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The Global Positioning System (GPS) has become a useful tool in providing relative survey control. The relative positioning accuracies of the GPS are commonly on the order of 1-10 parts per million (ppm). The drawback with relative positioning is the user must have one or more known control stations. In areas like the Continental United States (CONUS), survey control is abundant. However, in the near future, the Corps of Engineers may be asked to provide engineering and mapping support to countries which have limited or nonexistent geodetic control networks. In these areas, the engineer and surveyor will not have known control to initiate a survey. In this case, the surveyor will be required to establish one or more absolute control points. To achieve absolute positional accuracies of 1-3 meters, the user must occupy the unknown station for 4-6 hours. The data reduction would take place at the Defense Mapping Agency (DMA), Washington, DC, and the user could wait for several weeks to receive the adjusted coordinates. Recently, USAETL adapted the absolute positioning program created by DMA to run on a standard IBM XT or compatible personal computer. After a few hours of data collection, the absolute positioning program CORPSABS allows the user to estimate the three dimensional position within a matter of minutes. The positioning results can be refined when the DMA precise ephemerides become available. This paper quantifies the accuracy of absolute GPS positioning and evaluates its application to the civilian sectors of the Corps of Engineers.

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Absolute Positioning Using The Global Positioning System

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BIOGRAPHICAL SKETCH

Mr. Bryn Fosburgh is a research scientist with the U.S. Army Engineer Topographic Laboratories (USAETL). He is responsible for the development, testing and fielding of innovative survey techniques to the tactical army. Prior to employment at USAETL, Mr. Fosburgh was a geodetic surveyor with the Defense Mapping Agency (DMA). At the DMA, he was responsible for the planning, data acquisition, and data analysis of conventional, satellite and gravimetric surveys.

Mr. Thomas Cox is a research scientist with the USAETL. Mr. Cox is responsible for the development of navigation hardware and software for military systems. His current research includes the development of a low cost navigator for wheeled vehicles.

ABSTRACT

The Global Positioning System (GPS) has become a useful tool in providing relative survey control. The relative positioning accuracies of the GPS are commonly on the order of 1-10 parts per million (ppm). The drawback with relative positioning is the user must have one or more known control stations. In areas like the Continental United States (CONUS), survey control is abundant. However, in the near future, the Corps of Engineers may be asked to provide engineering and mapping support to countries which have limited or nonexistent geodetic control networks. In these areas, the engineer and surveyor will not have known control to initiate a survey. In this case, the surveyor will be required to establish one or more absolute control points. To achieve absolute positional accuracies of 1-3 meters, the user must occupy the unknown station for 4-6 hours. The data reduction would take place at the Defense Mapping Agency (DMA), Washington, DC, and the user could wait for several weeks to receive the adjusted coordinates. Recently, USAETL adapted the absolute positioning program created by DMA to run on a standard IBM XT or compatible personal computer. After a few hours of data collection, the absolute positioning program CORPSABS allows the user to estimate the three dimensional position within a matter of minutes. The positioning results can be refined when the DMA precise ephemerides become available. This paper quantifies the accuracy of absolute GPS positioning and evaluates its application to the civilian sectors of the Corps of Engineers.

BACKGROUND

The technique of absolute or point positioning involves the use of a single Global Positioning System (GPS) receiver to determine the three-dimensional location of a point on the earth's surface. The technique of relative positioning involves the positioning of one or more unknown locations relative to a previously established survey point. Because of reliable survey control in the Persian Gulf, the U.S. Army 30th Engineer Battalion (Topographic) requested the USAETL to develop a software routine capable of generating absolute positions using the broadcast and precise ephemerides. The software was required to operate on a personal computer using the Disk Operating System (DOS) and capable of accepting input files generated by the Geodetic Satellite Receiver (GESAR) Version 1.9 software on the Texas Instruments (TI) 4100 GPS receiver (Darnell,1988). To satisfy the immediate positioning requirements of the 30th Engineer Battalion (Topographic), the USAETL, in cooperation of the Defense Mapping Agency (DMA), converted DMA's GEOSTAR PREPROCESSOR (STARPREP) and Geodetic Absolute Sequential Positioning (GASP) programs to a DOS environment. The STARPREP and GASP routines have been extensively tested for accuracy and reliability (Malys and Ortiz,1989). Therefore, USAETL engineers and scientists did not deem it necessary to generate and test a new algorithm. USAETL's primary concern was to create CORPSABS, a user-friendly menu system that drives execution of DOS compatible versions of the data converters (GS/FIC Tools), screening/editing (PRTN), and the aforementioned STARPREP and GASP.

INTRODUCTION

The Navigation Satellite Timing And Ranging (NAVSTAR) Global Positioning System (GPS) has been used extensively in the last few years by the Corps of Engineers in the relative positioning of hydrographic vessels and the densification of geodetic and engineering survey control. Relative positioning provides the user accurate, timely positional data. The disadvantage with relative positioning is the requirement of known survey control. In some regions of the Continental United States (CONUS) or Outside CONUS (OCONUS) survey control may be sparse, unreliable, or nonexistent. If survey control is nonexistent or unreliable, the surveyor or engineer will be required to extend control from a distant locale. This option may not be practical because of time constraints, logistics, or lack of personnel or equipment. Absolute positioning using the GPS provides the user a control framework that could be strengthened with relative GPS or conventional survey techniques.

ACCURACY OF GPS ABSOLUTE POSITIONING

The accuracy achieved with absolute positioning is dependent on the length of station occupation, satellite geometry, number of satellites tracked and the ephemeris type used in post-processing (broadcast or precise). The recommended observational guidelines are listed in Table 1 (Malys and Jensen,1990b). Preliminary studies at USAETL have shown that horizontal positional accuracies of 3-5 meters Root Mean Square (RMS) error are obtainable when post-processing with the broadcast ephemeris and horizontal accuracies of 1-2 meters RMS are obtainable with the precise ephemeris. These results are consistent with those reported by Malys and Jensen, 1990a.

GPS RECEIVER ARCHITECTURE

A geodetic quality Precise Positioning Service (PPS) GPS receiver is required to achieve the stated positioning accuracies. The receiver must be capable of acquiring the L1 and L2 carrier frequencies, the L1 Coarse Acquisition (CA) code, L1 and L2 precise (P) codes, and L1 and L2 Y codes. A PPS receiver is capable of negating the effects of Selective Availability (SA) and Anti Spoofing (AS). The primary disadvantage of absolute positioning is the requirement of a PPS receiver. The Corps of Engineers, as an Army component, is authorized to procure PPS equipment; however, some Corps contractors may not be certified to use PPS equipment.

CORPSABS

The program CORPSABS is a DOS compatible menu driven software package that uses the GPS carrier beat phase observable to generate the three-dimensional WGS 84 coordinates of a control station. At present, CORPSABS requires a GESAR generated file from the TI 4100 GPS receiver as input. CORPSABS allows the user to process using the broadcast or precise ephemerides and satellite clock states. The main menu structure of CORPSABS allows the user to change site information (station name and height of antenna), meteorological data (temperature, pressure and relative humidity), and to delete or "turn off" satellites. The CORPSABS program consolidates the Applied Research Laboratories (ARL) data converters (GS/FIC Tools) with DMA,s screening editing (PRTN), preprocessor (STARPREP) and adjustment (GASP) programs.

Data Converters. Produce the Floating Point, Integer, Character ASCII (FICA) format data file from the GESAR input data (binary).

Screening/Editing. Provides for user correction of a priori station coordinates and meteorological data within the FICA file.

Preprocessor. The preprocessor corrects the carrier beat phase observable for the following systematic errors (Malys and Ortiz, 1989):

- Range Ionosphere
- Doppler Ionosphere
- Earth Rotation
- Hopfield or Chao Troposphere
- Satellite Clock
- General Relativity
- Satellite Antenna Offset

Adjustment Module. The adjustment module forms the GASP observable with the corrected carrier beat phase from the preprocessor module by creating a between epoch and between satellite difference equation. Three observation equations will be generated when four "acceptable" satellites are tracked at two consecutive epochs. These observables are used in the least squares estimation process to determine the unknown Earth Centered Earth Fixed (ECEF) station coordinates. A detailed description of the DMA's STARPREP and GASP routines can be found in Malys and Ortiz, 1988, or Malys and Jensen, 1990a.

APPLICATIONS

Tactical Military. The horizontal and vertical accuracies achieved by absolute positioning using the broadcast ephemerides satisfy most of the tactical army's (artillery and weapon systems emplacement) positioning requirements. The use of the precise ephemerides may be warranted in geodetic applications, such as the determination of transformation parameters and the establishment of initial survey control. Absolute positioning using GPS was used extensively in Operation Desert Shield/Storm to establish an initial survey control framework and the development of transformation parameters.

Corps of Engineers Civilian Components. Absolute positioning using GPS would be applicable for those field operating activities that have OCONUS surveying and mapping responsibilities. These Corps components could use GPS absolute positioning in the establishment of initial survey control in areas where the control network may be sparse or unreliable. Absolute positioning can be used in the positioning of reference stations for real-time code phase differential GPS (DGPS). Absolute positioning would also provide timely and accurate positioning of geophysical (drill rigs) and navigation equipment.

FUTURE DEVELOPMENT

The limitation of CORPSABS is the requirement that the data be collected from a TI 4100 GPS receiver. USAETL is currently creating a binary database that will be the input file to CORPSABS. This database will be generated by converting a ASCII file in the Receiver Independent Exchange (RINEX) format. It is expected that in the near future the RINEX format will become universal among GPS receiver manufactures. The ability of CORPSABS to accept RINEX-generated files will enable the user to utilize any geodetic quality PPS GPS receiver. By making the CORPSABS software receiver generic will make it possible to use GPS receivers that have advanced hardware enhancements. The capability to use these more sophisticated GPS receivers may significantly improve the accuracies of GPS absolute positioning.

CONCLUSION

Absolute positioning using GPS was used in Operation Desert Shield/Storm to provide initial survey control within theater and develop transformation parameters between the local datums and the World Geodetic System 1984 (WGS 84). The success of absolute positioning using GPS in Operation Desert Shield/Storm and the capability to estimate these positions within the theater of operation has provided the military surveyor a phenomenal positioning tool. Engineers and scientists should continue to investigate the applications of absolute positioning using GPS to the civilian components of the Corps of Engineers. The absolute positioning technique may not be practical for all Corps districts; however, those districts or divisions that support remote or overseas locations may benefit from the potential positioning accuracies of absolute positioning using the GPS.

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Many individuals within USAETL, DMA, and National Ocean and Atmospheric Administration (NOAA) were responsible for the success of absolute positioning in Operation Desert Shield/Storm. We would like to personally thank Mr. Jeffrey Walker, USAETL, for the difficult task of converting STARPREP and GASP to a DOS environment and Mr. Stephen Malys, DMA, for his technical support concerning the STARPREP and GASP software routines.

REFERENCES

Darnell, A.R., 1988, Users Guide To GESAR Version 1.9, U.S Government.

Malys, S., and Jensen, P.A., 1990a, Geodetic Point Positioning With GPS Carrier Beat Phase Data from The CASA UNO Experiment, Geophysical Research Letters, Vol. 17 NO. 5, pages 651-654.

Malys, S., and Jensen, P.A., 1990b, Guidelines, Operational Procedures, and Quality Control For The Estimation of Geodetic Point Positions From GPS Data Collected With The TI 4100 Receiver, Defense Mapping Agency (DMA) Technical Report, U.S. Government.

Malys, S., and Ortiz, M.J., 1989, Geodetic Absolute Positioning With Differenced GPS Carrier Beat Phase Data, Proceedings Fifth International Symposium on Satellite Positioning, Vol. 2, pages 487-499, Physical Science Laboratory New Mexico State University.

Table 1 TI 4100 Observation Requirements

Observation Criteria	Precision 0.75 meters 1σ	Precision 1.5 meters 1σ
Observation Period	4 Hours	1.5 Hours
Data Collection Interval	30 Seconds	30 Seconds
Minimum Number of simultaneously tracked satellites	4	4
Minimum Number of Scenarios of 4 Satellites	3	3
PDOP	A Falling PDOP is desirable for each scenario. For the last 40 minutes, the PDOP should be less than 10 and no greater than 5 at the end of the final scenario	Same
Satellite Geometry	Satellites should be distributed in all four quadrants. Satellites should be at a minimum elevation angle of 10 degrees or greater	Same
TI 4100 Operating System	GESAR	Same
Minimum Crystal Oscillator Warm-up time	1 hour	1 hour
Meteorological Observations	Recorded Every Hour Temp +/- 1 C Relative Humidity +/- 5 % Barometric Pressure +/- 1 millibar	Same
Antenna Height/- 0.010 meters	0.010 meters	