



# EGNOS

**The European Geostationary Navigation Overlay System  
– A cornerstone of Galileo**

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**The European Geostationary Navigation Overlay System  
– A cornerstone of Galileo**

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***European Space Agency  
Agence spatiale européenne***

*This book is dedicated to the memory of Jean-Pierre Dupont, who worked in the ESA EGNOS Project Office from 1996 to 2005, who was much respected by the EGNOS Project Team, and who contributed greatly to the consolidation of the EGNOS mission and its performance.*

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The Technical Editors also wish to express their gratitude to the many GNSS engineering experts who have contributed to the book, including our international colleagues from the USA, Canada, Japan, Russia and India.

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Last but not least, we wish to thank our managements at ESA and Alcatel Alenia Space for having supported us throughout this endeavour.

## Preface

The European Space Agency's (ESA) main mission is to shape the development of Europe's space capability and to ensure that investment in space continues to deliver maximum benefit to the citizens of Europe. The European Geostationary Navigation Overlay System (EGNOS) is yet another European success story of cooperation in space science and technology. In line with the ESA practice of "*Shape and Share*," the Agency is proud to have shaped, together with the European Industry, the EGNOS technology and to share it now with the GNSS user community.

EGNOS is the main European contribution to GNSS-1 to serve the needs of maritime, land transport, time and aeronautical applications in the European and neighbouring regions. EGNOS is the first-generation European GNSS System, and a first step towards Galileo, the second generation, based upon an independent European navigation-satellite constellation. EGNOS will be interoperable with equivalent US (WAAS) and Japanese (MSAS) SBAS systems, in addition to other emerging initiatives – as India's GAGAN and China's SNAS systems – aiming at contributing to a truly global navigation system. The EGNOS measured performances are excellent, providing the best SBAS performances worldwide today. Accuracies of the order of 1-2 metres and availabilities of better than 99% for APV are frequently measured in most of Europe. EGNOS services will start in 2007 with the declaration of the EGNOS Open Service, and the transfer of EGNOS ownership from ESA to the recently created GNSS Supervisory Authority (GSA) in 2007.

This book is technical in nature and presents a complete overview of the EGNOS mission, system and architecture. It has been written for those GNSS engineering professionals, applications developers, satellite-navigation users and university students wishing to have a complete picture of the EGNOS and Satellite-Based Augmentation System (SBAS) technologies, principles and related applications.

Under the excellent guidance of its Technical Editors, Dr Javier Ventura-Traveset and Dr Didier Flament, the book has been co-authored by many hard-working people in the companies and organisations that have contributed so much to the success of EGNOS, during the 8 years of EGNOS development and qualification efforts. On behalf of ESA, the European organisation in charge of the EGNOS technical development effort, and Alcatel Alenia Space, the EGNOS Industry Prime Contractor, we wish to express our appreciation to the more than 40 European companies, all over Europe, who have participated.

The EGNOS system is just a first step in an ambitious GNSS European strategy, which includes the implementation of Galileo, Europe's Global Satellite Navigation System, for which ESA has already successfully launched and tested the first satellite, known as GIOVE-A, in December 2005.

**Didier Faivre**, *Head of the ESA Navigation Department*

**Javier Benedicto Ruiz**, *ESA EGNOS Project Manager 1996-2000 and currently ESA Galileo Project Manager*

**Laurent Gauthier**, *ESA EGNOS Project Manager 2000-2005*

**Philippe Michel**, *ESA EGNOS Project Manager since May 2006*

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<sup>1</sup> Sylvain Loddo now works at ESA as Galileo System and Ground Segment Manager.



## Introduction

Satellite navigation has already found a large number of applications in a wide variety of fields. Recognising the strategic importance of those applications, a European approach was developed in the early 1990s. The European strategy for satellite navigation is based on two fundamental steps, namely GNSS-1 and GNSS-2.

The first-generation Global Navigation Satellite System, GNSS-1, is based on the existence of the current GPS and Glonass constellations and on the development of dedicated system augmentations, needed to achieve the level of performance required for certain applications, such as aviation. EGNOS is the European Satellite-Based Augmentation System (SBAS) and the main European contribution to GNSS-1. Similarly, other SBAS initiatives have been developed in the USA (the Wide-Area Augmentation System, WAAS) and Japan (the Multi-transport Satellite-based Augmentation System, MSAS).

The EGNOS programme has been managed through the European Tripartite Group (ETG)<sup>2</sup>, composed of the European Space Agency (ESA), the European Commission and Eurocontrol. On behalf of this tripartite group, ESA has been responsible for the system design, development and qualification of an Advanced Operational Capability (AOC) of the EGNOS system. EGNOS is the first European GNSS System, and also a first step towards Galileo, which together with GPS and Glonass modernisation, constitutes the core of GNSS-2. Galileo will be Europe's independent global satellite-navigation constellation and will provide a worldwide service.

EGNOS has been conceived to be a multimodal GNSS service, aimed at serving the needs of maritime, land-based, aeronautical and timing applications in the European region. EGNOS services are planned to start in 2007 with the inauguration of the EGNOS Open Service, and the transfer of EGNOS ownership from ESA to the newly created GNSS Supervisory Authority (GSA), in charge of authorising and supervising future EGNOS service provision.

This book on the EGNOS Programme and its GNSS context is aimed at providing a complete technical overview of the EGNOS and SBAS principles, technologies and related applications. More specifically, it: presents a thorough review of the EGNOS mission, system and architecture; provides a review of key related GNSS fundamental concepts; introduces other existing/planned SBAS systems; presents and discusses EGNOS performances and applications; and has a Chapter dedicated to the future GNSS systems, including Galileo and the planned GPS, Glonass and EGNOS modernisation programmes.

The book is organised into *five Chapters* as follows: EGNOS Fundamentals (*Chapter 1*); EGNOS System Architecture (*Chapter 2*); EGNOS Performance and Applications (*Chapter 3*); Other SBAS Systems (*Chapter 4*); and the Future of GNSS (*Chapter 5*). It contains a total of 41 articles, each dealing with a specific aspect of the EGNOS system. These have been written by recognised GNSS engineering experts in each specific domain, from European Industry and ESA, and internationally recognised experts from the USA, Japan, Russia, Canada and India.

*Chapter 1: EGNOS Fundamentals* includes a description the EGNOS System and Programme in the context of the overall GNSS Strategy (1.1); a basic review of the GPS (1.2) and GLONASS (1.3) systems; and a review of five fundamental aspects of EGNOS, namely: the GNSS standardisation process (1.8); an explanation of the EGNOS MOPS message format (1.9); the problems of the ionosphere (1.6); the concept of navigation integrity (1.4 and 1.5); and a general review of geodetic aspects relevant to EGNOS (1.7).

*Chapter 2: EGNOS System Architecture* is devoted to a technical presentation of the EGNOS system and its subsystems. Article 2.1 provides a complete engineering description of the

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<sup>2</sup> A formal Agreement based on Article 228 of the EC treaty was concluded on 18 June 1996 between the European Community, Eurocontrol and ESA, for the development of the European Contribution to the first-generation Global Navigation Satellite System (GNSS-1).

system, presenting its three distinct segments – space, ground and users – and providing a global overview of all of the EGNOS subsystems. This is followed by seven articles covering each of the subsystems, including their functional role in EGNOS; how they work (e.g. architectural description); how they have been developed (programmatic aspects); and the physical structure after their implementation.

*Chapter 3: EGNOS Performance and Applications* presents the EGNOS performances achieved during qualification (3.1) and under worst-case ionospheric conditions (3.3); a review of EGNOS and WAAS achieved performances (3.2); a synthesis of how the EGNOS system is operated today (3.4); a description of the EGNOS User Interface Document (3.5) produced by ESA to support the application developers and general users, and finally descriptions of nine different EGNOS GNSS applications, ranging over aviation (3.6 and 3.7), railways (3.8), maritime (3.9), Internet-based systems using the ESA SISNET technology (3.10), land mobile applications (3.11), agriculture (3.12) and sports (3.13), to guidance assistance for blind pedestrians (3.14). This wide variety of practical applications is a clear demonstration of the multi-modal role for which the EGNOS System has been conceived.

*Chapter 4: Other SBAS Systems* briefly presents the US Wide-Area Augmentation System (4.1); the Canadian WAAS deployment element (4.2); the Japanese MSAS system (4.3); and the Indian GAGAN system (4.4). Here, we wish to express our appreciation to our American, Canadian, Japanese and Indian colleagues for their contributions to this Chapter of the book, and also for the excellent spirit of cooperation that their engineering teams have always shown in the international SBAS context, very much facilitating the end goal of achieving a truly seamless global worldwide system composed of several fully interoperable systems.

The last part of this book, *Chapter 5*, is devoted to the future of GNSS, including Galileo (5.1), GPS modernisation plans (5.2), and four contributions (5.3 to 5.6) on current plans and ideas for EGNOS modernisation in the period 2006-2012. These include the potential EGNOS service extension beyond Europe, the future introduction of the new GPS L5 civil frequency, the possible integration scenarios for EGNOS and Galileo, and the ESA ALIVE concept, which proposes the complementary use of EGNOS in support of disaster awareness and mitigation efforts.

The book is complemented with *five Appendixes*: Appendix A is a complete list of Acronyms; Appendix B is a list of Frequently Asked Questions, including those most frequently posed to ESA's EGNOS Helpdesk service (EGNOS@esa.int); Appendix C is a list of useful related websites; Appendix D\* is a formal legal disclaimer regarding EGNOS; and Appendix E is a brief description of the SisNetLab education tool, developed by ESA engineers to support Universities and Small and Medium-sized Enterprises (SMEs), which may be downloaded from a dedicated ESA website ([www.esa.int/navigation/sisnetlab](http://www.esa.int/navigation/sisnetlab)).

This book has been written for a wide readership, ranging from the GNSS engineering specialist to the final system users and applications developers. It should also be helpful for complementing GNSS graduate or undergraduate University courses, including specialised Masters Programmes, in which SBAS GNSS technology and related applications form part of the curriculum. Many recognised GNSS engineering experts have participated in the book's preparation, providing contributions of very good quality and thereby very much simplifying our technical review/editorial work, for which we are extremely grateful.

As noted in the Preface, the EGNOS System has been developed in harmony with the ESA principle of “*Shape and Share*”, i.e. shaping space technology together with European Industry, and sharing the benefits and knowledge with Europe's citizens. This book follows the same principle, it being our strong and sincere wish to share our EGNOS and GNSS knowledge with all interested readers.

Dr. Javier Ventura-Traveset, ESA

Dr. Didier Flament, Alcatel Alenia Space

\* Note that EGNOS may not be used for safety-of-life applications until the corresponding European and National certification authorities conclude that the system is sufficiently safe and authorise its use.