering the co-operation between education, research and business in favour of innovation. For more information, please consult: **www.eknotproject.eu**

PRESENTATION OF THE E-KNOT TRAINING PROGRAM:

- The e-Knot professional training program is an ambitious program aimed at **providing GNSS training to employees of industry, research centres and institutions**. It is based on the provision of twelve **3-day free-of charge tutorials** over 3 years (2 in 2015, 5 in 2016 and 5 in 2017).
- This program is supported by the European Commission and the European GNSS Agency (GSA) through the e-Knot project under the grant agreement 641529

INSTRUCTORS

- The instructors of the e-KnoT professional training program are GNSS experts from the **Ecole Nationale de l'Aviation Civile** (France), **Politecnico di Torino** (Italy), **Universitat Politècnica de Catalunya** (UPC) and **Astri Polska.**

TRAINING PROGRAM SCHEDULE FOR 2016 (SEE FOLLOWING PAGES FOR DETAILS):

Course Title	Date	Location	Registration Deadline
Fundamentals of GNSS	10-12 April 2017	Astri Polska, Poland, Warsaw	10 March 2017
Multi-Sensor Navigation	22-24 May 2017	GSA, Czech Republic, Prague	21 April 2017
GNSS Receiver Signal Processing	13-15 June 2017	Polito, Italy, Torino	12 May 2017
Vulnerabilities of GNSS	03-05 October 2017	ENAC, France, Toulouse	04 September 2017
Precise Positioning	07-09 November 2017	UPC, Spain, Barcelona	06 October 2017

REGISTRATION GUIDELINES

The registration is **free-of-charge** (coffee breaks and lunches are included). Travel costs, hotel and living expenses have to be covered by the participant.

The tutorials are **open to any employee** coming from a company, an international/national institution or a research centre.

The registration deadline is **1 month before the start of the tutorial**. Confirmation of registration will be required 3 weeks before the start of the tutorial. If we don't receive a confirmation within the following week, we consider that the participant has cancelled his/her registration.

The selection process will follow a **first-come-first-served** basis. Priority will be given to employees coming from a H2020 company/institution/research centre (see box on the left for the list of H2020 countries).

You can register by submitting your information via the following online form:
http://signav.recherche.enac.fr/index.php/registration-e-knot-trainings/

28 EU countries + Iceland, Norway, Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro, Serbia,Turkey, Israel, Moldova, Switzerland, Faroe Islands

CONTACT INFORMATION

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http://goo.gl/Ie4v4P
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European Global Navigation Satellite Systems Agency
HORIZON 2020
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DLC
Universität der Bundeswehr München
UPC
astri polska
bavAIRia

Tutorial 1: Fundamentals of GNSS

OBJECTIVES:

This course provides a beginners' guide to GNSS technology. It introduces current systems and presents future systems that are becoming available. The course discusses the concepts behind global positioning, how the signal is used to determine location by a receiver and end-user applications. Later in the course the sources of GNSS error are discussed, as well as the various augmentations systems available for service enhancement. A concluding talk is presented on the future of GNSS and the European Galileo system.

TOPICS COVERED:

- **Fundamentals of Satellite Navigation**
  - What is navigation?
  - Position fixing
- **GNSS Systems**
  - GPS, GLONASS, Galileo, BeiDou, regional navigation systems
  - System architecture: space, control and user segments
- **GNSS signals**
  - Position and time determination
  - GNSS signal structure
- **Reference Systems: Coordinates and Times**
  - Coordinate systems, frames and transformations
  - Fundamentals of Time References
- **GNSS Receivers and Architecture**
  - Data acquisition & data formats: Receiver Front-end
  - GNSS receiver data processing from measurements to coordinates
- **GNSS software receiver Demonstrator**
  - Analysis of GNSS base-band processing chain using a GNSS software Receiver
- **Range Error Sources**
  - Satellite clock and ephemeris prediction errors
  - ionosphere and troposphere propagation errors
  - tracking errors
  - multipath
- **Differential GNSS / Augmentation Systems**
  - Spatial and temporal correlation of GNSS errors
  - EGNOS / WAAS
- **Precise Point Positioning**
  - Precise Satellite Orbits and Clocks
  - Carrier phase ambiguities: Floating vs Fixing
  - Accelerating the Filter Convergence: Fast-PPP

INSTRUCTORS:

Dr. Jaume Sanz Subirana is teaching at the Technical University of Catalonia (UPC), Barcelona, Spain, since 1983, receiving accreditation for Full Professor in 2010. Together with Dr. J.M. Juan, he created the Research Group of Astronomy and Geomatics (gAGE/UPC) in 1987. Its current research interests are in the field of GNSS data processing algorithms, ionospheric sounding, SBAS and GBAS, and High Accuracy Navigation. This last topic is one of the main research areas of gAGE/UPC, developing new algorithms which lead to the Wide Area RTK (WARTK) and Fast-Precise Point Positioning (F-PPP) techniques. He has been Principal Investigator in several international R+D projects. He is co-authoring more than 70 papers in peer-reviewed journals and about 200 works in meeting proceedings. He is co-authoring 5 patents on GNSS and 4 books on GNSS.

Dr. Adrià Rovira García received his Aerospace Engineering degree in 2010 and the Ph.D. in Aerospace Science and Technology in 2016 from the UPC, Spain. He is currently a post-doctoral researcher at UPC focused in enhanced algorithms for the Fast-Precise Point Positioning (F-PPP) technique. He co-authors 4 papers in peer-reviewed journals, 2 book chapters and 13 works in meeting proceedings, with 1 best presentation award from the US Institute of Navigation.

Dr. Nicola Linty is an assistant professor at Politecnico di Torino (Italy), working in the NavSAS research group, at the Department of Electronics and Telecommunications (DET). His research interests cover the field of signal processing and simulation, applied to telecommunications and satellite positioning and navigation. In particular, his work deals with the design and development of innovative architectures, techniques and algorithms for GPS and Galileo receivers, both professional high performance, commercial mass-market and software defined radio based. He has been involved in several international research projects and in 2015 he took part in the XXXI Italian scientific expedition to Antarctica.

Level of Difficulty:
Low (Entry Level)

Prerequisites:
Bachelor, Masters or Engineering in Physics, Telecommunications or Mathematics

Maximum Number of Participants:
35

When and Where:
10-12 April 2017
Kopernika 30 street, Warsaw, Poland

Start: 10 April at 09:45
End: 12 April at 16:00

Participation Fee:
Free of charge, also lunches and coffee breaks are provided

Registration Deadline:
10 March 2017

Information and Registration:
Enrol before deadline by filling the online form at
http://goo.gl/eUBBHx
If you have any questions please contact Sara Bouterfas at:
sara.bouterfas@enac.fr
+33 5 62 17 42 76

Tutorial 2: Multi-Sensor Navigation

OBJECTIVES:

The objectives of this training session are to present the stand alone positioning techniques such as GNSS, INS, Video, SoO, then aiding sensors that do not usually enable position estimation as such, then the classical Kalman Filter, and finally some useful examples of hybridization between all these systems.

TOPICS COVERED:

- **GNSS Positioning**
  - Definition of GNSS
  - Principle of GPS
  - Architecture of GPS
  - GPS Navigation Solution
  - GPS Performance
  - Evolutions of GPS
  - GALILEO
  - GLONASS
  - BEIDOU
  - SBAS : WAAS, EGNOS, MSAS, GAGAN
  - Multiconstellation Multifrequency GNSS
- **Principles of 3D inertial navigation**
  - INS Components
  - Reference and Coordinates frames definition
  - INS Navigation problem definition
  - INS Navigation Principle
  - INS Navigatin Properties
  - INS Sensors
  - Platform Implementation
  - Illustration of an IRS 3D Mechanization
- **Principles of Video Positioning**
  - Visual odometry
  - SLAM using monocular vision
- **Positioning using Signals of Opportunity**
  - Signals of Opportunity: what are they and why use them?
  - Example 1 : positioning using TV signals
  - Example 2 : positioning using 4G signals
  - Example 3 : positioning using WiFi signal
- **Aiding sensors**
  - Baroaltimeter
  - Wheel Speed Sensor
  - Magnetometer
  - LIDAR
- **Kalman Filter**
- **GNSS/INS/baro Hybridization for civil aviation**
- **GNSS/INS hybridization for terrestrial vehicles**
  - INS Mechanization
  - GNSS/INS Hybridization
- **GNSS/INS/Odometer hybridization for pedestrians**
  - INS Mechanization
  - GNSS/INS/Odometer Hybridization

INSTRUCTORS:

Dr. Paul Thevenon *graduated as electronic engineer from Ecole Centrale de Lille in 2004 and obtained in 2007 a research master at ISAE in space telecommunications. In 2010, he obtained a PhD degree in the signal processing laboratory of ENAC. From 2010 to 2013, he was employed by CNES to supervise GNSS research activities and measurement campaigns. Since the July 2013, he is employed by ENAC as Assistant Professor. His current activities are GNSS signal processing, GNSS integrity monitoring and hybridization of GNSS with other sensors.*

Dr. Christophe Macabiau graduated as an electronics engineer in 1992 from the ENAC (Ecole Nationale de l'Aviation Civile) in Toulouse, France. Since 1994, he has been working on the application of satellite navigation techniques to civil aviation. He received his PhD in 1997 and has been in charge of the signal processing lab of ENAC since 2000, where he also started dealing with navigation techniques for urban navigation. He is currently the head of the TELECOM lab of ENAC, which includes research groups on signal processing and navigation, electromagnetics and data communication networks.

Level of Difficulty:
Intermediate

Prerequisites:
The participants should have a scientific or engineering background, notions in estimation theory and signal processing would be a plus.

Maximum Number of Participants:
30

When and Where:
22-24 May 2017

European GNSS Agency
Janovského 438/2
170 00 Prague 7 – Holesovice
Czech Republic

Start: 22 May at 09:45
End: 24 May at 16:00

Participation Fee:
Free of charge, also lunches and coffee breaks are provided

Registration Deadline:
21 April, 2017

Information and Registration:
Enrol before deadline by filling the online form at:
http://goo.gl/eUBBHx
If you have any questions please contact Sara Bouterfas at:
sara.bouterfas@enac.fr
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Tutorial 3: GNSS Receiver Signal Processing

OBJECTIVES:

This course provides an overview of GNSS receiver signal processing. The course starts by looking at the specific case of GPS L1 C/A and its basic processing in a GPS receiver (acquisition, tracking and demodulation). It then investigates the effect of multipath and interference on such processing. The second part of the course introduces the innovations that are present in the new GNSS signals (Galileo, modernized GPS, etc…) and their implications on the structure and performance of GNSS receiver signal processing.

TOPICS COVERED:

- **GNSS Signal and Desired Properties**
  - Structure of the transmitted signal
  - Overview of GNSS propagation channel
  - Structure of the received signal
- **Typical GNSS Receiver Architecture**
  - Receiver antenna
  - Receiver front-end
  - Receiver signal processing overview
  - Structure of the signal entering the digital signal processing block
- **GPS L1 C/A Acquisition in Presence of Thermal Noise**
  - The correlation operation
  - Acquisition
- **GPS L1 C/A Tracking and Data Demodulation in Presence of Thermal Noise**
  - Carrier and carrier phase tracking
  - Code delay tracking
  - Data demodulation
- **Multipath Effects on Code and Carrier Tracking**
  - Typical multipath model
  - Carrier and code tracking multipath envelopes and general performance
  - Typical mitigation
- **Interference Effects on Code and Carrier Tracking**
  - Main interference threats and models
  - Case of NB and WB Interference and their impact
  - Pulsed interference effects and mitigation
- **Review of New GNSS Signals and Their Innovations**
  - Main innovations: PRN codes, data/pilot architecture, BOC and BOC-derived modulation, secondary codes, navigation message coding
  - Presentation of the transmitted civil GNSS signals
  - Correlation functions of the main GPS and Galileo main correlation signals
- **Acquisition of Future GNSS Signals in Presence of Thermal Noise**
  - Review of typical acquisition techniques for data/pilot signals
  - Impact of new signal structures on acquisition performance,
  - Introduction to secondary code acquisition strategies
- **Tracking of Future GNSS Signals in Presence of Thermal Noise**
  - Phase tracking of Future GNSS Signals
  - Code tracking of Future GNSS Signals
- **Receiver Testing**
  - Receiver testing introduction
  - Spirent testing environment
  - Examples of receiver testing campaigns

INSTRUCTORS:

Dr. Olivier JULIEN is the head of the Signal Processing and Navigation (SIGNAV) research group of the TELECOM lab of ENAC (Ecole Nationale de l'Aviation Civile), in Toulouse, France. He received his PhD in 2005 from the department of Geomatics Engineering of the University of Calgary, Canada. His research activity focuses on positioning and navigation for a wide range of applications including civil aviation, pedestrian and vehicular applications. He has a significant experience regarding advanced GNSS receiver signal processing and receiver design with a special interest in the design and use of future GNSS signals. He has been involved in numerous projects with industry and national/international institutions.

Dr. Nicola Linty is an assistant professor at Politecnico di Torino (Italy), working in the NavSAS research group, at the Department of Electronics and Telecommunications (DET). His research interests cover the field of signal processing and simulation, applied to telecommunications and satellite positioning and navigation. In particular, his work deals with the design and development of innovative architectures, techniques and algorithms for GPS and Galileo receivers, both professional high performance, commercial mass-market and software defined radio based. He has been involved in several international research projects and in 2015 he took part in the XXXI Italian scientific expedition to Antarctica.

Level of Difficulty:
Intermediate

Prerequisites:
The participants should have a scientific or engineering background, with preferably good notions in signal processing

Maximum Number of Participants:
30

When and Where:
13-15 June, 2017
D.E.T. Conference room – 5th floor, Department of Electronics and Telecommunications, Corso Castelfidardo 42/A, Torino

Start: 13 June at 09:45
End: 15 June at 16:00

Participation Fee:
Free of charge, also lunches and coffee breaks are provided

Registration Deadline:
12 May 2017

Information and Registration:
Enrol before deadline by filling the online form at:
http://goo.gl/eUBBHx
If you have any questions please contact Sara Bouterfas at:
sara.bouterfas@enac.fr
+33 5 62 17 42 76

Tutorial 4: Vulnerabilities of GNSS

OBJECTIVES:

This course provides an overview of GNSS vulnerabilities. The course starts by providing the fundamentals related to GNSS signal processing and GNSS position and time computation. It then provides a description of the origin, effect and mitigation means of a series of sources of vulnerabilities for a GNSS receiver.

TOPICS COVERED:

- **Reminders on GNSS Principles**
- **Reminders on Received GPS L1 C/A Signal Structure**
  - Transmitted GPS L1 C/A Signal Structure
  - Impact of the Propagation Channel on the Received GPS L1 C/A Signal
- **Reminders on GPS L1 C/A Receiver Signal Processing in Presence of Thermal Noise**
  - Correlation Operation
  - Acquisition of GPS L1 C/A
  - Carrier and Carrier Phase Tracking for GPS L1 C/A
  - PRN Code Delay Tracking
  - Data demodulation, Data synchronization, Pseudorange Generation
- **Reminders on Position Computation**
  - Least Squares and Weighted Least Squares Solutions
  - UERE and DOP
  - GPS Performance
- **GNSS Vulnerabilities and Mitigation**
  - Satellite Payload and Constellation Failure (Evil Waveform, Major Service Failure, Constellation Failure)
  - Multipath and NLOS
  - Interference
  - Voluntary interference (Jamming, Meaconing, Spoofing)
  - Low C/N0 and Cross-correlation issues
  - Atmospheric Disturbances (TEC Gradients, Ionosphere scintillation)
- **Test Cases**

INSTRUCTORS:

Prof. Fabio Dovis is associate professor at Politecnico di Torino, working at the Department of Electronics and Telecommunications, where he contributed to the creation of the Navigation, Signal Analysis and Simulation (NavSAS) group. His research interests are focused on Global Navigation Satellite Systems and on positioning techniques. His scientific work addresses the design of architectures for GNSS receivers and of advanced algorithms for interference detection and multipath mitigation, considering for both current and modernized GNSS signals. He has a relevant experience in international projects in GNSS as well as cooperation with industries and research centers.

Dr. Olivier JULIEN is the head of the Signal Processing and Navigation (SIGNAV) research group of the TELECOM lab of ENAC (Ecole Nationale de l'Aviation Civile), in Toulouse, France. He received his PhD in 2005 from the department of Geomatics Engineering of the University of Calgary, Canada. His research activity focuses on positioning and navigation for a wide range of applications including civil aviation, pedestrian and vehicular applications. He has a significant experience regarding advanced GNSS receiver signal processing and receiver design with a special interest in the design and use of future GNSS signals. He has been involved in numerous projects with industry and national/international institutions.

Level of Difficulty:
Intermediate to expert

Prerequisites:
The participants should have a scientific or engineering background, with preferably good notions in signal processing. The participants should also be familiar with GNSS.

Maximum Number of Participants:
30

When and Where:
03-05 Oct 2017

ENAC, 7 Avenue Edouard Belin
31055, Toulouse, France

Start: 03 Oct at 09:45
End: 05 Oct at 16:00

Participation Fee:
Free of charge, also lunches and coffee breaks are provided

Registration Deadline:
04 Sept 2017

Information and Registration:
Enrol before deadline by filling the online form at:
http://goo.gl/eUBBHx
If you have any questions please contact Sara Bouterfas at:
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Tutorial 5: Precise Positioning

OBJECTIVES:

The course enters in detail in the study of the concepts and techniques used in the positioning by means of the Global Navigation Satellite Systems (GNSS). The theoretical foundations are presented and the processing algorithms are implemented through guided exercises that are performed in the laboratory.
The analysis of the code and phase observables shows characteristic aspects of the GNSS (cycle-phase slips, ionospheric refraction, multipath, etc.). Satellite positions and their clocks offset are calculated from the navigation message. The different terms involved in modelling the pseudoranges (relativistic effects, atmospheric troposphere/ionosphere and instrumental delays, clock synchronism, etc.), arise and navigation equations are solved by least squares estimation and by Kalman filtering.
The practical sessions are made with different programs designed specifically for the course to implement different processing modules.

TOPICS COVERED:

- **Overview of GNSS Positioning Techniques**
- **GNSS measurements and their combinations**
  - Basics of pseudorange and carrier-phase measurements.
  - Cycle-slips detection and combination of observables
- **Satellite orbits and clocks**
  - Computation and accuracy
- **Position estimation with pseudoranges (SPS)**
  - Measurements modelling and error sources
  - Linear observation model and parameter estimation
- **Precise Point Positioning (PPP)**
  - Precise Satellite Orbits and Clocks
  - Carrier phase ambiguities: Floating vs Fixing
- **Introduction to Differential GNSS techniques (DGNSS)**
  - Spatial and temporal correlation of GNSS errors
  - Differential error mitigation and positioning

  Ambiguity resolution techniques (RTK)
  - Resolving Ambiguities one at a time
  - Resolving ambiguities as a set. LAMBDA method
- **Practical Lectures**
  - GNSS Data Processing Laboratory Exercises: the gLAB tool
  - Model components Analysis
  - Solving Navigation Equations: WLS and Kalman filter
  - Kinematic satellite LEO orbit estimation

INSTRUCTORS:

Dr. Jaume Sanz Subirana is teaching at the Technical University of Catalonia (UPC), Barcelona, Spain, since 1983, receiving accreditation for Full Professor in 2010. Together with Dr. J.M. Juan, he created the Research Group of Astronomy and Geomatics (gAGE/UPC) in 1987. Its current research interests are in the field of GNSS data processing algorithms, ionospheric sounding, SBAS and GBAS, and High Accuracy Navigation. This last topic is one of the main research areas of gAGE/UPC, developing new algorithms which lead to the Wide Area RTK (WARTK) and Fast-Precise Point Positioning (F-PPP) techniques. He has been Principal Investigator in several international R+D projects. He is co-authoring more than 70 papers in peer-reviewed journals and about 200 works in meeting proceedings. He is co-authoring 5 patents on GNSS and 4 books on GNSS.

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Level of Difficulty:
Intermediate

Prerequisites:
The participants should have a scientific or engineering background to attend this GNSS introductory course. Bringing a laptop with permissions to install GNSS software is required to conduct the practical exercises.

Maximum Number of Participants:
30

When and Where:
07-09 Nov 2017
Universitat Politècnica de Catalunya, Campus Nord, Barcelona, Spain
Address : C/ Jordi Girona, 1-3, 08034, Barcelona, Spain

Start: 07 Nov at 09:45
End: 09 Nov at 16:00

Participation Fee:
Free of charge, also lunches and coffee breaks are provided

Registration Deadline:
06 Oct 2017

Information and Registration:
Enrol before deadline by filling the online form at:
http://goo.gl/eUBBHx
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