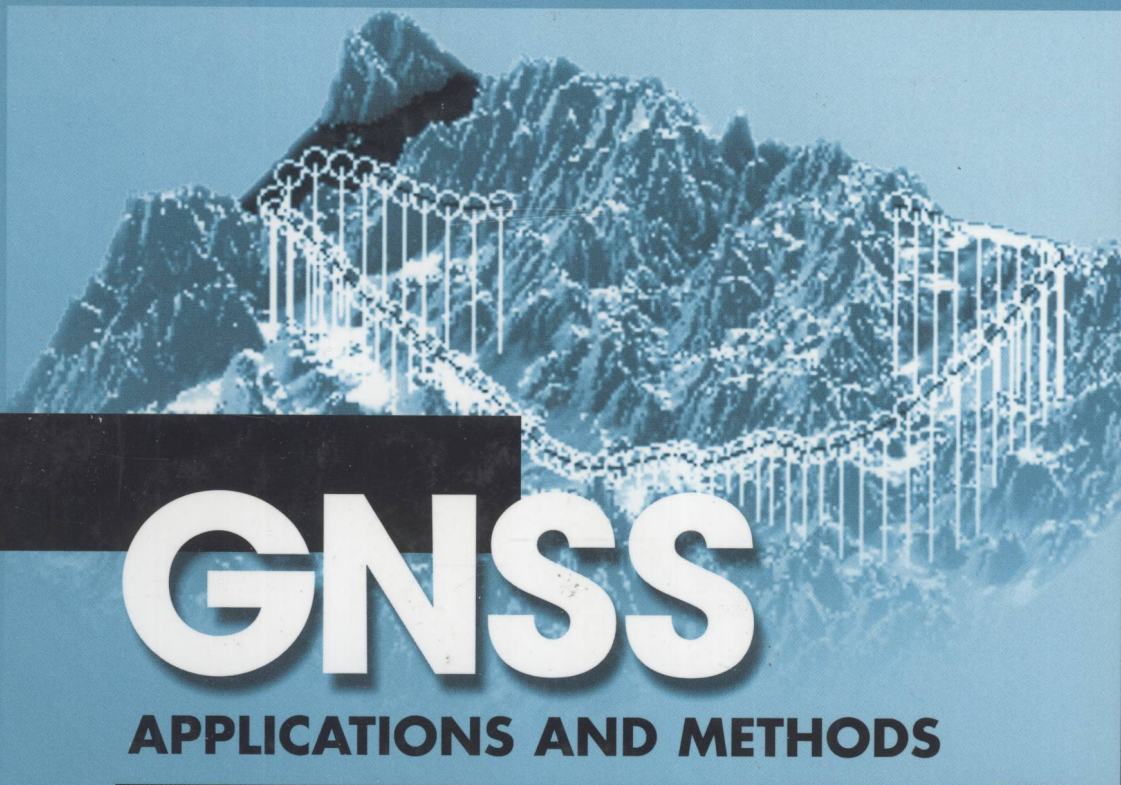




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# GNSS

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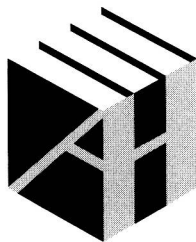
# GNSS Applications and Methods

Scott Gleason  
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*Editors*



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# Preface

Over the last decade, the number of applications that utilize global satellite navigation systems (GNSS) has steadily increased. Perhaps the most visible manifestation of this change is the development and wide use of consumer technologies that are based on GNSS. For example, these days it is not unusual for automobiles or mobile phones to be equipped with a Global Positioning System (GPS) navigation system. Additionally, scores of applications have emerged that even the original system designers could not have imagined. One such example is environmental remote sensing. In view of this trend, it is reasonable to expect that more satellite navigation based applications, in parallel with new satellite navigation systems, will be arriving in the future.

In the past, the group of professionals that were familiar with the detailed workings of GNSS came from a select group. As the number of applications grows, so will the need for professionals to understand this technology and how to apply it. As new applications emerge and existing applications expand, this group of knowledgeable professionals is growing to include individuals in a wide range of technical disciplines. The primary motivation for writing this book was to provide what we believe is an important need for this widening field of professionals—to provide the professional (and, perhaps, even hobbyist) interested in GNSS the opportunity to gain a practical or *hands-on* experience working with algorithms, applications, and data. We hope this book will allow the reader to learn about GNSS by “doing,” as we believe it is the most effective way to understand a complicated subject. This book will allow readers to expand on the basic theory behind GNSS systems and apply new insight to practical engineering and scientific applications.

A second motivation for this book is the fact that until now, the books most individuals relied on to learn about basic GPS applications have been the seminal two-volume set *Global Positioning System: Theory and Applications* edited by B. Parkinson, J. Spilker, P. Axelrad, and P. Enge. These books, informally known as the “GPS blue books,” have been a valuable resource for nearly every student of satellite navigation and will remain a useful reference for years to come. They could very well be on a shelf within arms reach of many readers. However, since the initial publication of the “GPS blue books,” several advancements have occurred in various traditional fields of navigation and GNSS. For example, microelectromechanical systems (MEMS)-based inertial sensors as well as inexpensive, compact, and powerful computing resources have become readily available. The availability of computer processing tools and the relative ease with which some of these applications can be both described and *demonstrated*, convinced us that it is possible to



provide a more hands-on approach for those wishing to learn about GNSS and GNSS applications. It is now possible to give interested professionals the chance to “have a go” at implementing GNSS-based algorithms and applications themselves. We believe that providing an additional resource that delves into as many new applications as possible, accompanied by numerous practical examples, all compatible with freely available tools and released under free and open source licenses, would be a welcome new resource for developers.

This book is not intended to provide a comprehensive treatment of GPS or satellite navigation in general terms. Nor is it intended to replace the “blue books” or even some currently available excellent texts such as *Global Positioning System: Signals, Measurements and Performance* (Second Edition) by Pratap Misra and Per Enge, or *Understanding GPS: Principals and Applications* (Second Edition) edited by Elliot Kaplan and Christopher Hegarty. Instead, our intent is to provide a book that compliments these fundamental texts, providing an additional resource for scientists and engineers who are looking for a basic overview of GNSS principals and practical introductions to a wide range of navigation applications.

This book will allow individuals to start “digging” deeper into specific applications where GNSS plays an important role and start answering the question: How is GNSS utilized to solve this particular problem? For those already familiar with the operation of GNSS receivers but interested in pursuing a specific application, this book will give them useful examples. For the adventurous, it will allow them to explore new areas and (hopefully) encourage them to ask “Where do I go from here?” or “What’s next?”

To this end, the book is organized as follows: Chapters 1 through 5 present the basics of GNSS navigation, or what could be considered traditional uses of GNSS. This introduction to basic GNSS principles includes: GNSS signal acquisition and tracking; GNSS position, velocity, and time (PVT) estimation; and differential GPS techniques and algorithms. These chapters include both a GNSS measurement simulator to demonstrate traditional position and velocity applications, and a complete software implementation of a GPS receiver, which processes actual off-air signals.

Following are several chapters that address GNSS integrated with other navigation systems. These include GNSS combined inertial navigation systems (Chapters 6 and 7); LADAR (Chapter 8); various radio frequency (RF) measurements (Chapter 9); and terrestrial radio navigation systems such as LORAN (Chapter 11).

Additionally, there are numerous chapters that address specific application areas or unique uses of GNSS signals. These chapters cover such broad application areas as: aviation (Chapter 10); indoor and weak signal navigation (Chapter 12); spacecraft applications (Chapter 13); and geodesy and surveying (Chapter 14). Finally, two novel scientific applications will be presented demonstrating how GNSS signals can be used for remote sensing of the environment (Chapters 15 and 16). We hope these chapters will expand the reader’s horizon about the possible uses of GNSS.

Of course, the only GNSS that has consistently been available and operational over the last decade is GPS. In anticipation of GPS modernization efforts, an overview of new signals and systems being developed for GPS is provided. A related topic to this is the emergence of new GNSS constellations such as the European

Galileo project. Both of these topics are the subject of the final chapter of the book (Chapter 17). For more details on the specific content of each chapter and the tools and data sets available on the DVD included with this book, please refer to the summary road-map included in Chapter 1.

In closing, we would like to acknowledge the fact that we had considerable support from many individuals in preparing this book. While it would be impractical to list all individuals that helped in preparation of this book, we would like to acknowledge those individuals that helped review various revisions of the manuscript and provide critical feedback, and those that tested and evaluated the software routines that go along with the various chapters in the book. In alphabetic order of last names these individuals are Mounir Adjrad, Vibhor Bageshwar., Susmita Bhattacharyya, Paw Yew Chai, Maria Paola Clarizia, Jason Da Ponte, David De Lorenzo, Paul Groves, Steve Hilla, Thomas Jakel, Alexander Mittleman, Oliver Montenbruck, Curtis Olson, Rohit Pandita, Todd Walter, Gary Wick, Zhiqiang Xing, and Guijin Zheng.

*Finally, we would like to note that all of the editor and contributor royalties from the sale of this book will be split between the following charitable organizations: Médecins Sans Frontières (Doctors Without Borders) and The Institute of Navigation's student scholarship and awards program.*

*For additional information on many of the applications and code included within this book, readers are encouraged to visit the Web site, [www.gnssapplications.org](http://www.gnssapplications.org).*

Scott Gleason  
Demos Gebre-Egziabher  
August 2009



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