

## GPS Information Sources — Part 2

By James E. Ferguson, OLS

[NOTE: Part 1 of this article was printed in the last issue of *The Quarterly*.]

I have what I believe is a treat for you this issue - an article that summarizes the many sources of written information relating to GPS.

With the vast amount of interest in computer based information sources, it is easy to overlook the wealth of data in the written word, and best of all you can read just about anywhere.

Our colleagues at the University of New Brunswick have been at the leading edge of GPS technology and applications for some time and the author of this article, Richard Langley, is well qualified to write on the subject of GPS. In this article, I found his classification of the reviewed material invaluable in finding relevant work quickly and easily. And, his close association with the who's who of the industry has helped him see what

publications are coming along in the near future.

I hope that you find this article interesting and informative and I urge you to start your own "GPS User's Bookshelf." By the way, if you haven't already received the free booklet of information related to geodesy and geomatics (Internet sites, publications etc.) please contact the Association office.

## The GPS User's Bookshelf cont'd

By Richard B. Langley, University of New Brunswick

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### ADVANCED

A wealth of printed material is available at the advanced level, ranging from technical papers in specialized journals to conference proceedings to monographs and technical manuals.

**The Red Books.** The most famous publications in the advanced category are the collected reprints of selected papers from *Navigation*, the journal of the Institute of Navigation (ION) of Alexandria, Virginia. Officially titled *Global Positioning System*, but commonly referred to as "the red books" they are currently the best source of detailed technical information about GPS. Four paperback volumes have been issued. Volume I (246 pages) was published in 1980 and contains the seminal papers detailing the design and development of GPS and its early tests. Volume II (257 pages) followed in 1984 and covers GPS developments (receiver design, applications and test results) during the first few years of the 1980s. Volume III (293 pages) was published in 1986 and contains papers on enhanced receiver design, DGPS, combined sensor

operation, and system operation and applications. The latest red book, Volume IV (and the largest at 378 pages) is dedicated to DGPS and kinematic GPS. The selected papers are divided into three groups: DGPS error sources, DGPS reference stations and wide-area DGPS, and kinematic and carrier-phase-aided DGPS. The number and breadth of coverage of the papers in the last category are so extensive that they have been subclassified into general implementations, land survey applications, hydrographic survey, aircraft positioning and landing and attitude and azimuth determination.

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**Global Positioning System, Theory and Practice.** Surveyors and geodesists

were among the first to seize GPS as a new tool for their work even when only a handful of the Block I satellites were in orbit. It is therefore not too surprising that several of the books on GPS have been authored by individuals from the geodesy and geomatics community. One of these books is *Global Positioning System, Theory and Practice* by Drs. Bernhard Hofmann-Wellenhof, Herbert Lichtenegger, and James Collins. The book meticulously covers the details of how GPS observations are processed to provide accurate positions - including the mathematical models - with the assumption that the reader is familiar with calculus and the method of least-squares adjustment. Although the book emphasizes GPS as a precise surveying tool, it also covers point positioning and navigation. There are also brief discussions of attitude determination using GPS and the use of airborne GPS for photo control. The authors suggest that the book can be used as a classroom text at the senior undergraduate or graduate levels or read, selectively, by professional surveyors,



navigators, and others with a desire to know how to position themselves with GPS. The first edition of the book was published in 1992, and the authors have already updated the book twice, with the second edition in 1993 and the third in 1994. The material in the book is quite up-to-date, therefore, and covers the more recent advances in GPS technology including on-the-fly ambiguity resolution, DGPS and operation under full operational capability. The third edition of this paperback book runs to 355 pages and, like the first two editions, is published by Springer-Verlag (New York, New York).

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**GPS Satellite Surveying.** Another GPS book from the geodesy and geomatics community is Alfred Leick's *GPS Satellite Surveying*. First published in 1990, with a second, much expanded edition in 1995, this 560-page hard-cover book is a comprehensive and thorough exposition of GPS as used in surveying. The material has been distilled in large measure from lecture notes used for courses on GPS and satellite geodesy, least-squares adjustment computations, geodetic models, and integrated geodesy taught at the University of Maine, where Dr. Leick is a professor. The book includes a handy set of appendices covering elements of linear algebra, linearization of nonlinear models, one-dimensional statistical distributions, rotation matrices, spherical trigonometry, a sample network to illustrate least-squares adjustment principles, and the basic operation and use of GLONASS. The book is published by John Wiley & Sons (New York, New York).

**ICD-GPS-200.** Navstar GPS Space Segment/Navigation User Interfaces, more commonly known as *Interface Control Document (ICD)-GPS-200*, is one of two official documents that are indispensable for GPS research and development. *ICD-GPS-200* is the nonclas-

sified publication that defines the functional characteristics necessary for compatibility between the GPS space segment - the satellites and their signals - and the navigation user segment - GPS receivers. It details the structure and tolerances of the signals transmitted by the satellites, fully describes the navigation message, and outlines the algorithms needed to implement navigation message decoding. Everything about the signals is documented except for the characteristics of selective availability and anti-spoofing, which are classified. The original versions of the ICD were prepared by the Satellite Systems Division of Rockwell International, in its capacity as the GPS space segment and interface control contractor. These versions were originally available only through official channels. In 1991, a publicly accessible version of *ICD-GPS-200* was approved for unlimited distribution, and it was subsequently updated in 1992. This version, available from the ARINC Research Corporation (Fountain Valley, California) and other suppliers, is printed on 115 U.S. letter-size pages, and is soft bound.

**Global Positioning System Standard Positioning Service Signal Specification.** This DoD (Washington, D.C.) document defines the service to be provided by GPS to the civil community. The main part of the text is divided into two sections with three annexes attached at the end. Section 1 introduces the Standard Positioning Service (SPS), gives the policy definition of SPS, defines some key terms and presents an overview of GPS. Section 2 provides the detailed SPS ranging signal characteristics. Much of the material in this section is also discussed in *ICD-GPS-200*, except the SPS document makes no reference to the L2 signal or to the P-code. The three annexes discuss the SPS performance specification, the SPS performance characteristics, and the means of measuring GPS performance. The 108-page second edition, published in June 1995, is available in soft-covered, hard-copy format or may be downloaded from the U.S. Coast Guard's Navigation Information Centre (NIC). For Web users, the specific URL of the directory containing the parts of the publication in PDF format is (<gopher://204.217.48.100:70/11%5Cgps%5Creports%5Csigspec>);

Web users can also arrive at this directory through the GPS Reports and Publications link on the main GPS Web page.

**The Global Positioning System: A Shared National Asset.** This report of the U.S. National Research Council's (NRC's) Committee on the Future of the Global Positioning System contains the technical portion of a congressionally requested study carried out jointly by the National Academy of Sciences and the National Academy of Public Administration (NAPA). In *The Global Positioning System: A Shared National Asset*, the committee outlines a number of suggested improvements to the existing GPS configuration as well as technical enhancements for future consideration. The 264-page report is available from the National Academy Press (Washington, D.C.).

**The Global Positioning System: Charting the Future.** This is the companion to NRC's report. Jointly authored by a NAPA panel and the NRC committee, *The Global Positioning System: Charting the Future* addresses both the technical aspects stemming from the tasks of the NRC committee (two of the chapters of the NRC report and some of its appendices are included in the joint report) as well as the policy, management, and funding issues considered by the NAPA panel. The 336-page paperback report is available from NAPA (Washington, D.C.). A shorter summary report is also available.

## PROCEEDINGS and JOURNALS

As valuable as the aforementioned books are as reference sources, the latest research and development work in GPS technology and its applications is presented at conferences and published in the proceedings of those conferences as well as in professional journals. Many recent conferences have dealt with GPS in whole or in part, so I will not attempt to list them all here. I will mention only a couple of the regularly occurring conferences: the annual International Technical Meeting of ION's Satellite Division and the biennial Position Location and Navigation Symposium of the Institute of Electrical and Electronics Engineers Aerospace and Electronics Systems Society (Piscataway, New Jersey). (Check the "Calendar" section of *GPS World*



each month for upcoming conferences and other events.)

Many journals in the navigation, geodesy, surveying, and geographic information systems fields include papers on GPS and its applications. Again, I will not attempt to list all journals that include papers on GPS but rather will highlight just a few. I have already mentioned ION's journal, *Navigation*, in conjunction with its "red books." *Navigation* is published four times a year and comes with membership in ION. The American Geophysical Union's (Washington, D.C.) *Journal of Geophysical Research* carries papers reporting on developments in high-accuracy applications of GPS such as in geodesy and crustal deformation monitoring. The *Journal of Surveying Engineering* of the American Society of Civil Engineers (New York, New York) also frequently carries GPS-related papers. And of course, we mustn't forget *GPS World* and the *GPS World Newsletter*.

## FORTHCOMING

Although all these publications are valuable additions to any user's library, room can always be found on the bookshelf for a few more. The following are some books scheduled for publication this year. [Editor's note: some of these publications may already be available.]

**GPS - Theory and Applications.** One of the most eagerly anticipated books on GPS, *GPS - Theory and Applications* has been edited by a team of researchers who have been instrumental in the development of GPS and its applications: Drs. Bradford Parkinson, James Spilker Jr., Penina Axelrad, and Per Enge. The work, to be published by the American Institute of Aeronautics and Astronautics (AIAA) of Washington, D.C., as volumes 163 and 164 of AIAA's *Progress in Astronautics and Aeronautics* series, explains the technology, performance and the applications of GPS. According to advance information released by AIAA, the first volume will be in two parts: Part 1 will be on the GPS fundamentals and will cover such topics as the history of GPS, signal structure, signal-tracking theory and GPS receiver operation, and navigation algorithms and solutions. Part 2 will be on GPS performance and error effects and will delve into

atmospheric, multipath, and interference effects; foliage attenuation; ephemeris and clock message accuracy; and selective availability. The second volume will be in four parts covering DGPS and integrity monitoring, integrated navigation systems, GPS navigation applications, and special applications. AIAA expects to have copies available for distribution this month.

**GPS for Geodesy.** This book is also much anticipated. It contains the edited lecture notes for the intensive short course by the same name first held in Delft, The Netherlands, in March/April 1995. The course was organized by the Faculty of Geodetic Engineering of the Technical University (TU) Delft, the Department of Geodesy and Geomatics Engineering of the University of New Brunswick (UNB), and the Office of The Netherlands Geodetic Commission and drew on the expertise of a team of six well-known academics who teach and carry out research in the GPS field: Peter Teunissen from TU Delft, Alfred Kleusberg and Richard Langley from UNB, Gerhard Beutler from the University of Bern, Yehuda Bock from the Scripps Institute of Oceanography and Clyde Goad from Ohio State University. The lecture notes from this one-week-long advanced course - called an "international school" by its organizers - provide the necessary information to understand fully the potential and limitations of GPS as used in geodesy. Each chapter in *GPS for Geodesy* covers the material of one of the 10 lectures: reference systems, GPS satellite orbits, propagation of GPS signals, GPS

receiver-Verlag and will be available early this year.

**The Global Positioning System and GIS.** Ann Arbor Press (Chelsea, Michigan) has recently announced the forthcoming publication of this book written by Professor Michael Kennedy of the University of Kentucky. *The Global Positioning System and GIS* is billed as a unique educational tool intended as an introduction for all mapping science professionals, managers, and students either as a classroom text or as a self-teaching guidebook. The case-bound book, scheduled to run at least 250 pages and to be published in February, explains how GPS works, examines software and hardware options, and provides theory to application in a concise manual.

**Understanding GPS: Principles and Applications.** Another book soon to be published is *Understanding GPS: Principles and Applications*. Edited by Elliott Kaplan, a senior member of the technical staff of the MITRE Corporation, and written by a team of 16 leading experts in the GPS field, this book for engineers and scientists working with GPS will be one of the first to provide an in-depth description of modern digital GPS receiver operation. In addition, it will cover such topics as the fundamentals of GPS, DGPS accuracy-enhancing techniques, GPS integration with other navigational sensors, GLONASS, and the Inmarsat geostationary overlay. This approximately 570-page, hard-cover book will be published by Artech House (Boston, Massachusetts) in March.

## CONCLUSION

In this short article, I have been able to discuss only some of the publications on GPS currently available. In addition, for example, there are many technical reports issued by university, government, and industry research groups that are available to engineers and scientists developing GPS receiver systems and applications - as well as to the sophisticated GPS user - covering such topics as system enhancements, receiver design, and the testing of a whole spectrum of GPS applications. Future "Innovation" articles will highlight the research in some of these reports.

Stay tuned.



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receivers and observables, GPS observation equations and positioning concepts, single-site GPS models, short-distance GPS models, GPS carrier-phase ambiguity-fixing concepts, medium-distance GPS measurements, and GPS as a tool for regional and global geodynamics. The lecture notes will be published by Sprin-