International Technical Symposium on Navigation and Timing

Ecole Nationale de l’Aviation Civile
Toulouse - France

Nov. 16-17, 2015

Scope of the Symposium

The objective of this symposium is to gather experts and innovators that will present their views/work on specific navigation and/or timing-related topics, with an emphasis on technical aspects. The symposium is composed of three sessions (this year “Positioning in Challenging Environments”, “GNSS Signals and System Design” and “Air Navigation”). Each session will last for half a day and will consist of four presentations followed by a panel discussion that will allow the audience to interact with experts.

Registration:

The Symposium is free of charge but the number of seats is limited, so registration is mandatory.

You can register using the following address:
http://signav.recherche.enac.fr/index.php/symposium-registration/

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Catalina Rodriguez
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2015 Invited Speakers

Martin Haueis
Head of Localization and Data Management,
Daimler AG, Germany

Christopher J. Hegarty
Director for CNS Engineering & Spectrum,
MITRE Corporation, USA

Mikael Mabilleau
Navigation services manager,
Egis Avia, France

Oscar Pozzobon
Founder and Technical Director,
Qascom, Italy

Mark L. Psiaki
Professor,
Cornell University, USA

John F. Raquet
Director of the Autonomy and Navigation Technology Center,
US Air Force Institute of Technology, USA

Lionel Ries
Head of the Navigation / Location Signals Department,
CNES, France

Francis Soualle
Navigation System Engineer,
Airbus Defence and Space, Germany

Morten Stakkeland
Development Engineer, Research and Development Navigation,
Indra Navia, Norway

AJ Van Dierendonck
AJ Systems, USA

Lauri Wirola
System Architect,
HERE, Finland

Zheng Yao
Assistant Professor,
Tsinghua University, China

Sherman Lo
Senior Research Engineer
Stanford University, USA
### Programme

**Monday Nov. 16th 2015**

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<td>13:30-14:00</td>
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**Session «Positioning in Challenging Environments»**

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<td>Role of Vision Sensors in Robust/Safe Navigation Systems</td>
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<td>Positioning Needs and Associated Challenges for Autonomous Vehicles</td>
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<td>16:40-17:15</td>
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**Tuesday Nov. 17th 2015**

**Session «GNSS Signals and System Design»**

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<td>Completing the Landing - Evaluating Continuity in GBAS</td>
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Biographies

Dr. Martin Haueis received his diploma degree in Microsystems Research from the University of Karlsruhe. Research stays at NTT and Yaskawa Electric Corporation in Japan accompanied his studies on sensor technologies. He subsequently joined the sensor research group at the Federal Institute of Switzerland, Zurich (ETH). There he earned his PhD for his research in the area of micro-electro-mechanical systems in sensor applications. Dr. Haueis worked several years at Lucent Technologies’ Bell Laboratories in Murray Hill, USA, leading projects for reliability research on novel MEMS based telecommunication systems before joining central research at DaimlerChrysler AG in 2003. Dr. Haueis has been the head of vehicle localization and data management in the driver assistance systems research division at Daimler AG. Dr. Haueis has worked on GNSS and vison based localization systems and new digital maps for autonomous driving.

Dr. Christopher J. Hegarty is the Director for CNS Engineering & Spectrum with The MITRE Corporation, where he has worked mainly on aviation applications of GNSS since 1992. He received B.S. and M.S. degrees in electrical engineering from WPI and a D.Sc. degree in EE from GWU. He is currently the Chair of the Program Management Committee of RTCA, Inc., and co-chairs RTCA Special Committee 159 (GNSS). He is a Fellow of the ION and IEEE, and co-editor/co-author of the textbook Understanding GPS: Principles and Applications, 2nd Ed.

Sherman Lo is currently a senior research engineer at the Stanford GPS Laboratory. He is the Associate Investigator for the Stanford University efforts on the FAA evaluation of alternative position navigation and timing (APNT) systems for aviation. He works on developing aviation APNT systems that are robust to GPS interference. He was Associate Investigator for the Stanford University efforts on the FAA development of enhanced Loran. His other current research areas include navigation security and modernized GNSS. He has over 85 conference, 20 journal, 12 magazine publications and 8 issued US patents. He has been a Technical Chair for Institute of Navigation (ION) GNSS, ION/IEEE Position Location and Navigation Symposium (PLANS) and the International Loran Association (ILA) Symposium. He is currently the Secretary for the ION Northern California Chapter. He has previously been ION Western Region Vice President, ION Meetings Chair and a member of the ILA board. For his work and efforts, he has received the Institute of Navigation (ION) Early Achievement Award (2005), the International Loran Association (ILA) President’s Award (2003) and Medal of Merit (2009), and the Royal Institute of Navigation Michael Richey Medal best paper winner (2011).

Mikael Mabilleau has graduated from ENAC (Ecole Nationale de l’Aviation Civile) and has integrated Egis Avia as CNS project Engineer. He is now the navigation services manager in Egis Avia. He has been involved since 2006 in Galileo standardisation activities for Civil Aviation. He follows the standardisation activities of the EUROCAE WG 62, RTCA Special Committee 159 and ICAO NSP group (Navigation System Panel). He is involved in several projects looking at GNSS evolutions for civil aviation operations such as the next generation of SBAS systems, new over-bounding technics for SBAS and ABAS user or Advanced RAIM technical feasibility analysis for all phases of flight down to precision approach. He is also involved in study of the solar activity impact on civil aviation application during the last solar peak. Mikael has become one of the focal point on multi-modal GNSS and space activity within the Egis group.

Oscar Pozzobon is the founder and technical director of Gascom. He received a degree in information technology engineering from the University of Padova in 2001 and a master degree from the University of Queensland in telecommunication engineering in 2003. He is coordinating different projects regarding interference and signal authentication with the European Space Agency (ESA), the European GNSS Agency (GSA) and the European Commission. Particularly, he is currently involved in the design of the ESA advanced multi-constellation simulator and in the design of the authentication schemes for the Galileo Commercial Service (CS) demonstrator. He has been working in the domain of GNSS authentication since 2001, and has been one of pioneers of the concepts of Trusted GNSS receivers, Navigation Messages Authentication (NMA), Signal Authentication Sequences (SAS) and Remote Processing Authentication (RPA). In 2011 he has been involved in Galileo IOV and FOC Verification and validation activities as part of a contract with Thales Alenia Space. His main interests are GNSS and cryptography, where he holds more than 30 publications and 3 patents.

Prof. Mark L. Psiaki holds a B.A. in Physics (1979) and an M.A. (1984) and Ph.D. (1987) in Mechanical and Aerospace Engineering, all from Princeton University. He has been on the faculty of the Sibley School of Mechanical and Aerospace Engineering at Cornell University since 1986 and currently holds the rank of professor. He has conducted research in the areas of estimation and filtering, GPS/GNSS receivers, navigation and remote sensing using GNSS signals, GNSS security and integrity, spacecraft attitude and orbit determination, aerospace vehicle guidance, numerical trajectory optimization, and dynamic modeling of satellites, aircraft,
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and wheeled vehicles. He has authored or co-authored over 60 refereed journal articles and 60 additional conference or trade magazine papers. He holds 5 patents. He is a fellow of the Institute of Navigation. He has received 6 best paper awards for AIAA conferences along with the Institute of Navigation’s Tycho Brahe award and its Burka award for the best paper in a volume of Navigation. He has spent 2 sabbatical leaves at the Aerospace Engineering Faculty of the Technion in Haifa, Israel, where he held appointments as a Lady Davis visiting associate professor. Another sabbatical was spent as an NRC Senior Research Associate at the Air Force Research Lab, Kirtland AFB, NM.

Prof. John F. Raquet is the Director of the Autonomy and Navigation Technology (ANT) Center at the US Air Force Institute of Technology (AFIT), where he is also a Professor of Electrical Engineering. He has degrees in geomatics engineering (Ph.D., University of Calgary, 1998), aero/astro engineering (SM, Massachusetts Institute of Technology, 1991), and astronautical engineering (BS, US Air Force Academy, 1989). He has been involved in navigation research for over 25 years, has published over 150 navigation-related conference and journal papers, and taught 59 navigation-related short courses to over 2,600 students in many different organizations. Dr. Raquet is a Fellow of the Institute of Navigation (ION), and is currently the ION Executive Vice President. In 2010, Dr. Raquet was a Fulbright Scholar at the Tampere University of Technology in Finland.

Lionel Ries is head of the navigation / location signals department in CNES, the French Space Agency. The department activities cover signal design and processing, receivers and payloads regarding location and navigation systems including GNSS (Galileo, GNSS space receivers), Search & Rescue by satellite (SARSAT,MEOSSAR), and Argos (Advanced Data Collect and Location by Satellite, mostly for environment and wildlife monitoring). He also coordinates CNES research activities for future location / navigation signals, user segments equipment and payloads.

Francis Soualle received the Dipl.-Ing. in 1998 in Digital Communication Techniques at Supelec in Paris. Since 2000 he works at Airbus Defence and Space GmbH. He is involved in the main European RNSS programs (Galileo first and second generation, EGNOS V3). His main focuses are RNSS architectural concepts, signal and receiver performances, and system time generation.

Dr. Morten Stakkeland is working with GBAS integrity algorithms in Indra Navia AS. He has an MSc degree from the Department of Physics, University of Oslo, and a PhD degree from the Department of Cybernetic Engineering, the Norwegian University of Science and Technology.

A. J. Van Dierendonck (BSEE ‘61; MSEE ‘65; PhDEE ‘68) AJ made major contributions to Global Positioning Systems (GPS) technology spanning 40 years. In particular, he is the co-inventor of the use of narrow correlator technology, which is now an industry standard for GPS receivers for multipath mitigation. He was also a major contributor in the design of the GPS L5 signal. He has received awards from U.S. Institute of Navigation (ION) including the Burka Award (which he received twice), the Kepler Award, and the Thurlow Award. He has also received the Kershner Award from the IEEE. He also is an ION Fellow, an IEEE Fellow, and is in the U.S. Air Force’s GPS Hall of Fame. He is currently the owner of AJ Systems and a partner of GPS Silicon Valley in Los Altos, California. For GPS Silicon Valley, he has provided receivers to the international community for monitoring ionospheric scintillation. He recently received the Iowa State University Alumni Association’s Distinguished Alumni Award for being internationally recognized for preeminent contributions to their professions or life’s work.

Dr. Tech. Lauri Wirola received both his Master of Science and Doctor of Technology degrees from Tampere University of Technology, Finland, in 2005 and 2010, respectively. He majored in physics and minored in mathematics and industrial economics. Dr. Wirola has worked with various positioning-related topics over the last 10 years ranging from Assisted GNSS techniques to cellular/wifi-based solutions. Currently he works as a System Architect for the HERE cellular/wifi positioning service. Dr. Wirola has published widely on especially Assisted GNSS-related techniques and holds tens of patents in the area.

Dr. Zheng Yao received the B.Eng. in electronics information engineering and the Ph.D. degrees (with honor) in information and communication engineering from Tsinghua University, Beijing, China, in 2005 and 2010, respectively. Since 2010, he has been a faculty member in the Department of Electronic Engineering, Tsinghua University, Beijing, China, where he currently is an Associate Professor. His current research mainly targets next generation satellite navigation signals design, and personal and vehicular positioning in challenging environments such as urban canyons and strong multipath environments.
Abstracts

Opening Talk

Dr. AJ Van Dierendonck (AJ Systems, USA):
“IMPACTS OF 42 YEARS OF EXPERIENCE ON GNSS”

When a person works on a system for nearly 42 years, he or she should have had contributions on key actions/decisions/findings on that system or related systems. That certainly is the case for AJ’s contributions, starting in 1974 as a systems engineer on the initial GPS Control Segment and User Segment development, including contributions to early Navigation Messages, Interface Specifications and Differential GPS. As GPS entered modernization, his contributions included inputs to the modernization of GPS signals, GPS receivers, Satellite Based Augmentation Systems, and even Galileo. This briefing describes some of these important contributions.

Session «Positioning in Challenging Environments»

Prof. John F. Raquet (US Air Force Institute of Technology, USA):
«ROLE OF VISION SENSORS IN ROBUST/SAFE NAVIGATION SYSTEMS»

Vision-based navigation has become an increasingly popular alternative navigation approach, in large part due to increased computational capability and very inexpensive sensors (cameras). This talk will give a framework of how all navigation systems operate, and place image navigation in that framework. Overall approaches to vision navigation will be described, including a description of the benefits and tradeoffs of such systems. Finally, methods for obtaining true, quantified integrity in robust/safe navigation systems using vision will be discussed.

Dr. Martin Haueis (Daimler AG, Germany):
«POSITIONING NEEDS AND ASSOCIATED CHALLENGES FOR AUTONOMOUS VEHICLES»

Autonomous vehicles use precise digital maps to complement onboard environmental perception. New digital maps for autonomous driving differ from standard navigation maps. Novel map attributes, high-map accuracy and positioning quality of the vehicle demand new mapping technologies and positioning sensing of the autonomous vehicle. This paper gives an overview of localization concepts such as vision-based landmark localization and precise positioning. Related results from the autonomous Bertha Drive are presented for discussion of real-world use cases and associated challenges for autonomous vehicles.

Dr. Lauri Wirola (HERE, Finland):
«PRECISE POSITIONING IN URBAN ENVIRONMENT»

Precise positioning in urban environments is notoriously difficult for GNSS-based methods due to signal blockage, multipath, and other adverse effects. However, the imminent introduction of self-driving cars and the introduction of decimeter-accurate high precision maps such as HERE HD Maps™ means that the positioning technologies must step up to the challenge. It is quite self-evident that there is no single solution to the problem. Thus, the presentation will cover a wide range of options ranging from high-accuracy GNSS technologies and various inertial/optical sensors to WiFi- and 5G-based methods. Visions, ideas, and challenges are highlighted and thought is also given to the role standards.

Lionel Ries (CNES, France):
«TECHNICAL DEVELOPMENTS IN GNSS SPACE RECEIVERS»

Space agencies have been among the early users of GNSS since mid-80s for satellite orbitography (as an alternative to legacy Doppler orbit determination, demonstrated with Sputnik's). Since then, helped by emulation from the ground user-segments, GNSS in space spread to most known field of applications: General purpose PNT of space vehicles, precise orbit determination, attitude determination, atmospheric sounding, rendezvous, formation flying. Although at first glance, such applications sound familiar to ground users, nevertheless, their implementation in space faces specific design challenges: accommodation to severe space environment, small series (currently, <10 to ~100 equipment) and, very high dynamics. After recalling the state-of-the-art of space receivers, focus will be given to emerging use cases:

- Use of GNSS at low signal-to-noise ratio (SNR) for satellite transfer from LEO to GEO
- Safety-critical applications (launchers, re-entry vehicles)
- Radio Occultation, using "Non-Line-of-Sight" signals refracted by the atmosphere

A specific topic will also report trends aiming the reduction of form-factor and costs, to fulfill requirements for nano-satellite and large-scale production: space-qualified vs. cheaper, commercial-grade technologies, SDR, GNSS processing within the avionics “On-board Computer”.
Civilian Global Navigation Satellite System signals are under increasing threats from spoofers. Several sophisticated spoofers have been developed and tested recently. These new devices are dangerous because they are undetectable by traditional receiver autonomous integrity monitoring. The Iranians claim to have used spoofing to capture a classified U.S. spy drone in Dec. 2011, and there have been rumors of “spoofing in the wild” on the Korean peninsula. Various strategies are being developed to detect attacks by the new class of spoofers and to recover navigation capabilities after an attack. This presentation will focus on the new spoofers and the new defenses.

Oscar Pozzobon (Qascom, Italy):
«STATE OF THE ART IN GNSS AUTHENTICATION AND OPPORTUNITIES FOR SYSTEM EVOLUTIONS»

GNSS authentication is becoming a top priority for a number of applications in order to achieve trust and robustness in future critical GNSS applications. The current trends focus the implementation of authentication services either at user segment, system level, or both, in the so called hybrid approach. At user segment, state of the art technologies with autonomous techniques include antenna based detection and mitigation techniques, receiver based with Digital Signal Processing (DSP) and/or receiver based with observable data, and integration with sensors. The Galileo system currently foresees a dedicated signal for authentication services: The Galileo Commercial Service. This signal is transmitted in the E6 frequency. Design approaches and preliminary results of this service from the test campaigns will be presented and discussed. Finally, the current proposals for Galileo OS authentication will be discussed for both current FOC implementation (Galileo 1) and future evolutions (G2G).

Ass. Prof. Yao Zheng (Tsinghua University, China):
«BEIDOU NEXT GENERATION SIGNAL STRUCTURE AND EXPECTED PERFORMANCE – CHALLENGES AND PROPOSED SOLUTIONS»

Signal design is one of the key contents in the construction of global navigation satellite system (GNSS). It not only relates directly to the positioning and timing performance of the system, but also has profound effects on promotion, application and commercialization of the system. Now China has launched the construction process of BeiDou satellite navigation system (BDS) Phase III, of which the signal design is one of the key technique. The limitation of frequency resources, constraint of compatibility and interoperability with other GNSS, as well as the demand for positioning, navigation, and timing services have presented serious challenges to the signal design. Through years of effort, significant progresses are achieved in BDS next generation signal design. Multiple advanced signal solutions have been proposed. In this presentation, based on the review of key aspects, requirements, and constraints in BDS signal design, the progress of BDS Phase III signal design is introduced, and the developing trends of BDS signal in future is prospected as well.

Francis Soualle (Airbus Defence and Space, Germany):
«EFFECTS AND DETECTION OF CLOCK FAILURES FOR GNSS SYSTEM TIMES BASED ON FLYING CLOCKS»

The objective of this presentation is to highlight the effects of clock anomalies not only onto the navigation solution, but also onto the stability of a GNSS time scale when this one is generated partly or fully with on-board satellite clocks, called “flying clocks”. A comparative study of typical detection algorithms against such failures is also proposed. In a first part a review of the most common categories of atomic frequency standards used on-board navigation satellites is proposed. In a second part, the most encountered types of clock failures, as well as their statistics, are described. The third part will focus onto the different architectural options for the System Time Scale Generation (STSG) function, from the master clock up to the composite clock based on a Kalman filter fed with satellite and/or station clocks. In the fourth part the effects of clock anomalies for an STSG function involving flying clocks will be discussed. Then, the main techniques of clock failure detection, either based on the monitoring of clock differences, or of the KF-innovation will be presented. In the last part two typical scenarios of clock failures (one being a frequency jump, the other a degradation of the clock stability) will be proposed to illustrate the application and performances of the aforementioned detection algorithms.
Gold partners: Silver Partners: Bronze partners:

Dr. Christopher J. Hegarty (MITRE Corporation, USA):
«NEXT-GENERATION GNSS AVIONICS STANDARDS AND SPECTRUM PROTECTION»

Next-generation GNSS Avionics Standards and Spectrum Protection - Work is now underway within avionics standards bodies including RTCA, Inc., EUROCAE, and the International Civil Aviation Organization (ICAO) on the development of next-generation GNSS avionics standards. Whereas the majority of currently-deployed, certified avionics only process coarse/acquisition (C/A)-code signals from the U.S. Global Positioning System (GPS) and regional Satellite-based Augmentation Systems (SBASs) on a single-frequency, next-generation standards will embrace other global constellations (GLONASS, Galileo, BeiDou) and dual-frequency equipment. This presentation will summarize next-generation GNSS avionics standards activities. The presentation will also address changes that are occurring to the radio spectrum environment that future GNSS avionics must operate within, and efforts that are underway to ensure that this future spectrum environment provides adequate protection for aviation safety applications.

Dr. Morten Stakkeland (Indra Navia, Norway)
«COMPLETING THE LANDING - EVALUATING CONTINUITY IN GBAS»
The talk will give a short introduction to the GBAS concept, and describe the concept of continuity risk; the likelihood that an operation is discontinued after it has been initialized. Using real world examples like ionospheric scintillations that may cause short term unavailability on individual satellites, the challenges related to quantifying continuity risk and meeting the relevant requirements will be outlined. Specifically, the difference between an average risk and a specific risk approach will be addressed. It will also be discussed how adding an additional constellation like Galileo to GBAS may be used to ease the requirements on single satellites.

Mikaël Mabilleau (Egis Avia, France)
«HORIZONTAL ADVANCED RAIM: OPERATIONAL BENEFITS AND FUTURE CHALLENGES»
Multi-constellation signals will have a positive impact on the integrity monitoring performance of receiver autonomous integrity monitoring (RAIM) algorithms. Increasing reliability and resilience of next generation GNSS services is an agreed objective of the Global Air Navigation Plan agreed by ICAO member states. This includes supporting approaches with lateral as well as vertical guidance to achieve an increased level of safety and other operational and environmental benefits. Multi-constellation and multi-frequency technology (MCMF) introduces airborne implementation challenges without mentioning the Integrity Support Message (ISM) introduced in MCMF advanced RAIM (ARAIM) for vertical approach guidance. It is not sure if and in which form ISM is required for horizontal guidance and positioning applications. The presentation introduces these trade-offs focusing in particular on horizontal positioning and associated implementation issues. Based on these identified system trade-offs, the achievable level of performance for various navigation and surveillance applications is analyzed in several operational contexts. The presentation will include evaluation of the availability of the accuracy and integrity requirements. The objective of these evaluations is to derive suitable and beneficial performance targets for horizontal ARAIM to sustain robust operations in civil aviation. Recommendations for core constellation service provider may be discussed having in mind the latest outcomes of civil aviation standardization bodies.

Sherman Lo (Stanford University, USA)
«RESILIENT ALTERNATIVE PNT CAPABILITIES FOR AVIATION TO SUPPORT CONTINUED PERFORMANCE BASED NAVIGATION OPERATIONS»
Abstract: Positioning, Navigation, and Timing (PNT) services are key enablers of essential safety and security applications and capacity and efficiency applications worldwide, and for ground, sea, and aviation users the primary/go-to source of PNT has become a Global Navigation Satellite System (GNSS). In 2001 the landmark Volpe Transportation Systems Center’s GPS Vulnerability Report warned the world of the vulnerability of these GNSS-based services and the need for resilient PNT alternatives. The US Federal Aviation Administration’s (FAA) Alternate Position, Navigation, and Timing (APNT) program is researching alternative strategies to ensure a safe, secure, and effective transition and from a GNSS-PNT available to a GNSS-PNT non-available, impaired, or untrusted environment. This paper concentrates on the FAA’s APNT research to date, evaluation of alternative solutions, the results of real-world testing, identification of technical challenges and potential mitigations, and plans for further investigations
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**Symposium’s Partners**

**Gold Partners**

**Airbus Defence and Space:** is a division of Airbus Group formed by combining the business activities of Cassidian, Astrium and Airbus Military. The new division is Europe’s number one defence and space enterprise, the second largest space business worldwide and one of the 10 largest global defence enterprises. It employs more than 38,000 employees generating revenue of approximately €13 billion per year.

**Silver Partners**

**European Satellite Services Provider (ESSP)** is a French private company owned by 7 European ANSPs (Aena, DGAC/DSNA, DFS, ENAV, NATS, NAV-P and skyguide). Since 2005 ESSP has been a key player and partner for the European GNSS Agency (GSA) and the European Commission in setting up the provision of EGNS services. In 2014, ESSP and the GSA established a new 8 years frame Contract for the provision of the three EGNOS services: Open Service, Safety of Life and EDAS. ESSP has been certified since July 2010 as the first pan-European Air Navigation Service Provider for Civil Aviation, demonstrating its commitment in delivering outstanding services towards users.

**Spirent:** At Spirent, specialist engineering and development teams have been involved in every aspect of satellite and navigation navigation. We offer solutions for all aspects of navigation and various other applications in construction, agriculture, marine and many others. We provide the most advanced avionics systems, backed up by a global services and support network.

**ELTA:** is known worldwide since 40 years for its activities in the field of navigation, earth observation and telecommunication. ELTA is highly skilled in technologies such as radio frequency, microwaves, digital signal processing and man-machine interfaces. With its long partnership with Thales Alenia Space and under a CNES contract, ELTA has recently upgraded its flagship product; NAVYS. This GNSS simulator performs advanced testing of GNSS systems; ionospheric impact; standardisation - to operational aspects - PBN; concept of operations; operational implementation and safety issues.

**ABBIA GNSS Technologies:** ABBIA is a dynamic technological company with a clear passion: GNSS. ABBIA’s mission is to contribute in making the Earth a better place providing more wealth, more welfare and more safety to people by putting its knowledge and expertise at the service of humanity by means of innovative products and services based on radio-navigation satellites signals. To overcome this ambitious mission, ABBIA counts with an international young talented team highly motivated to learn, research and face new challenges. ABBIA’s key providing GNSS services are fivefold: Consulting engineering, Software tools development, Telematics’ systems, Training for engineers and operators and R&D. ABBIA expertise is today well recognized by the stakeholders as a key company in the European GNSS marketplace.

**Egis Avia:** Egis is an international group with over 12,000 employees and a turnover of $1bn. The group offers consulting, engineering and operations services across many sectors. In aviation, we provide consultancy and engineering services to airports, ANSPs, airlines or institutions. Through a fully-integrated approach, we work across complementary segments: airport, air traffic management and air navigation, and aircraft. Egis has been developing a strong expertise in GNSS applications and connected services. Our capabilities cover a wide range of activities from technical - GNSS systems; ionospheric impact; standardisation - to operational aspects - PBN; concept of operations; operational implementation and safety issues.

**GMV:** provides solutions, integrated systems, specialized hi-tech products and services. Its activities take in the whole life cycle of the system, ranging from consultancy and engineering services up to the development of software and hardware, the integration of turnkey systems right through to operational support. These products and services are supplied through its various subsidiaries to eight different sectors: aeronautics, defense and security, space, healthcare, information security, information technologies for the public and private sector, telecommunications and transport.

**Syntony:** SYNTONY GNSS is an industrial company, specialised in the design and manufacturing of scientific and technical products dedicated to radio navigation, radiofrequency and electronics domains. The company is a new business start-up, created as a spin-off of SILICOM, a Software Engineering company. It works mainly in AERONAUTICS, SPACE and INDUSTRIALS domains. The entire technological properties of SYNTONY GNSS arose after a 15 years research work, on our own and in partnership with well-known industrial groups from aerospace domain.

**Thales Avionics:** We design, build, deliver, maintain and upgrade advanced avionics systems and suites (for civil and business aircraft, helicopters, military aircraft and UAVs). By working together with aircraft manufacturers we ensure all types of aircraft are equipped with easy to use, secure, interactive cockpits and avionics systems, backed up by a global services and support operation.

**Septentrio:** designs high-precision GNSS receivers for use in challenging aeronautical ground infrastructure and airborne applications. These include positioning for both navigation and payload referencing; and for manned, remotely piloted and unmanned platforms. Our receivers are used for GIS, aerial survey, mapping; and various other applications in construction, agriculture, marine and navigation. We offer solutions for all aspects of navigation including stabilized VTOL hovering, centimeter accurate geotagging of images, interference mitigation and GNSS-Inertial precision guidance.