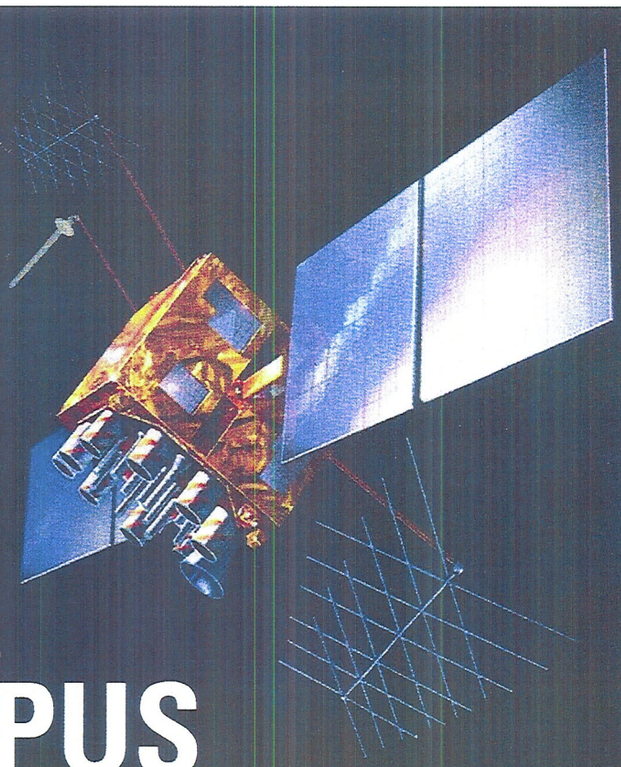
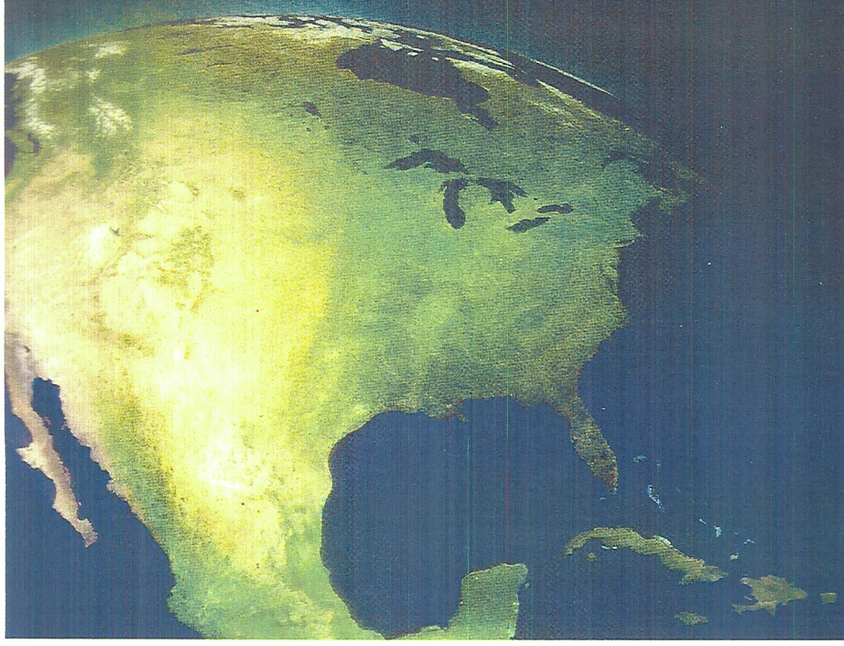


CORS and OPUS for Engineers

Tools for Surveying and Mapping Applications



Edited by
Tomás Soler, Ph.D.

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CORS AND OPUS FOR ENGINEERS

Tools for Surveying and Mapping Applications

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Tomás Soler, Ph.D.

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"Accuracy of OPUS Solutions for 1- to 4-h Observing Sessions" and "Accuracy Assessment of the National Geodetic Survey's OPUS-RS Utility" were originally published in *GPS Solutions*, as described on the first page of each paper. Both papers appear with kind permission of Springer Science+Business Media.

"Continuously Operating Reference Station (CORS)," "Statistics of Range of a Set of Normally Distributed Numbers," "Heuristic Weighting and Data Conditioning in the National Geodetic Survey Rapid Static GPS Software," "Constraining Network Adjustments to OPUS-RS Coordinate Observations," "Efficiency and Reliability of Ambiguity Resolution in Network-Based Real-Time Kinematic GPS," "Network Calibration for Unfavorable Reference-Rover Geometry in Network-Based RTK," and "Transforming Positions and Velocities between the International Terrestrial Reference Frame of 2000 and North American Datum of 1983" were originally published in ASCE's *Journal of Surveying Engineering*, as described on the first page of each paper.

Front cover: artist's rendering of a GPS Block IIR-M satellite in orbit courtesy of the U.S. National Executive Committee for Space-Based Positioning, Navigation, and Timing; back cover: photograph of CORS reference station LCRH courtesy of the U.S. National Oceanic and Atmospheric Administration.

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Contents

Foreword

Juliana P. Blackwell, Director
National Geodetic Survey

The history of the National Geodetic Survey (NGS), an office of the National Oceanic and Atmospheric Administration (NOAA), spans more than 200 years. On February 10, 1807, Congress endorsed the scientific vision of President Thomas Jefferson by authorizing him to establish a Federal agency to survey the coasts of the United States with the following words:

"Be it enacted by the Senate and the House of Representatives of the United States of America in Congress assembled, That the President of the United States shall be, and he is hereby authorized and requested, to cause a survey to be taken off the coasts of the United States, in which shall be designated the islands and shoals, with the roads or places of anchorage, within twenty leagues of any part of the shores of the United States; and also the respective courses and distances between the principal capes, or head lands, together with such other matters as he may deem proper for completing an accurate chart of every part of the coasts within the extent aforesaid."

In 1878, the mission to survey the coasts was expanded and the Coast and Geodetic Survey was created with the mission to establish accurate geodetic control throughout the entire United States and its territories. Since 1970, NGS has served as the current link in the chain of scientific organizations tasked with providing the most accurate geodetic framework for supporting positioning activities conducted in our Nation.

In the mid-1980's, Global Positioning System (GPS) technology started to become operational in conjunction with advancements in digital processing. Soon thereafter, NGS seized this opportunity and pioneered the use of these modern tools to accomplish its mission far more effectively than was previously possible. In particular, NGS scientists implemented two major innovations: the Continuously Operating Reference Station (CORS) network, and a Web-based utility called the Online Positioning Users Service (OPUS), both of them now well established. These innovations have transformed the way GPS surveying has been practiced in the United States for more than a decade.

This Monograph is a collection of articles describing a wide range of applications associated with CORS and OPUS. NGS is sponsoring this Monograph with the goal of sharing with the scientific community detailed information about CORS and OPUS. Most articles were written by NGS staff; others by investigators under contract with NGS. Still other articles were written by independent professionals who have extensively evaluated these innovative services. To all of the authors we extend our sincere thanks for researching and expanding the knowledge of NGS' GPS-based services to the geospatial community. The legacy of scientific exploration and innovation envisioned by President Jefferson continues.

Introduction

Tomás Soler, Ph.D., Chief Editor
Journal of Surveying Engineering
National Geodetic Survey

The broadening universe of Global Navigation Satellite Systems (GNSS) has radically changed the way we comprehend and practice surveying today. The Global Positioning System (GPS) was the first GNSS constellation put in place and still remains the most popular georeferencing tool among a plethora of users because of its useful practicality. Nobody questions anymore the advancements that GPS has brought upon many scientific disciplines in general, and all aspects of surveying and mapping in particular. Undoubtedly, GPS surveying has replaced traditional surveying in a variety of engineering, topographic and mapping endeavors. The advantages of reduced observation times in the field, automated data processing, and the superb accuracy of the derived coordinates are factors difficult to disregard lightly. Recently, even the prices of required equipment and supplementary software have been drastically reduced, ensuring the continued dominance of GNSS technology into the future.

This Monograph originated around the theme of GPS precise positioning. A source of inspiration has been the work and numerous studies on this subject conducted at NOAA's National Geodetic Survey (NGS), eager to accomplish its mission to define, maintain, and provide access to the U.S. National Spatial Reference System. NGS soon recognized the opportunity that GPS offered and embarked on the arduous process of replacing its classical observational methodologies while attempting to educate the land surveying community of the advantages of performing GPS positioning. The Continuously Operating Reference Station (CORS) concept was the first to be developed, soon followed by the Web-based utility called the Online User Positioning Service (OPUS) which provides positional coordinates in each of two popular reference frames: the International Terrestrial Reference Frame of 2000 (ITRF2000) and the CORS96 realization of the North American Datum of 1983, (NAD 83 (CORS96)).

The Monograph comprises a collection of articles – about half of them previously published in the ASCE's *Journal of Surveying Engineering* – describing various aspects associated with CORS and OPUS applications. Thirteen additional articles are published here for the first time. The ordering of the papers does not follow a strict chronology although they are sequentially organized with respect to three major topics: CORS, OPUS-S (static), and OPUS-RS (rapid static). The primary intent of this compilation is to provide detailed information to the civil engineering community at large, in a single, comprehensive publication, about new GPS technical procedures available to professionals working in the field of surveying engineering. Assembled as a unit, these contributions represent the latest available literature describing advanced methods for obtaining accurate positional coordinates referred to modern sophisticated spatial reference frames such as ITRF2000 and NAD 83 (CORS96).

The articles presented herein describe both theoretical to empirical research. It is our hope that the articles of this Monograph help develop an understanding of these current GPS applications among academic researchers as well as among professional engineers working on surveying, GIS, and mapping applications.

I thank all contributors and the ASCE Publications Department staff for providing the opportunity to produce this Monograph with the hope that its dissemination may significantly contribute to the knowledge of accurate GPS positioning. Finally, special appreciation goes to the ASCE Geomatics Division EXCOM members who debated and approved the idea of publishing this Monograph.

Review of *CORS and OPUS for Engineers. Tools for Surveying and Mapping Applications*, edited by T. Soler

American Society of Civil Engineers, Reston, VA; 2011; ISBN: 9780784411643. Price: Nonmember, $90.00; ASCE Member, $67.50

John V. Hamilton, M.ASCE

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This book (actually a monograph) is a collection of articles by a number of very well qualified authors describing various aspects associated with continuously operating reference stations (CORS) and online positioning user service (OPUS) applications, about half of which were previously published in ASCE's *Journal of Surveying Engineering*. The National Geodetic Survey (NGS), which operates the CORS network and provides the OPUS utility, has sponsored the monograph, and many of the authors are NGS staff. The monograph has been cosponsored by ASCE's Geomatics Division, which among its principal missions pursues the fostering and encouragement of the instruction and dissemination of geomatics technical issues.

The first two articles give an introduction to the CORS, including the history of the development of the National CORS, and present criteria for establishing and operating a CORS.

The next article describes in moderate detail the current flavors of OPUS—OPUS-S, OPUS-RS, and OPUS-DB—followed by a number of papers that go into more depth regarding the orbits used, accuracies attainable, and methods that can be applied to improve the accuracy of the solutions. The extended output from OPUS is described at length in an article by Peter Lazio, who, as a GPS manager in an engineering firm, has ample hands-on experience with CORS and OPUS applications.

One article is devoted to the basics of the teqc utility, employed by NGS and many other practitioners to convert raw data to RINEX and for QC checking. Two additional articles by Lazio describe methods that can be used to edit RINEX to improve poor solutions and problem data sets. Lazio also produced two other articles describing procedures by which the results of OPUS processing can be used in combined least squares adjustments.

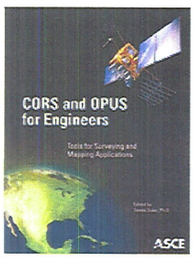
Two articles by a large group of authors from The Ohio State University, NGS, and other academic institutions describe the software developed for the OPUS-RS processor and for ambiguity resolution over long lines.

The final articles in the monograph are by NGS's William Henning, describing the optimal methodology for determining precise RTK surveys; a contribution expanding on the horizontal time-dependent positioning (HTDP) utility; and two articles outlining methods to transform positions and velocities between reference frames and between epochs.

In the opinion of the reviewer, this monograph embodies a timely and opportune compendium, partially theoretical, but mainly composed of pragmatic step-by-step applications (e.g., how to combine OPUS results with modern surveying observations; how to understand error messages in OPUS-RS submissions) that may be very useful to frequent OPUS customers. The advantage of this collection of papers is that it gathers, in a single volume, the necessary didactic material to comprehend, in an intelligible manner, questions that may arise when using any of the different options available to surveying and mapping professionals submitting GPS data to the OPUS web portal.

In summary, this monograph is one of the most useful reference tools for any surveyor or engineer involved in accurate positioning who regularly accesses the CORS and OPUS Internet utilities, and it will be considered an indispensable source of information that should be on every geospatial GPS data user's desk.

CORS and OPUS for Engineers



CORS and OPUS for Engineers

Tools for Surveying and Mapping Applications

Edited by Tomás Soler, Ph.D.

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Description
Sponsored by the Geomatics Division of ASCE and the National Geodetic Survey of the U.S. National Oceanic and Atmospheric Administration.

CORS and OPUS for Engineers describes new global positioning system (GPS) technologies and procedures that are immediately relevant to civil engineering professionals engaged in high-accuracy positioning. This collection of 22 articles, half new and half previously published in peer-reviewed journals, assembles the latest thinking on the use of two advanced services-CORS and OPUS-for obtaining accurate positional coordinates. Created and managed under the auspices of the National Geodetic Survey, the CORS (continuously operating reference stations) network contains more than 1,600 permanent, geodetic-quality receivers that collect GPS data around the clock at locations distributed throughout the United States, its territories, and a few foreign countries. These data are then made freely available to the public via the Internet. OPUS (online positioning user service) is a free, automated, Web-based utility that provides its users with accurate and reliable positional coordinates in a timely fashion by processing each user's GPS data with corresponding data from the CORS network. Together, CORS and OPUS form the backbone of today's high-accuracy, three-dimensional positioning activities.

Both theoretical and empirical, this collection is a must-have for practitioners and researchers involved in surveying, GIS, remote sensing, and mapping applications that utilize GPS technology.

Reader Reviews

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By Anonymous

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