Chapter 7
GPS Receiver and Equipment Selection

7-1. General

Selection of the right GPS receiver for a particular project is critical to its success. Receiver selection must be based on a sound analysis of the following criteria: applications for which the receiver is to be used (e.g., static or dynamic, code or carrier), accuracy requirements, power consumption requirements, operational environment, signal processing requirements, and cost. GPS receivers range from high-end, high-cost, high-accuracy "geodetic quality" to low-end, low-cost, low-accuracy "resource grade" or "recreational" models. Moderate cost, meter-level accuracy "mapping grade" receivers are also available. Dozens of vendors produce GPS receivers and there are hundreds of models and options available. This chapter presents only a brief overview on GPS survey equipment and selection criteria. References to specific brands, models, prices, and features in this chapter will be rapidly out of date. Current comparative information on GPS receivers and options is readily available in various trade magazines, such as *GPS World*, *POB,* and *Professional Surveyor.* Prior to initiating procurement, USACE commands are also advised to consult ERDC/TEC or other commands for technical guidance on GPS instrumentation options.

7-2. Types of GPS Receivers

There are two general types of GPS receivers: Code Phase and Carrier Phase. Geodetic quality receivers process both code and carrier phases. Geodetic quality receivers (and auxiliary equipment) can cost between $10,000 and $25,000. Resource grade (recreational navigation) receivers typically process only the L1 C/A-code and perform absolute positioning. These receivers cost between $100 and $1,000. Some moderate cost ($1,000 to $5,000) hand-held mapping grade receivers can process either differential code or carrier observations. Within these types there are C/A and P-code receivers, one- or two-channel sequential receivers, multi-channel receivers, codeless receivers, single- and dual-frequency receivers, all-in-view receivers, continuous tracking, code-correlation, cross-correlation, squaring, and a variety of other signal processing techniques. Reference *NAVSTAR GPS User Equipment Introduction* (DoD 1996) or (Kaplan 1996) for further details on receiver signal processing methods.

a. Code Phase receivers. A code receiver is also called a "code correlating" receiver because it requires access to the satellite navigation message of the P- or C/A-code signal to function. This type of receiver relies on the satellite navigation message to provide an almanac for operation and signal processing. Because it uses the satellite navigation message, this type of receiver can produce real-time navigation data. Code receivers have "anywhere fix" capability and consequently, a quicker start-up time at survey commencement. Once locked onto the GPS satellites, an anywhere-fix receiver has the unique capability to begin calculations without being given an approximate location and time.

b. Carrier Phase receivers. A carrier phase receiver utilizes the actual GPS signal itself to calculate a position. There are two general types of carrier phase receivers: (1) single frequency and (2) dual frequency.

(1) Single-Frequency receivers. A single-frequency receiver tracks the L1 frequency signal. A single-frequency receiver can be used effectively to develop relative positions that are accurate over baselines of less than 20 km or where ionospheric effects can generally be ignored.

(2) Dual-Frequency receivers. The dual-frequency receiver tracks both the L1 and L2 frequency signal. A dual-frequency receiver will more effectively resolve baselines longer than 20 km where ionospheric effects have a larger impact on calculations. Dual-frequency receivers eliminate almost all ionospheric effects by combining L1 and L2 observations. All geodetic quality receivers are multi-channel, in which a separate channel is tracking each satellite in view. Most manufacturers of dual-frequency receivers utilize codeless techniques, which allow the use of the L2 during anti-spoofing. Other signal processing techniques include squaring, code-aided squaring, cross-correlation, and z-tracking. Receivers that utilize a squaring technique are only able to obtain 1/2 of the signal wavelength on the L2 during anti-spoofing and have a high 30 dB loss. Receivers that use a cross-correlation technique have a high 27 dB loss but are able to obtain the full wavelength on the L2 during A/S.

7-3. GPS Receiver Selection Considerations

There are numerous factors that need to be considered when purchasing a GPS receiver (or system) for project control or mapping purposes. The following factors and features should be reviewed during the selection process.

a. Project applications. Current USACE applications include land-based, water-based, and airborne positioning, with a wide range of accuracy requirements. Land applications include real-time topographic surveying, geodetic control, resource mapping, navigation, survey control, boundary determination, deformation monitoring, and transportation. Most of these applications require carrier phase, geodetic-quality receivers. Water or marine applications include navigation and positioning of hydrographic surveys, dredges, and drill rigs--typically using meter-level differential code phase positioning techniques. GIS development applications are commonly performed with low cost, resource-grade, hand-held, GPS receivers--using either absolute positioning or code differential techniques. Airborne applications include navigation and positioning of photogrammetric-based mapping and require high-end geodetic GPS receivers along with inertial measurement units (IMU). Some receivers can be used for all types of applications and accuracies--e.g., a GPS receiver may contain capabilities for performing code, carrier, RTK, GLONASS, FAA WAAS, or USCG positioning. Generally, the more applications a receiver must fulfill, the more it will cost. It is important for the receiver's potential project applications be defined in order to select the proper receiver and the necessary options, and to avoid purchase of a $50,000 GPS system when a $10,000 system would have sufficed.

b. Accuracy requirements. A firm definition of the point positioning accuracy requirements is essential when deciding on the type of GPS receiver that will be required. Receiver cost typically increases as accuracy is increased. For example, a "geodetic-quality" receiver is usually specified for high-quality Corps project control work, particularly when precise vertical control is being established. Accuracy requirements will further define procedural requirements (static or kinematic), signal reception requirements (whether use of either C/A- or L1/L2 P-codes is appropriate), and the type of measurement required (pseudorange or carrier phase measurements). If only meter-level GIS feature mapping is involved, inexpensive, single-frequency GPS receivers are adequate, if combined with differential corrections.

c. Power requirements. The receiver power requirements are an important factor in the determination of receiver type. Receivers currently run on a variety of internal and external power sources from 110 VAC to 9 to 36 VDC systems. Most systems operate on small rechargeable internal batteries and draw some 1 to 5 watts. A high-end GPS receiver can operate only a few hours on its internal batteries, whereas a low-end, resource grade receiver that draws less power may operate 1 to 2 days on a set of flashlight (AA) batteries. Use of external gel-cell batteries should be also considered as a power source. If continuous structural monitoring or navigation is performed, then the receiver must have an external power option.

d. Operational environment. The operational environment of the survey is also an important factor in the selection of antenna type, antenna and receiver mounting device, receiver dimension and weight, and durability of design. For example, the harsher the environment (high temperature and humidity variability, dirty or muddy work area, etc.), the sturdier the receiver and mount must be. Most receivers are designed to operate over wide temperature ranges and in 100% humidity conditions. Many Corps applications require receivers to be mounted in small workboats exposed to harsh sea conditions and salt water spray. The operational environment will also affect the type of power source to be used.

e. Baseline length. For static control surveys, the typical baseline lengths encountered will determine the type of receiver that is required. Single-frequency receivers are usually adequate for baseline lengths of less than 20 km. Beyond 20 km lengths, dual-frequency receivers are recommended. Real-time kinematic operations require geodetic quality, dual-frequency receivers over all baseline lengths. Precision vertical work may also require dual-frequency receivers.

f. Data logging. Most geodetic quality receivers log data to an external logging device--e.g., a Survey Controller or directly to a laptop computer. Some geodetic quality receivers can also log data internally for later downloading through a communications port. Resource grade hand-held type receivers can collect, process, and display data internally. The amount of storage required is a function of the typical project, data logging rate--1-sec, 5-sec, etc. Most high-end units use memory cards for additional storage requirements. Quality receivers will have 2 to 4 RS-232 ports, with high data transfer rates (e.g., 9,600 to 115,200 baud).

g. Operator display. Most modern receivers and data controllers contain simple icon-based displays for selecting GPS survey modes and data logging options. Costs and options will vary with the size of a LCD display on the receiver or controller. Quality receivers provide audible and visual warnings when data quality is poor.

h. Satellites and channels tracked. Most quality receivers are designed to track 12 or more channels in parallel mode. Many receivers can track 12 or more satellites--some can track "all-in-view."

i. Time to start and reacquire satellites. GPS receivers vary in the time required to cold start (1 to 3 minutes) and warm start (< 1 minute). OTF initialization (and reinitialization) time is also varied. These criteria may be significant for some Corps topographic RTK surveying applications where loss of lock is common due to structures or canopy cover.

j. Size and weight. Size and weight are important if receivers are used for RTK topographic surveys or mapping type work. Most geodetic quality and hand-held receivers weigh from 1 to 5 pounds. RTK remote systems approach 10 pounds when all auxiliary equipment is included.

k. FAA WAAS, USCG, and commercial provider DGPS capability. Receivers with varied code DGPS capabilities are needed in some remote or mountainous areas--especially when one of the DGPS provider signals is poor or unreceivable. Some receivers are designed to acquire commercial, FAA WAAS, and USCG DGPS pseudorange corrections.

l. GLONASS capability. The ability to acquire and process Russian GLONASS satellites (and other future GNSS systems) would be advantageous in mountainous or urban areas where NAVSTAR GPS satellites are partially blocked. The acquisition of additional satellites also provides higher geometric accuracy.

m. Antenna type. A wide variety of antennas are available from GPS receiver manufacturers. In addition, optional antenna types can be ordered with the same receiver. Some antennas are built into the receiver and others are external. Multipath minimization will require more expensive antennas for static control survey applications. These include antennas configured with ground planes and choke rings. For high accuracy work, antenna reference points should be modeled, as illustrated in Figure 7-1.

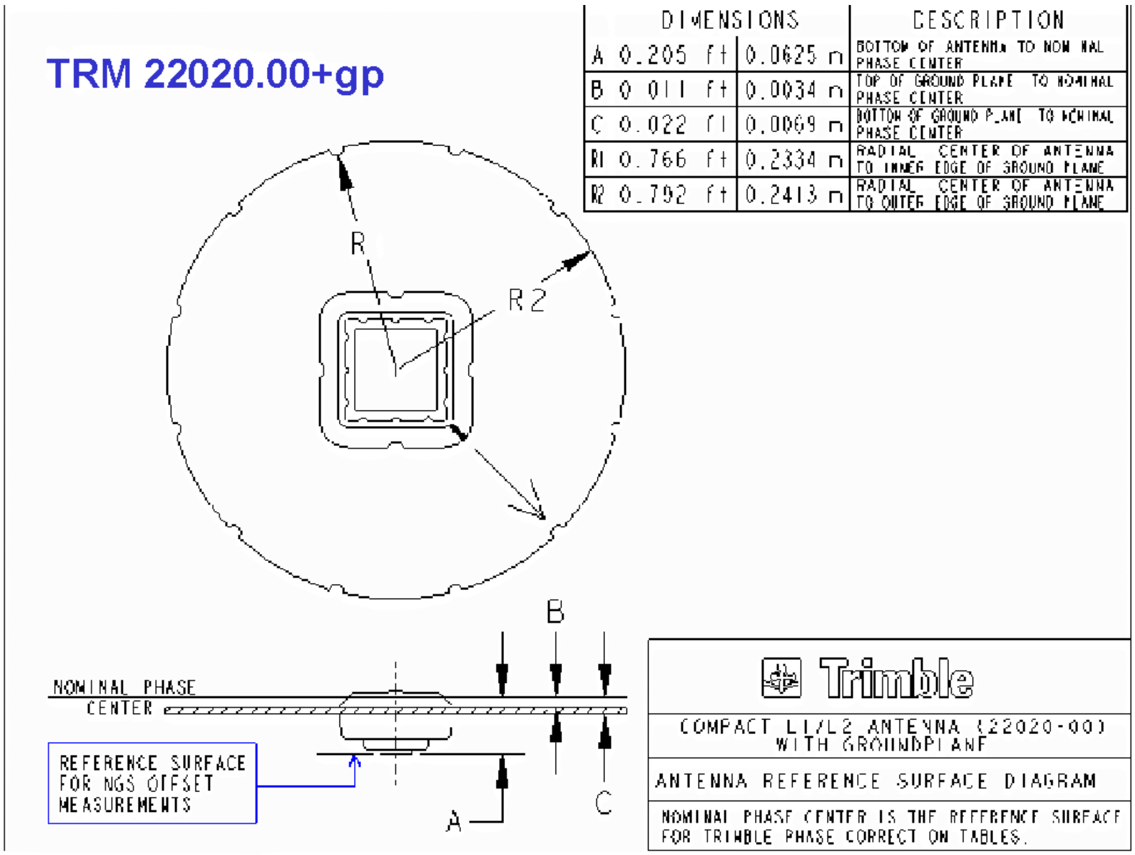


Figure 7-1. Typical antenna reference and offset diagram

n. Processing requirements. Operational procedures required before, during, and after an observation session are manufacturer dependent and should be thoughtfully considered (and tested) before purchase of a receiver. Often, a receiver may be easy to operate in the field, requiring very little user interface, but a tremendous amount of time and effort may be required after the survey to download the data from the receiver and process it (i.e. post-processing software may be complicated, crude, or underdeveloped). Also, whether a post-processed or real-time solution is desired represents a variable that is critical in determining the type of receiver to use.

o. Cost. Cost is a major factor in determining the type of receiver the user can purchase. Receiver hardware and software costs are a function of development costs, competition among manufacturers, and product demand. Historically, costs for the acquisition of GPS equipment have steadily fallen to the current range of prices seen today. Cost estimates must include full GPS systems along with auxiliary equipment, software, training, etc. A sample schedule for many of these cost items is shown at the end of this chapter.

p. Data exchange formats. In order to transfer data, a common exchange format is required. GPS vendors usually have their own proprietary data formats. However, most GPS receiver data can be put into a common text format, such as the Receiver Independent Exchange (RINEX) format, which is used for post-processed data. RINEX is more fully described in a later section. Real-time data exchange, such as that used on RTK surveys, is typically handled using the RTCM SC-104 format standard. Vendors often allow for optional outputs, such as ASCII, DXF, ArcInfo, DGN, NMEA 0183, etc.

7-4. Military Grade GPS Receivers

Military Grade GPS receiver systems provide high accuracy positioning for real-time and post-processed military survey applications. These applications include precise positioning and orientation of artillery, ground-based surveys, and surface navigation. Military receivers use the Precise Positioning Service (PPS) providing advanced P(Y) Code positioning technologies accurate to approximately 4 –16 meters (SEP). Using the secure (Y-code) differential GPS (SDGPS) can increase the accuracies to the sub-meter level. PPS receivers require a crypto key to decode the encrypted P-Code and typically have to be re-keyed each year.

a. PLGR. The Precise Lightweight GPS Receiver (PLGR), manufactured by Rockwell Collins, is a hand-held receiver designed to operate as a stand-alone unit, providing position, navigation information, velocity and time. Figure 7-2 depicts the PLGR+96 on the left and PLGR II on the right.

Figure 7-2. PLGR+96 (left) and PLGR II (right)

b. MSGR. Trimble Navigation offers the 4000 Military Survey GPS Receiver (MSGR) that is a dual-frequency geodetic-quality PPS receiver, providing all the capabilities of high-quality C/A-Code receivers, including the ability to perform RTK and differential (DGPS) surveys.

Figure 7-3. Trimble Navigation 4000 MSGR

7-5. GPS Receiver Manufacturers

Up-to-date listings of manufacturers are contained in various surveying trade publications and are listed on the ERDC/TEC web site. Contact should be made directly with representatives of each vendor to obtain current specifications, price, availability, material, or other related data on their products. Prior to purchase, it is recommended that receivers be tested to ensure they meet performance requirements and will efficiently transfer positional and feature data to post-processing devices and/or CADD/GIS platforms. Most GPS equipment required for USACE applications is listed on the GSA Supply Schedule and can be obtained directly off that schedule without competition--see FAR 8.4, Section 8.404.

7-6. Other Auxiliary Equipment

A significant amount of auxiliary equipment may need to be acquired when making a GPS receiver selection. Some of this equipment is discussed below.

Figure 7-4. Miscellaneous auxiliary equipment needed for a GPS survey

a. Data link equipment for real-time positioning. The type of data link needed for real-time positioning (i.e. code or carrier RTK) should be capable of transmitting digital data. The specific type of data link will depend on the user's work area and environment. Most manufacturers of GPS equipment can supply or suggest a data link that can be used for real-time positioning. Depending on the type and wattage of the data link, a frequency authorization may be needed in order to transmit digital data over radio frequencies (RF). Frequency authorization requires coordination with the frequency coordinator in the District and HQUSACE, and is a difficult and involved process. Some radio and GPS manufacturers produce low-wattage spread spectrum transmitters that do not require frequency authorization. These low-wattage broadcasts are normally only useful for topographic RTK surveys not exceeding 1 km from the reference station. The data link may be built into the receiver or in an external unit. Some Corps districts have obtained approval to broadcast RTK correctors on approved frequencies in the VHF range--162-174 MHz. Local VHF broadcasts have been used to transmit RTK corrections out to 10-15 miles offshore--for controlling hydrographic surveys on dredging projects. Use of wireless technology (e.g., local and satellite cell phones) may prove to be more effective and efficient data links than VHF links, especially if frequency authorizations cannot be obtained. Many commercial vendors are now using wireless satellite links to transmit DGPS correctors to users.

Figure 7-5. Common data links for code and RTK GPS receivers

b. USCG radiobeacon receivers. The USCG provides a real-time pseudorange corrections broadcast over medium frequency (270-320 kHz marine band) from a radiobeacon transmitter tower. These towers exist in most coastal areas, the Mississippi River Basin, and the Great Lakes regions. The range from each tower is approximately 120 to 300 km. These corrections can be received by using a radiobeacon receiver and antenna tuned to the nearest tower site. USCG beacon receivers are usually contained in one unit that contains the antennas and GPS processing/display features--see Figure 7-5. Similar configurations are made for wide area, commercial-provider, differential GPS services.

c. Computer equipment. Most manufacturers of GPS receivers include computer specifications needed to run their downloading and post-processing software. Most high-end desktop and notebook/laptop computers are capable of processing GPS data. Portable laptop computers are essential for performing near real-time data post-processing--especially in remote locations. An internal CD-RW drive is also recommended for archiving the large amounts of data that will be collected.

d. Antenna types. There are three basic types of GPS antennas. These are (1) ground plane antennas, (2) no ground plane, and (3) choke ring antennas. Both the ground plane and the choke rings are designed to reduce the effect of multipath on the antenna.

e. Associa ted survey equipment. There are several accessories needed to support the GPS receiver and antenna. These include backpacks, tripods, tribrachs, and tribrach adapters, to name a few. Calibrated fixed height (usually 2 meter) range poles can be used to eliminate the need to measure antenna heights. Most of the other equipment needed is similar to what is used on a conventional survey.

7-7. Resource Grade GIS Mapping Receivers

Dozens of hand-held resource grade GPS receivers are produced that can display and log geospatial positional data in real-time. USACE applications for these inexpensive receivers are varied. They will provide sufficient accuracy for vessel, vehicle, and personal real-time navigation. They may also be used for building GIS databases where 10-30 meter horizontal accuracy is adequate for a feature, e.g., land use, point features, flood inundation limits, emergency operations, dredge disposal monitoring, etc. The following descriptions for some representative receivers were obtained from a 2000 US Forest Service report entitled *Performance Testing of the Garmin eTrex, Garmin GPSIII Plus, Magellan GPS 2000XL, and Magellan Blazer Recreation Type Global Positioning System Receivers*, and from other similar USFS test reports. In these reports, testing indicated that all the receivers were capable of meeting USGS quadrangle map accuracy standards (14.8 meters at 95%) in open areas. The following list is not representative of all the resource grade receivers on the market, nor does it include other models by the same vendor--those listed are only representative of the receivers tested by the USFS. For updated information on testing of resource grade receivers, consult the USFS GPS web site by linking through the ERDC/TEC web site.

- **Garmin eTrex**: This is a very small, lightweight, field-ruggedized with some armoring, and waterproof unit that stores 500 waypoints. Battery life is about 22 hours for 2 AA batteries. This receiver has PC communications with an optional data cable allowing uploading of waypoints. Weight is 6 ounces. Display is 64 x 128 characters. The cost of this unit is approximately $120.

- **Garmin GPS III Plus** : This is a small, lightweight, and waterproof unit that stores 500 waypoints. It has a 4-color grayscale background map display and can store up to 1.44 mg of Garmin format map data. No other map formats are supported. These maps are on an optional CD at 100,000 scale, the cost is an additional $120. A data upload cable is supplied for uploading maps and waypoints. Display is 100 x 160 characters. Weight is 9 ounces. The cost of this unit is approximately $380.

- **Magellan GPS 2000XL**: This is a slightly larger unit which is waterproof, field ruggedized with wraparound rubber armoring, and scratch-proof display. The GPS 2000 XL receiver stores 200 waypoints. This unit offers NMEA data output for PC communication. The battery life is about 24 hours for 4 AA batteries. Weight is 10 ounces. Cost is approximately $150.

- **Magellan Blazer 12**: This is a small, lightweight, and waterproof unit that stores 100 waypoints. Battery life on this receiver is about 20 hours for 2 AA batteries. No NMEA data output. The Blazer 12 shares the same receiver and quadrifilar antenna with the other Magellan 300 series receivers; however the user interface menus, number of waypoints, the availability of NMEA ports, and many other features, vary. The accuracy of other 300 series receivers should be similar to the Blazer. Weight is 6.8 ounces. The cost of the Blazer12 is approximately $110.

- **Trimble GeoExplorer**: Trimble Navigation GeoExplorer 3c is a 12-channel Global Positioning System (GPS) receiver. The manufacturer's list price for the GeoExplorer 3c (without map background) is $3,780; the GSA price is $3,495. The manufacturer's list price for the GeoExplorer 3 (with map background) is $4,495; the GSA price is $4,090. The external antenna is an optional item for the GeoExplorer 3c. The manufacturer's list price for the antenna is an additional $195 and the GSA price is currently $177.

- **Trimble Pathfinder Pro XR.** The Trimble Navigation Pathfinder Pro XR is a 12-channel Global Positioning System (GPS) receiver. The Pathfinder Pro XR version 3.24 has an integrated GPS and DGPS radio beacon antenna. The TSC1 data collector can be used with the Asset Surveyor version 4.3 Software. The manufacturer's list price is $10,995; the GSA price for the Pathfinder Pro XR is $10,005.

7-8. Common Data Exchange Formats

a. RINEX. The Receiver INdependent EXchange (RINEX) format is an ASCII type format that allows a user to combine data from different manufacturer's GPS receivers. Most GPS receiver manufactures supply programs to convert raw GPS data into a RINEX format. However, one must be careful since there are different types of RINEX conversions. Currently, the NGS distributes software that converts several receiver's raw GPS data to RINEX. NGS will distribute this software free of charge to any government agency. Portions of typical RINEX data files are shown below. For each satellite tracked, the code distance and L1/L2 phases and Doppler count values are listed.

SAMPLE RINEX DATA FILE (San Juan, PR Jacksonville District, Ashtech Z-12 Receiver)

```
2IU             OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
ASHTORIN                                28 - JUN - 02 10:04 PGM / RUN BY / DATE
                                                            COMMENT
0003                                                        MARKER NAME
                                                            MARKER NUMBER
                                                            OBSERVER / AGENCY
                    ASHTECH Z-XII P3    5J00      1C63      REC # / TYPE / VERS
                                                            ANT # / TYPE
  2453884.6500 -5532961.0300  2004535.4500                  APPROX POSITION XYZ
       2.03800        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     7    L1    L2    C1    P1    P2    D1    D2            # / TYPES OF OBSERV
   15.0000                                                  INTERVAL
                                                            LEAP SECONDS
  2002     6    25    14    53   30.000000      GPS         TIME OF FIRST OBS
  2002     6    25    16    24   30.000000      GPS         TIME OF LAST OBS
                                                            END OF HEADER
 02  6 25 14 53 30.0000000  0  9G30G29G26G04G05G24G23G07G10          0.000824454
   -53922.08817     -40565.76855  24455490.816  24455491.4555   24455501.0845   244.850   190.792
  -661208.301 9    -483872.18747  22216675.275  22216675.4604   22216683.1604  3159.150  2461.675
  -820204.442 9    -618074.31947  22985123.892  22985124.3594   22985133.6494  3935.982  3066.999
   128043.142 9      93257.10846  23165282.101  23165282.0234   23165290.6074  -623.838  -486.108
   153403.432 9     116423.82546  23937298.328  23937298.3884   23937308.7384  -768.304  -598.678
  -166500.297 9    -125905.16547  22117555.722  22117555.8774   22117562.4454   793.354   618.198
  -264887.037 9    -197951.30346  22994119.533  22994119.7104   22994129.0024  1453.557  1132.642
   631877.719 9     456127.79446  23737042.567  23737042.5564   23737055.5554 -3149.638 -2454.263
    60447.345 9      43299.05948  21136470.357  21136469.9054   21136476.3494  -330.782  -257.752

02  6 25 16 24 15.0000000  0  8G29G26G04G24G23G08G10G06             0.000647879
 -9746894.726 9  -7563623.36248  20487724.730  20487724.5844   20487730.9614    53.897    41.998
-15098913.388 9 -11744332.87548  20267971.265  20267971.3024   20267977.8754   975.770   760.340
  7481368.270 9    5823092.22845  24564595.467  24564595.5644   24564609.5154 -2091.033 -1629.376
 -1518814.840 9  -1179665.38447  21860226.133  21860225.8804   21860234.9044  -476.719  -371.469
 -2944679.055 9  -2286098.15047  22484172.149  22484171.6184   22484179.9644   -68.190   -53.135
 -4418906.717 7  -3437358.05045  24462270.403  24462269.6634   24462286.6644  -294.665  -229.609
  5736700.177 9    4466347.01547  22216631.531  22216630.7024   22216638.0044 -1310.212 -1020.944
-10589645.118 9  -8230960.83247  22710603.800  22710603.6414   22710611.8954  1959.993  1527.267
```

SAMPLE RINEX DATA FILE (New Orleans District, Trimble 4000SSE receiver)

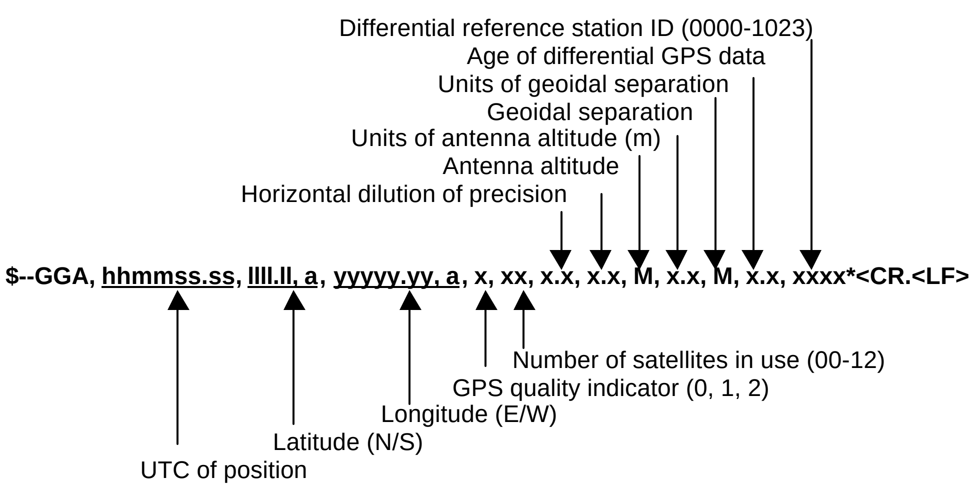
```
     2.10           OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
DAT2RINW 3.10 001   Huber               25MAR02  6:52:52    PGM / RUN BY / DATE
Huber               USACE                                   OBSERVER / AGENCY
4936                TRIMBLE 4000SSE     Nav 7.29 Sig 3.07   REC # / TYPE / VERS
00000000            TR GEOD L1/L2 GP                        ANT # / TYPE
----------------------------------------------------------- COMMENT
Offset from BOTTOM OF ANTENNA to PHASE CENTER is  62.5 mm   COMMENT
----------------------------------------------------------- COMMENT
4936                                                        MARKER NAME
4936                                                        MARKER NUMBER
  -13020.5085 -5531624.9704  3164468.2517                   APPROX POSITION XYZ
       1.5468        0.0000        0.0000                   ANTENNA: DELTA H/E/N
*** Above antenna height is from mark to BOTTOM OF ANTENNA. COMMENT
----------------------------------------------------------- COMMENT
Note: The above offsets are CORRECTED.                      COMMENT
Raw Offsets: H=       1.6093 E=       0.0000 N=       0.0000 COMMENT
----------------------------------------------------------- COMMENT
     1     1     0                                          WAVELENGTH FACT L1/2
     4    L1    C1    L2    P2                              # / TYPES OF OBSERV
     1.000                                                  INTERVAL
  2002     3    21    14    27    2.0000000                 TIME OF FIRST OBS
  2002     3    21    16    31   49.0000000                 TIME OF LAST OBS
     0                                                      RCV CLOCK OFFS APPL
     5                                                      # OF SATELLITES
     4  4578  4579  4521  4521                              PRN / # OF OBS
     7  7488  7488  7488  7488                              PRN / # OF OBS
     8  7488  7488  7488  7488                              PRN / # OF OBS
    11  7248  7248  7185  7185                              PRN / # OF OBS
    27  5719  5719  5719  5719                              PRN / # OF OBS
                                                            END OF HEADER
 02  3 21 14 27  2.0000000  0  4   7  8 11 27
   -116189.39216  22284950.00806    -87567.87956  22284956.61746
    -24189.13717  20059524.33607     -6825.36657  20059529.75047
       388.50517  21728548.97707       302.52057  21728554.56647
     96650.22817  20791241.16407     72757.93557  20791247.08247
 02  3 21 14 27  3.0000000  0  4   7  8 11 27
```

b. Real-time data transmission formats. There are two common types of data formats used most often during real-time surveying. They are (1) RTCM SC-104 and (2) NMEA.

(1) Transmission of data between GPS receivers. The Radio Technical Commission for Maritime Services (RTCM) is the governing body for transmissions used for maritime services. The RTCM Special Committee 104 (SC-104) has defined the format for transmission of GPS corrections. The RTCM SC-104 standard was specifically developed to address meter-level positioning requirements. The current transmission standard for meter-level DGPS is the RTCM SC-104. This standard enables communications between equipment from various manufacturers. It should be noted that not all manufacturers fully support the RTCM SC-104 format and careful consideration should be made to choose one that does. RTCM SC-104 can also be used as the transfer format for centimeter-level DGPS, and will support transmission of raw carrier phase data, raw pseudorange data, and corrections for both. Some GPS receiver manufacturers also have their own proprietary transfer formats--e.g., Trimble's Compact Measurement Record (CMR).

(2) Transmission of data between a GPS receiver and a device. The National Maritime Electronics Association (NMEA) *Standard for Interfacing Marine Electronic Devices* covers the format for GPS output records. The standard for corrected GPS output records at the remote receiver is found under NMEA 0183, Version 2.xx. NMEA 0183 output records can be used as input to whatever system the GPS remote receiver is interfaced. For example, GPS receivers with an NMEA 0183 output can be used to provide the positional input for a hydrographic survey system or an Electronic Chart Display and Information System (ECDIS). These are evolving standards and newer versions are being developed for different data types. The NMEA 0183 Version 2.00 (1992) "GGA" standard for GPS "fix data" is outlined below. This version has been subsequently updated--users need to ensure NEMA version compatibility between devices. Other NEMA 0183 standards include: GST (Position error statistics), GSV (Number of satellites in view, PRN, etc.), PTNL (Local coordinate position output), and ZDA (UTC day-month-year).

GGA--Global Positioning System Fix Data (Time, Position, and Fix Related Data for a GPS Receiver) [Version 2.00]



7-9. GPS Training and Operation Manuals

Training should be included in the purchase of any GPS receiver system, especially if the equipment is new to a District. In addition to receiver operation, training should include baseline reduction, and network adjustment. The Corps PROSPECT program provides a one-week training course on code and carrier GPS surveying. This course covers all chapters contained in this engineer manual. Major GPS vendors offer training in all facets of GPS surveying unique to their equipment or software. In addition, continued technical support should be included to cover all software and firmware upgrades.

7-10. Guide Specifications for Procuring Geodetic Quality GPS Receivers

The following guide specification is intended for procuring geodetic-quality GPS receivers and auxiliary equipment. These specifications would have application where "commercial-off-the-shelf" receivers available on GSA Schedules would not meet a particular application, and detailed specifications are needed. These specifications are intended to include GPS receivers, supplemental GPS equipment (antennas, tripods, power, etc.), baseline reduction software, adjustment software, real-time data links, and personnel training. These specifications may be modified for meter-level code phase receivers if required; however, code only receivers rarely require such detailed specifications. These guide specifications were originally developed in the late 1980s. They were first published as a USACE Guide Specification in 1991 and later incorporated into the 1996 edition of this manual. They have been modified to reflect 2002 technology. Guidance comments are shown in blue text and outlined by asterisks. Optional and/or selectable specifications are noted by asterisks and brackets.

****
NOTE: The sample below represents a typical schedule for procurement of GPS instrumentation and related equipment. This schedule must be tailored based on the specific technical requirements outlined in Section C of the contract.
****

Supplies/Services and Prices

Item No.	Description	Quantity	U/M	U/P	Amt
0001	Geodetic quality GPS survey receiver system, related equipment, software, data link, and other components, in accordance with the technical specifications found in Section C.	*[___]	EA	___	___
0002	* [GPS baseline reduction software]	___	___	___	___
0003	* [Network adjustment software]	___	___	___	___
0004	* [Data link for real-time applications]	___	___	___	___
0005	* [GPS receiver system, data reduction, processing and adjustment software training]	___	___	___	___
0006	* [other items]				

****
NOTE: Add other items to the schedule as necessary. These may include tripods, range poles, tribrachs, spare batteries, data storage devices, laptop computers, communication/modem devices, software/hardware for navigation (e.g., survey vessel positioning and guidance control). Hardware/software interface requirements to existing survey systems (e.g., hydrographic systems) may also be separately scheduled.
****

Section C

Description / Specifications

C.1. General DGPS Description.

The geodetic-quality differential Global Positioning System (DGPS) to be procured under this solicitation is intended for use in *[static and/or kinematic] positioning applications using the GPS carrier phase as the principle observable. The system will yield 3-dimensional vectors between a reference and "rover" station to an accuracy of *[10 mm + 2 ppm or better on baselines of 1 to 100 km when operating in a static mode] [and] *[3 cm or better on baselines up to 25 km when operating in a kinematic mode]. *[The system is intended to operate in real time with the incorporation of a communications link, as specified further in Section C of this solicitation.] *[The system will have the capability to resolve the initial integer cycle ambiguity in a robust manner, automatically, while the rover is constantly in motion, known as on-the-fly (OTF), with no more than 60 sec of data, on baselines up to 25 km in length.] *[The OTF ambiguity resolution software will operate in *[real time] *[and/or] *[post-processing applications].

C.2. Receiver Requirements.

Unless otherwise specified, the performance requirements given below shall be met by the GPS receivers in conjunction with the antenna assembly and antenna cable.

C.2.1. GPS Signal Levels. GPS receivers delivered shall acquire and track GPS signals and otherwise perform as specified herein.

C.2.2. Cryptographic Keys. *[Unless otherwise specified,] GPS receivers shall perform as specified herein without requiring cryptographic keys, whether or not GPS selective availability (S/A) and/or anti-spoofing (A/S) are activated.

****
NOTE: Two versions of C.2.3. are given. L1 only receivers are adequate for static geodetic survey operations. Robust kinematic operations and OTF ambiguity resolution requires more capable hardware observing the full wavelength L1 and full wavelength L2 carrier phase. Choose one of the two clauses.
****

*[C.2.3. GPS Observables. The GPS receivers delivered shall provide, at a minimum, the following time-tagged observables: full L1 C/A-code, L1 P-code, continuous full wavelength L1 carrier phase, L2 P-code, and continuous full wavelength L2 carrier phase.]

*[C.2.3. GPS Observables. The GPS receivers delivered shall provide, at a minimum, the following time-tagged observables: full L1 C/A-code and continuous full wavelength L1 carrier phase.]

(1) Measurement Time Tags. Signal measurements (observables) shall be time tagged with the time of receipt of the signal referenced to the receiver clock. Time tags shall have a resolution of 1 microsec or better. Time tags shall be within 1 microsec with respect to GPS time.

(2) Carrier Phase Accuracy. The receiver shall have L1 *{the following is required for OTF operatio*n}*[and L2 full wavelength] carrier-phase measurement accuracies of 0.75 cm (RMS) or better, exclusive of the receiver clock offset.

****
NOTE: The following C.2.3. (3) is for RTK/OTF operation only.
****

*[(3) Code Accuracy. The receiver shall have an L1 C/A-code phase measurement accuracy of 30 cm (RMS) or better, exclusive of receiver clock time and frequency offsets.]

C.2.4. Receiver Output. The GPS receiver shall be able to output the GPS observables as described in C.2.3. with a latency of less than 1 sec *[and, simultaneously, a differential code position and the timing information stated in 2.6]. The GPS receiver shall be able to output the information from the full GPS navigation message. This shall include ephemeris data, almanac data, ionospheric parameters, and coordinated universal time (UTC) parameters. The UTC and ephemeris data shall be available by request or if a change has occurred in those parameters.

C.2.5. Receiver Data Rate. The GPS observable data described above shall be available at a minimum of a 1 Hz rate.

C.2.6. 1 Pulse Per Second (PPS) Output. GPS receivers delivered shall have a 1 PPS time strobe and its associated time tag. The 1 PPS pulse and time tag shall be accessible through a port (or ports) on the GPS receiver so that external system components can be time synchronized to UTC time.

C.2.7. Internal Receiver Testing. The receiver shall perform a self-test and checks to detect electronic malfunctions and/or faulty data collection, including cycle slips. The receiver shall provide immediate *[audio]*[visual] notification of failures. The receiver shall perform any needed calibrations automatically.

C.2.8. Reinitialization. The receiver shall be capable of reinitializing itself and resume normal operation after a power interruption without operator assistance. The data collected by the GPS receiver shall not be lost due to power interruption but stored in the receiver or other archiving media.

C.2.9. Multiple Satellite Tracking. The receiver must be capable of tracking and observing all signals previously stated on a minimum of *[______] [all satellites in view] satellites simultaneously, each on an independent channel.

C.2.10. Operating Conditions. The GPS receivers delivered shall meet the following criteria:

(1) Successfully acquire and track unobstructed GPS satellites, visible 5 deg and higher above the horizon, in all weather conditions.
(2) Operate at humidity ranges of 0 to 100 percent.
(3) Operate within the temperature range of -20 o C to +50 o C.
*[(4) Be waterproof and able to operate in an ocean environment aboard open survey launches.]
*[(5) Operate in heavy rain, 50.8 mm/day (2 in./day).]
*[(6) Operate in fog.]
*[(7) Operate in and resist corrosion in salty air conditions.]

C.2.11. Receiver Power Requirements. The GPS receivers delivered shall meet the following criteria:

(1) Be self-protecting from power surges, spikes, and reverse polarity.
(2) Allow the operator to switch power sources (AC, DC, or battery) while maintaining receiver operation and without loss of stored data.
(3) Provide a *[visual] *[audible] warning for low power.
(4) Be capable of operating using *[a battery pack] *[and] *[or] *[AC power] *[and] *[or] *[12-VDC] *[24-VDC] *[external DC power].
*[(5) The battery pack shall meet the following criteria:]
*[(a) Contain rechargeable battery/batteries that can operate the receiver for at least *[____] hr on a single (re)charge.]
*[(b) Be *[either] *[internal] *[or] *[external] to the receiver.]
*[(c) Include all cables, hardware, etc. necessary to connect/install the battery pack. The batteries shall be water and dust tight and be protected from damage and inadvertent shorting of the terminals.]
*[(6) For operation using *[AC] *[and] *[external DC] *[power.]
*[(a) When operating under *[AC] *[or] *[DC] power, the unit shall be capable of simultaneously charging the battery pack. The battery pack shall power the receiver if the normal power supply is interrupted.]
*[(b) The AC power supply *[shall be internal] *[may be internal or external] to the receiver.]
*[(c) The power supply/battery charger shall provide all voltages necessary to operate the receiver and (re)charge the battery pack.]
*[(d) The power supply/battery charger shall be designed to automatically protect the battery pack from overcharging.]
*[(e) All cables and connectors needed to connect the power supply/battery charger to the power line *[and receiver] shall be included.]
*[(f) The AC power supply/battery charger shall operate from *[115-V] *[and 230-V] AC (10 percent) *[50/] 60 Hz, single phase power.]
*[(g) The unit shall operate from external *[12-VDC] *[24-VDC] *[9 to 32-VDC] power.]

****

NOTE: Not all manufacturers provide a battery that is internal to the receiver. Moving the battery pack external to the receiver does not affect the functioning; it is a matter of design. For example, doing this could substantially decrease the size of the unit. Different manufacturers have different setups for the batteries. The District is encouraged to know what will work best for them based upon District requirements and determine the necessary battery life. Note also if redundant battery packs should be procured.

****

C.2.12. Manuals. At least *[one set] [two sets] of complete operation and maintenance manuals shall be included with each receiver and shall cover all auxiliary components furnished with each receiver. *[Updates shall be furnished as they become available.]

*[C.2.13. Field Planning. The receiver shall have internal software that, as a minimum, is capable of computing the availability and positions of satellites for any given time and the current position of the GPS receiver *[and terrestrial position] using data gathered by the GPS receiver.]

*[C.2.14. Dimensions. The dimensions of the receiver shall not exceed *[___] length by *[___] width by *[___] height, all such that one person can easily transport the unit.]

*[C.2.15. Weight. The receiver shall be transportable by one person. [One complete field station consisting of receiver, battery pack, antenna, and antenna cable shall not exceed * [___] kg * (__) lbs.]

*[C.2.16. Data Collector. The *[receiver] [external survey data collector] shall be capable of recording and controlling data on an *[internal]*[external] storage device. This device shall be capable of storing a minimum of *[___] megabytes (mb) of data.]

*[C.2.17. Additional Options for Meter-level DGPS Operations.]

****

NOTE: The following section is optional. It is possible for "geodetic type" GPS receivers as described previously to perform differential code (meter-level) positioning using standard broadcast messages from systems such as the US Coast Guard radio beacon network, FAA WAAS networks, or commercial provider networks. If this type of positioning is required, then the following options should be included in the solicitation.

****

*[(1) Format. The reference station receiver shall output DGPS pseudorange correction data in the RTCM SC-104 format, Version x.x and US Coast Guard Broadcast Standard] *[FAA WAAS] [commercial provider network].
*[(2) Format. The remote station receiver shall accept and apply correction data in RTCM SC-104 format, version 2.1.]
*[(3) Accuracy. Real time positioning accuracy relative to the reference station shall be *[2] [__] m 95% within a range of at least 100 miles from the reference station.]
*[(4) Waypoints. The receivers shall have the ability to accept up to *[___] waypoints that can be selected by the helmsman.]
*[(5) Position Rate. The receiver shall be capable of providing output position fixes at rates within the range of [__] Hz to [__] Hz.]
*[(6) Velocity. The receiver shall be capable of determining *[velocity and] position while moving at speeds of up to [5.14] * [___] meters per sec (*[10] *[___] knots).]

*[C.2.18. Additional Options for Geodetic Grade Static Survey Operations.]

*[(1) Accuracy Specification. The GPS reference receiver shall be capable, when used in conjunction with a remote GPS receiver, of 10 mm + 2 ppm accuracy or better on baselines of 1 to 100 km in length when used in the static differential mode. The receivers shall have an accuracy of 5 mm or better on baselines less than 1 km.]

C.2.19. GPS Antenna Assembly.

(1) Antenna Mount. The GPS antenna shall be capable of being mounted on a standard surveyor's tripod *[and or range pole] with a 5/8-in. by 11-in. threaded stud *[or to a standard wild type tribrach].
(2) Antenna Phase Center. The center instability of the 3-dimensional phase center of the GPS antenna shall be no greater than 3 mm.
(3) Receiver/Antenna Separation. The system shall allow the antenna to be located at least *[30] *[___] m from the receiver so that it can be operated remotely from the receiver with no system degradation.
(4) Antenna Cables. *[One] *[___] antenna cable(s) shall be furnished with each receiver. *[[One] *[each] of these cables should be at least *[__] m,] * [and the other cable should be at least *[__] m.] All appropriate connectors should already be attached to the cable ends. *[These cables shall be capable of being cascaded for a total length of *[___] m of cable for setup flexibility.]
(5) GPS Survey Antenna. Survey antennas shall receive GPS signals at the L1 *[and L2] frequency *[frequencies] and provide these signals to the GPS receiver. The antenna shall have an omnidirectional horizontal pattern and shall incorporate *[choke ring] features that minimize multipath error.

*[(6) Antenna Assembly. The antenna assembly shall include the following items:
*[(a) A method to minimize ice and snow buildup.]
*[(b) A method to reduce bird nesting capability.]
*[(c) The ability to withstand strong winds up to * [___] meters per sec (*[___] knots).]
*[(d) A method to orient (to north) after mounting.]
*[(e) A mechanical mark for height measurement with known offset from phase center.]
*[(f) Operation within the temperature range of -40 o C to +65 o C.]
*[(g) Dimensions. The dimensions of the antenna shall not exceed *[45 cm] in length by *[45 cm] in width by *[15 cm] in height, all so that one person can easily transport the unit.]
*[(h) A method to reduce the effects of multipath.]
*[(i) A method to amplify the signal for cable lengths in excess of 15 m.]
*[(7) Each antenna shall be 100 percent sealed/watertight. *[One] *[___] GPS antenna shall be provided with each GPS receiver unit.]
*[(8) Antenna Pole. An antenna pole shall be provided for use during survey operations. It shall be *[a fixed height pole of 2 m] *[extendible from a length of 1 m (+/- 0.2 m) to 2 m (with a variance of 0.5 m)] and shall allow rapid attachment and detachment of the GPS survey antenna. The pole shall include a built-in leveling device and legs that are *[collapsible and attached] *[detachable].]
*[(9) Tribrach. A standard tribrach (with adapters) shall be provided with each antenna. The tribrach shall allow the antenna to be mounted atop the tripod. The tribrach shall be able to be mounted on top of a standard surveyor's tripod with a 5/8-in. threaded stud and shall include adapters to allow mounting of standard target sets.]
*[(10) Vehicular Antenna Mount. A survey antenna mount shall be provided that can easily be attached or detached from the vehicle. This mount shall be designed so that it remains firmly in place at speeds of up to 88.5 km/h (55 mph) on a level roadway. The mount shall be designed so that its use does not require vehicle modification.]

C.2.20. Input and Output (I/O) Ports.

(1) Standards. All I/O ports will be compatible with the RS-232 standard.
(2) I/O Ports. *[I/O ports shall be compatible with any processor, data terminal, or storage devices used in the positioning system.] *[The vendor shall provide complete documentation of the I/O ports including connector, signal descriptors, connector pin outs, communications protocols, command and message descriptions, need to set up the receiver and extract and decode the observed data.]

****
NOTE: The following options [C.2.20(3) and C.2.20(4)] are not required for the OTF system operation. They would be used for differential code position interface to marine systems such as electronic charts or hydrographic survey systems.
****

*[(3) Real time positional data out of the remote receiver will adhere to the NMEA 0183 data sentences format and will be output over an RS-232 compatible port.]
*[(4) The receiver shall have the capability to output the data, position fixes, and calibration data through a RS-232 compatible serial port.]

[C.3. Not Used]

C.4. GPS Baseline Processing and Reduction Software.

C.4.1. General. The GPS baseline processing software must be fully compatible with the receivers listed in Paragraph C.2.

****
NOTE: If the computer processing system is NOT included as part of this solicitation, then the type of processor must be given to verify software compatibility.
****

C.4.2. Data Computations. The baseline reduction software shall compute, at a minimum, *[the carrier-phase integer cycle ambiguity using static and kinematic techniques, including those commonly known as "known baseline," "rapid static," "antenna swap," "stop-and-go," and "OTF"] *[and subsequently] the 3-dimensional differential baseline components between observation stations, within the accuracy specifications given in Paragraph C.1.

C.4.3. Ephemerides. The baseline computations must include options for using both the broadcast and precise ephemerides.

C.4.4. Output Data. The results of the baseline processing shall be in any user-selected form, such as *[geocentric coordinates,] *[state plane coordinates based on the North American Datum of ____,] *[state plane coordinates based on the North American Datum of 1983,] *[and] *[or] *[Universal Transverse Mercator projection coordinates].

C.4.5. Batch Processing. The software shall have the capability to post-mission process data sets unattended in a batch mode.

C.4.6. Multiple Copies. The Government shall be allowed to operate the software simultaneously on *[_____] computer platforms.

C.4.7. Absolute Point Positioning. The software shall be capable of processing pseudorange data to obtain single point positions of a single receiver.

*[C.4.8. Real-Time Capability. The software shall be capable of resolving carrier cycle integer ambiguities in real time when the observing stations are connected via a communications link *[as specified elsewhere in this solicitation] using the computational procedure given in Paragraph C.4.2., and subsequently compute 3-dimensional differential baseline components.]

*[C.4.9. Real-Time Output. The results of the real-time baseline processing shall be in any user-selected form, such as geocentric coordinates, state plane coordinates based on the North American Datum of 19XX, or Universal Transverse Mercator projection coordinates. The results will be time tagged with an accuracy of 50 msec, at the time of signal reception at the antenna. The results will be written to a memory device *[both]*[internal and] external to the device performing the computations and shall be sent to an external computer system, at the selection of the user.]

C.4.10. Updates. All baseline processing software updates shall be provided for a period of *[4] years from the date of delivery.

C.5. Network Adjustment Software.

C.5.1. The network adjustment software shall allow for the direct input of data from the post-mission processing software specified in Paragraph C.4. The adjustment software shall include routines to easily edit, correct, manipulate, and output results. The software shall have the capability of simultaneously adjusting a minimum of *[1,000] [____] observations.

C.5.2. The network adjustment software shall be based on the theory of least-squares. It shall be capable of performing both minimally and fully constrained adjustments. Output statistics shall include relative line (distance) accuracies between all points in the network and point confidence limits for each point in the network. Normalized residuals shall be displayed for all input vectors.

C.5.3. The network adjustment software shall transform geocentric coordinates and geographic coordinates to any user defined projection, such as the North American Datum of 1983 and 1927 state plane coordinate system.

C.5.4. Multiple Copies. The Government shall be allowed to operate the software simultaneously on *[_____] systems.

C.5.5. Updates. All baseline processing software updates shall be provided for a period of *[4] years from the date of delivery.

C.5.6. Geoid Modeling. The software shall include the *[Geoid xx] [most recent geoid] model available to the public from the National Geodetic Survey.

*[C.5.7. The network adjustment software shall accept and incorporate data from conventional survey methods such as angles, distance, and elevation differences.]

C.6. Data Link for Real-Time Applications.

C.6.1. The data link shall be completely functionally integrated with the receivers and processors procured under this solicitation. This includes the incorporation of modems for the complete interface of radio to processor/receiver.

C.6.2. The data link shall provide data from the reference station to the "roving" station to allow the system to compute positions of the roving station using a kinematic processing technique, as specified in Paragraph C.1. of this solicitation, at a rate of at least one position per second, with no more than one (1) percent loss of position data. The data link equipment shall be identical at both stations to allow transmission from the "roving" station to the reference station. The kinematic processing technique shall not be a function of the data link used. The data link shall transmit all receiver raw observables, as specified in Paragraph C.2. of this solicitation, to the other receiver used in the differential GPS system.

C.6.3. *[The data link system shall operate at the *[frequency of _____]*[frequencies of ___ ___ ___]]. *[The data link shall operate at a frequency that does not require license for use.] *[The data link shall utilize a commercially available carrier phase broadcast that follows the criteria found elsewhere in Section C of this specification. The proposal will include a fee schedule for prescription and monthly service.]

****
NOTE: The frequency used for a VHF broadcast must be coordinated with the FOA frequency manager. Modulation rates and/or channel bandwidth requirements also may have to be specified. The unlicensed frequency will also be low power, hence, very short range. Optional cellular phone or geostationary satellite data links may also be specified.
****

*[C.6.4. The data link shall have an omnidirectional broadcast range of *[8]*[16]*[24]*[32]*[40] km (*[5]*[10]*[15]*[20]*[25] miles) and maintain the positioning capability stated in Paragraph C.6.2.]

*[C.6.5. A mounting kit shall be included to mount the data link antenna to a mast or range pole.]

*[C.6.6. The data link antenna shall be *[suitable for installation on small hydrographic survey launches (less than 7 m)] *[and]*[have an antenna cable of at least *[____] m]].

*[C.6.7. Power Supply. The data link (including modem) shall operate on the same power source as the GPS receiver.]

C.7. Training.

C.7.1. Upon delivery, the vendor shall provide training of at least *[4] days at *[location] *[to *[4] persons] on the operation of all software and hardware delivered as part of this contract.

*[C.7.2. At a future date, determined by the contracting officer based on coordination with the vendor, and not exceeding 6 months after delivery, the vendor will give an additional *[2] days training at *[location].]

C.8. Miscellaneous Requirements.

C.8.1. All power cables, computer cables, and any other item not mentioned in these specifications needed to make this equipment fully operable shall be furnished as part of this contract.

*[C.8.2. Ruggedized shipping containers shall be furnished for all hardware delivered under this solicitation.]

*[C.8.3. Survey Planning. Survey planning software shall be provided that, as a minimum, includes the following items: tabular and graphic satellite rise/set times, elevations, and azimuths for user-specified geographic locations and times; sky plots of SV positions with provisions for plotting satellite obstructions on the screen; listing of GDOP, PDOP, HDOP, and VDOP; and the selection of specific SV constellations to support in-depth kinematic survey planning.

*[C.8.4. All *[hardware]*[and]*[software] updates will be provided to the Government for a period of * [___] years from the date of delivery, free of charge or delivery cost.]

*[C.8.5. The vendor shall provide repair and maintenance of all hardware delivered under this solicitation for a period of *[___ (--)] years, free of charge.]

****
NOTE: At this point, other unique items may be added to the requirements if called for and/or requiring specification in Section B. Any specific vessel installation requirements for receivers, data links or antenna should be added. As-built vessel drawings or installation sketches should be attached to the contract. If DGPS is to be integrated with an existing navigation and/or survey system, manuals, drawings, etc. associated with that system should be referenced and attached at the appropriate contract section. Both hardware and software connections and modifications to the existing system must be detailed if such effort is to be an item of work under this contract.
****

Section D
Packaging and Marking

D.1. Preparation for Delivery. The system shall be packaged for shipment in accordance with the supplier's standard commercial practice.

D.2. Packaging and Marking. Packaging shall be accomplished so that the materials will be protected from handling damage. Each package shall contain a properly numbered, dated, and signed transmittal letter or shipping form, in duplicate, listing the materials being transmitted. Shipping labels shall be marked as follows:

US Army Engineer District, _________________
ATTN: {include office symbol and name}
Contract No. _______________________________
[Street/PO Box] {complete local mailing address}

Section E
Inspection and Acceptance

*E.1. Acceptance Test. All equipment and related components obtained under these specifications shall be fully certified prior to contract award as meeting the performance and accuracy in Section C. *[Any test previously performed for the Federal Geodetic Control Subcommittee (FGCS) will be acceptable for such certification by the vendor; otherwise the vendor shall be required to demonstrate, at the vendor's expense, the acceptability of the system in the manner prescribed in Paragraph E.2. If the FGCS test is to be used in lieu of a demonstration acceptance test, all results from the FGCS test shall be supplied to the contracting officer for evaluation by technical personnel.]

*E.2. Final Acceptance Test. At the option of the Government, a final acceptance test will be performed to demonstrate total system conformance with the technical specifications and requirements in Section C.

E.2.1. The acceptance test will be conducted with the system operating in the modes stated in Paragraph C.1. of this solicitation.

E.2.2. The DGPS positional accuracy will be tested against the accuracy and ranges specified in Paragraph C.1. of this solicitation. The resultant DGPS accuracy will be evaluated with the 95% error statistic. Inaccuracies in the comparative testing network / system will be properly allowed for in assessing the test results.

E.2.3. Final acceptance testing will be performed at *[the point of delivery indicated in Section D] *[________________], and will be performed within *[____] days after delivery. The supplier will be notified of the results within *[____] days after delivery. If the equipment fails to meet the acceptance test(s), the supplier will be given *[____] days after notification thereof to make any modification(s) necessary to enable retesting. The supplier will be notified of the place, date, and time of testing and, at his option, may send a representative to attend such tests.

E.2.4. If after a second test, the system fails to perform in accordance with the technical specifications, the Government will *[______________].

E.3. Warranty Provisions. For *[1] year after delivery by the vendor, all equipment failures, other than those due to abuse, shall be corrected free of charge. Equipment shall be repaired within 5 working days of receipt at the repair facility, or loaner equipment will be provided at no expense to the Government until repairs are completed and the equipment has been returned to the district. The cost of shipping equipment to the vendor for repair shall be paid by the Government while the vendor will pay for returning the equipment to the District.

Section F
Deliveries or Performance

F.1. Delivery and final acceptance of all equipment shall be made within *[___] days after contract award. Delivery shall be made at the USACE facilities at the address identified in Paragraph D.2. of this solicitation. Final acceptance will depend upon all equipment meeting all requirements specified in this contract.

F.2. The contractor shall deliver all material and articles for shipment in a manner that will ensure arrival at the specified delivery point in satisfactory condition and that will be acceptable to carriers at the lowest rates. The contractor shall be responsible for any and all damage until the equipment is delivered to the Government.

****

NOTE: The following is a list of hardware and software items/options that should be provided by bidders to determine their capability of providing an adequate DGPS-based positioning system. These items should be tailored to specific system requirements as developed in Section C of this solicitation, and would be used only when technical proposals are being evaluated.

****

GPS Receivers.
Signal levels .
Operation without cryptographic keys.
Observables.
Measurement time tags.
Carrier phase signals and accuracy.
Code phase signals and accuracy.
Receiver output.
Receiver data rate.
PPS output.
Internal receiver testing.
Reinitialization.
Multiple satellite tracking.
Operating conditions.
5 deg SV acquisition.
Humidity range.
Temperature range.
Waterproof.
Corrosion resistance.
Power requirements.
Surge protection.
Power transfer from AC to DC and reverse.
Low power warning.
External power source.
Battery pack.
Charge/recharge capacity.
Battery connections/cables.
Manuals.
Field planning software.
Dimensions.
Weight.
Data logging device.
RTCM output.
RTCM input.
Waypoints.
Position update rate.
Velocity output.
Antenna.
5/8-in. by 11-in. mounting.
Phase center stability.
Cable length and quantity.
Frequency reception.
Environmental considerations.
Waterproof.
Antenna pole.
Tribrach.
Vehicle mount.
Input/Output ports.
RS-232 standard.
Compatibility with other components.
NMEA position string.
Serial port.

Computer Processing Systems.
Software/hardware compatibility.
Operating system.
Processor chip.
Clock speed.
Hard drive capacity and access speed.
Random access memory.
CD-RW drive.
VGA graphics adapter.
Power source.
Four extra serial ports (in addition to a mouse port).

Baseline Processing Software.
Compatibility with receivers and computers.
Data computations.
Ephemerides.
Output data.
Batch processing.
Multiple copies.
Absolute point positioning.
Real-time output.
Updates.

Network Adjustment Software.
Compatibility with other software supplied.
100 station minimum.
Theory of Least-Squares.
Transformation capability.
Multiple copies.
Updates.
Conventional survey data input.

Data Link for Real-Time Application.
Compatibility with receivers and computers.
1-sec update rate.
Transmission of raw observables.
Frequency.
Broadcast range.
Data loss (less than 1 percent).
Mounting kit.
Power supply.

Training and Technical Support.
At delivery.
At future date.
Software upgrades.

Miscellaneous Requirements.
Cables, etc.
Shipping containers.
Survey planning software.
Hardware and software updates.
Maintenance and repair.