TECHNICAL MEMORANDUM H-4

SPECIFICATION OF A NAVSTAR GLOBAL POSITIONING SYSTEM (GPS) RECEIVER FOR A DIFFERENTIAL GPS GROUND SYSTEM

The paper lists the minimum requirements of a NAVSTAR Global Positioning System (GPS) receiver to be implemented into a differential GPS ground system.

by

Daryl L. McCall
Richard N. Turner

Avionics Engineering Center
Department of Electrical and Computer Engineering
Ohio University
Athens, Ohio 45701

Revised October 1984

Prepared for

NASA Ames Research Center
University Affairs Office
Mail Stop 241-25
Moffett Field, California 94034

Contract: NAG2-231

SPECIFICATION OF A NAVSTAR GLOBAL POSITIONING SYSTEM (GPS)
RECEIVER FOR A DIFFERENTIAL GPS GROUND SYSTEM

Table of Contents

Table of Contents (Continued)

List of Figures

1.0 INTRODUCTION

NASA Ames Research Center and the Ohio University Avionics Engineering Center are currently involved in the specification and development of a Differential Global Positioning System (DGPS). Ames is developing and evaluating the airborne unit of this system and Ohio University is specifying and eventually developing the ground unit. One step towards the successful completion of a functional ground unit will be in choosing a currently available GPS receiver that will accurately measure the propagation times of the satellite signals and have the capability to be electrically interfaced with and controlled by a Digital Equipment Corporation (DEC) PDP-11/34A computer.

This document describes the minimum requirements and characteristics of a NAVSTAR Global Positioning System (GPS) receiver, which is to be procured and configured into the DGPS ground system.

Ohio University will seek guidance and approval from the project's NASA technical monitor as to the final selection of the receiver.

1.1 Background

The receiver, as specified by this document, will be used in the DGPS ground segment. The ground segment will calculate pseudorange corrections for all of the satellite vehicles (SVs) in view and telemeter those corrections to an airborne unit. The airborne unit will in turn apply those corrections to its pseudorange measurements to obtain a more precise position fix (see figure 1.1.1).

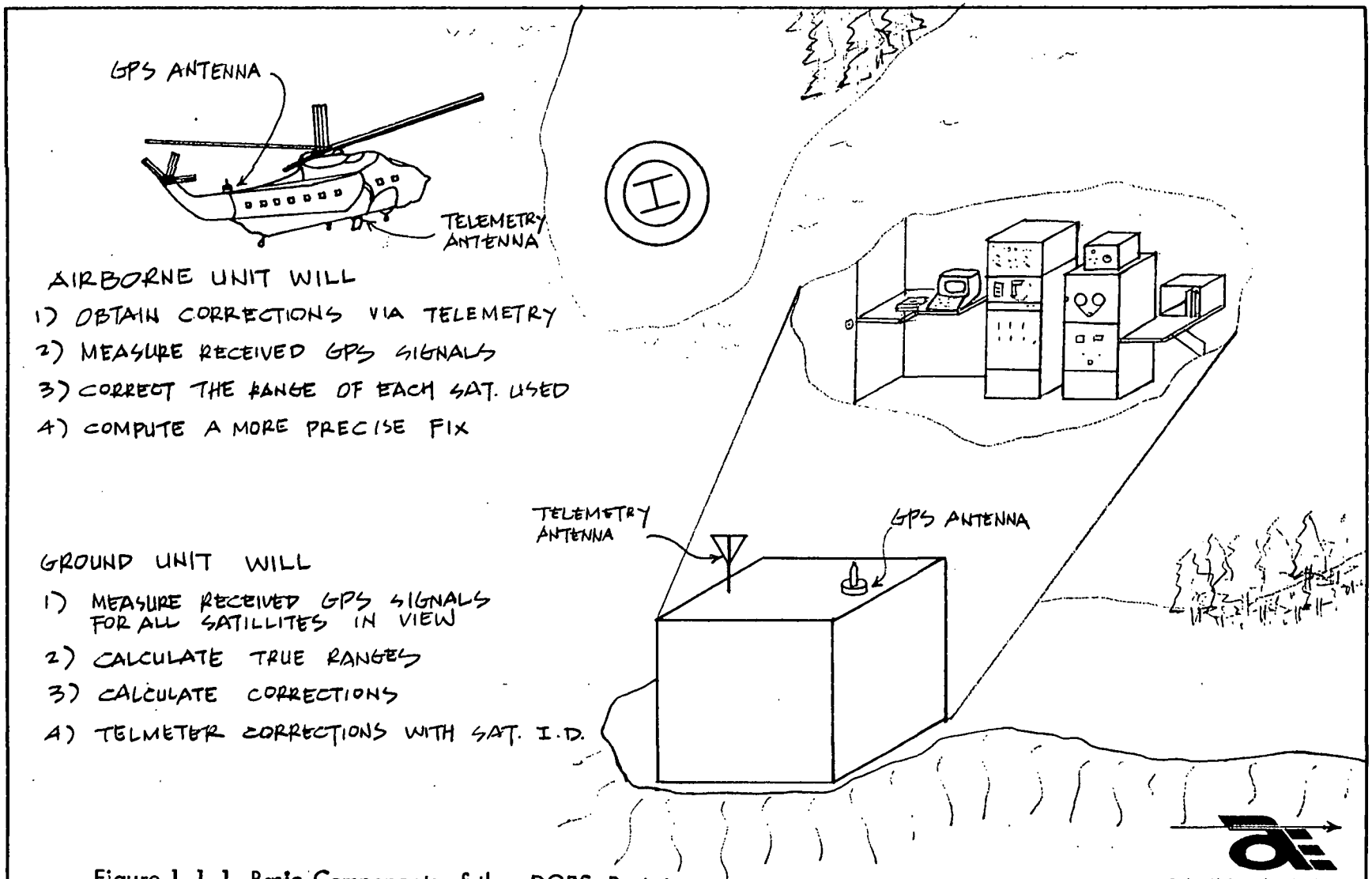

Figure 1.1.1 Basic Components of the DGPS Prototype.

DATE: 4/84	CONTRACT NO: NAG 2-231	PROJECT: GPS

AVIONICS ENGINEERING CENTER, OHIO UNIVERSITY, ATHENS, OH 45701

2.0 GENERAL STANDARDS

2.1 Basic Receiver Characteristics

The GPS receiver system shall consist of no fewer than two and no more than four separate components. An example configuration consists of an antenna, preamplifier, receiver processor, and a control/display unit (CDU) (see figure 2.1.1).

2.1.1 Code Tracking

The receiver shall receive the GPS L1 frequency (1575.42 MHz) and track the Standard Positioning Service (SPS) C/A code. The receiver shall provide:

- Pseudorange derived from the C/A code.
- Pseudorange rate derived from the Doppler shift observed in the L1 carrier.
- Receiver position and clock bias computed from four pseudoranges obtained from the C/A code of four satellites.

The architecture of the receiver may contain any number of channels so long as the receiver meets or exceeds the requirements set forth in this specification.

2.1.2 Receiver Component Interconnection and User Assembly

The receiver shall be preconfigured for use prior to shipping. Other than attaching cable connectors for receiver power, preamplifier, antenna, and the control/display unit (CDU), the user will not be required to perform any complex assembly, soldering, or troubleshooting to make the receiver function to the manufacturer's specifications.

2.1.2.1 Receiver Power Distribution

The electrical power, required for the entire system, shall have one entry point into the system and shall be distributed by cable(s) to the extremities of the system (see figure 2.1.1).

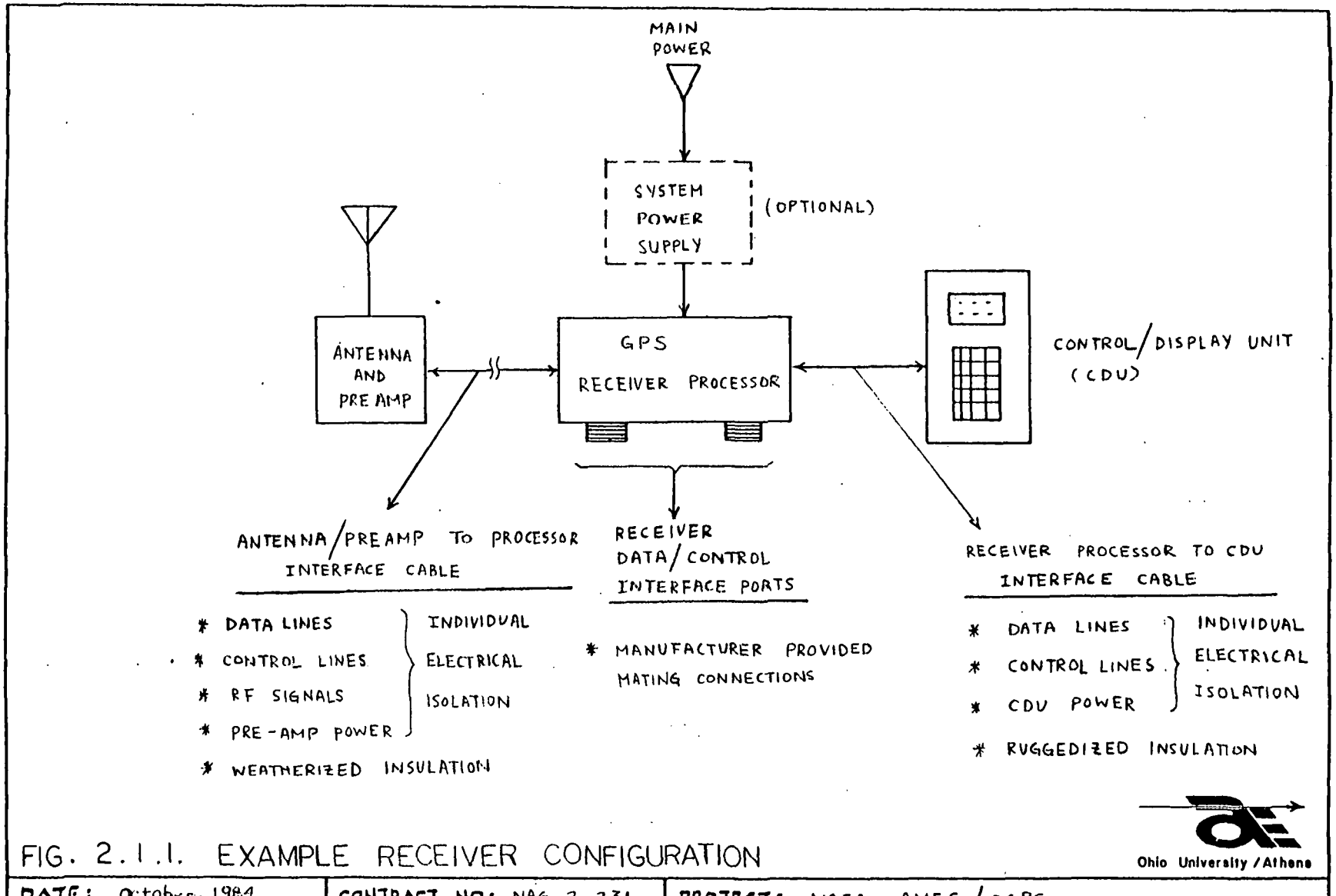

FIG. 2.1.1. EXAMPLE RECEIVER CONFIGURATION

Ohio University / Athens

DATE: October, 1989	CONTRACT NO: NAG 2-231	PROJECT: NASA AMES / DGPS

AVIONICS ENGINEERING CENTER, OHIO UNIVERSITY, ATHENS, OH 45701

3.0 TECHNICAL SPECIFICATIONS

Listed are the minimum requirements for the DGPS ground system GPS receiver. GPS receivers which deviate from this specification may be considered providing the manufacturer supplies, along with the bid, documentation clearly stating the nature and extent of such deviations.

3.0.1 Overview of Receiver Requirements

Tracking Carrier	: Frequency - L1 (1575.42 MHz) Tracking jitter - 0.33 cm RMS
Code	: C/A Code (SPS) Tracking jitter - 6 m RMS
Antenna	: L Band Hemispherical coverage
Power	: Single input, 110-120 VAC, 60 Hz, (<=500 W)
Data output (see note 1)	: Data Set I - Available at 1 SV/sec Data Set II - Available one/30 sec or upon command
Data Set I	: Pseudorange - 0.1 m resolution Pseudorange rate - 0.05 m/sec resolution GPS System Time - 20 ns RMS jitter 0.3 ns resolution S/N - actual or Figure of Merit from which S/N can be derived
Data Set II	: Data Blocks I, II, III Message Block Position Fix - station latitude, longitude, and altitude in WGS-72 coordinates SV IDs - tracked and visible
Data input (see note 2)	: SVs to be tracked (up to 8) Data request Initialization/startup data
Interface	: RS-232 at 4800 or 9600 Baud or, IEEE 488 or, 16-bit parallel with handshaking or commonly accepted industry standard (GPIB, etc.)
Size	: Not to exceed 19 W, 48 H, 24 D
Mounting	: Standard rack mounts
Deliverable items	: Receiver system hardware Receiver software algorithms Manuals (receiver-operator, -technical, and -service) Warranty, maintenance, and service information Delivery terms

(1) - Data sets I and II are to be available simultaneously.

(2) - The receiver shall be controlled externally by a PDP-11/34A as specified in Section 3.3.

3.1 Receiver Position and Satellite Data - Content and Resolution

The receiver shall provide the following information in real time, for each of up to eight satellites within line-of-sight of the receiver's antenna at a sequencing rate of at least one satellite per second:

- Satellite ID
- Pseudorange
- Pseudorange rate

3.1.1 Accuracies and Resolutions

3.1.1.1 Pseudorange Measurements

The receiver will provide pseudorange measurements to each satellite, as scaled from the signal propagation time, with no more than 6 meters RMS jitter and to a resolution of 0.1 meters. Higher accuracies and resolutions are acceptable.

3.1.1.2 Pseudorange Rate Measurements

The receiver will provide pseudorange rate measurements, as scaled from the measured Doppler shift of the L1 carrier, to a resolution of 0.05 meters/second. The carrier tracking loop will be able to track a carrier cycle with an accuracy of 0.33 cm RMS jitter or better.

3.1.1.3 GPS System Time

The receiver will provide GPS system time relevant to the measured pseudorange and pseudorange rate data, with no more than 20 nanoseconds RMS jitter and to a resolution of 0.3 nanoseconds. These specifications are based on the requirements outlined in Section 3.1.1.1.

3.1.1.4 Signal-to-Noise Ratio Information

The receiver output shall include with the pseudorange, pseudorange rate, and GPS system time, a number proportional to or representative of the quality of the signal-to-noise ratio (SNR) for each satellite tracked. This figure shall represent the SNR measured at the antenna.

3.1.2 Satellite Navigation Messages

The receiver will provide the GPS Navigation Message concurrently with the pseudorange, pseudorange rate, GPS system time, and signal-to-noise information.

3.1.2.1 GPS Navigation Message

Upon initialization, the receiver will sequentially provide the entire navigation message for each satellite in view. This message will consist of Data Blocks I, II, III, and the Message Block.

After initialization, the receiver may only provide Data Blocks I and II. The receiver shall continue to collect Block I and Block II data without interruption while acquiring pseudorange and pseudorange rate data from each satellite in view. Data Block III and the Message Block would only be provided upon the user's request.

3.1.2.2 Position Estimation

The receiver shall provide a position estimate and a receiver clock correction based upon the best estimates of the C/A code derived pseudorange measurements from four satellites. The receiver shall be able to choose the four satellites based upon the constellation of four which provide the best geometry (i.e. best GDOP).

It shall be possible to bypass the receiver's satellite selection routine and have the receiver provide the position estimates and clock corrections based upon the C/A code time delay measurements of four satellites of the user's choosing.

3.1.2.3 Ionospheric Corrections

Ionospheric corrections shall be made available to the receiver operator at a resolution equal to that of the pseudorange measurements.

It is required that the pseudorange and pseudorange rate measurements be provided to the user without the ionospheric corrections applied. However, corrected measurements will be acceptable provided the manufacturer supplies enough information so that the effects of these corrections can be defeated in near real time.

3.1.2.4 Data Format

The data to be provided by the receiver via the electrical interface will be in a well documented format so that it may be utilized by PDP FORTRAN-IV routines either directly or after simple conversion.

3.2 Receiver Interface/External Control

3.2.1 User Interface/Control Display Unit

All of the hardware necessary for the user to program the receiver to operate in the various modes as specified by the manufacturer, will be provided with the unit and must be accessible to the user without requiring entry inside the receiver enclosure. This operator interface shall be either a front panel keypad and display or remote terminal.

3.2.2 Acceptable External Control Architectures

This receiver will be used in a research program which will require the receiver to be externally controllable by a PDP-11/34A computer.

The data/control lines shall conform to one of the following accepted standards:

- IEEE 488

- RS-232 serial (either 4800 or 9600 Baud for the realtime data and the navigation message information)

- 16-bit parallel interface employing common handshaking techniques or commonly accepted industry standard (GPIB, etc.)

3.3 Receiver Capabilities, Operation, and Control

3.3.1 Satellite Selection

The receiver shall have an auto-search and track capability for satellites as selected by the receiver's satellite selection routine. The ground system shall have the capability to override this selection so that a user selected set of satellites (up to eight) may be tracked. Furthermore, it shall be possible for the user to select the set of four satellites that are used in the receiver's position estimation algorithm.

The data block containing satellite ID, pseudorange, pseudorange rate, GPS system time, and signal/noise ratio shall be updated and provided at a rate greater than or equal to one SV per second.

3.3.2 Computer Control of the Receiver

A DEC PDP 11/34A computer will be interfaced with the receiver for data collection and receiver control. User control of the receiver, with the exception of powering up the receiver, shall be relinquishable to the PDP-11/34A by means of 1) customized control software, 2) electrical interface(s), and 3) the receiver's interface port(s). The former two items shall either be developed or purchased by the buyer and the latter item(s) shall be furnished with the receiver, including the mating connectors.

The PDP-11/34A shall be able to control the following receiver functions:

- Choice of satellites to be tracked (up to eight).

- Choice of data available from the receiver via the serial or parallel data port. Satellites to be used in the receiver position estimation algorithm.

3.4 Enclosure Dimensions and Mounting Requirements

3.4.1 Enclosure Size

The receiver system, with the exception of the antenna and preamplifier, will not require any more space than is offered by a 19 inch wide/24 inch deep/48 inch high equipment rack.

3.4.2 Receiver Mounting

The receiver shall be capable of being mounted in a standard 19 inch equipment rack. The manufacturer shall supply any additional hardware necessary to accomplish rack mounting of the receiver.

3.4.3 Antenna/Preamplifier Assembly Mounting

The antenna, preamplifier, or consolidated antenna/preamplifier assembly shall be capable of performing to the manufacturer's specifications when mounted on a building rooftop, the top of a panel truck, or on a portable tripod structure.

The antenna or antenna/preamplifier assembly shall be capable of operating at a distance of not less than 100 feet from the receiver.

3.5 Environmental Specifications

3.5.1 General

The manufacturer shall include, with the receiver, signed test reports indicating that the receiver has met or exceeded the environmental requirements set forth in the following sections.

3.5.2 Temperature and Humidity

The receiver shall be capable of operating under the following temperatures and humidities:

Operating Temperature	40F to 110F (4C to 43C)
Storage Temperature	-40F to 150F (-40C to 66C)
Operating Rel. Humidity	20% to 80%
Storage Rel. Humidity	5% to 90%

3.5.3 Rain and Moisture

The antenna or antenna/preamplifier assembly, antenna cabling, and mating connectors shall be capable of operation under rainy conditions such as would be expected in the field.

3.5.4 Dust

The receiver and antenna or antenna/preamplifier assembly shall be shielded from the effects of dust that might inhibit normal operation.

3.5.5 Altitude

The receiver must also be able to operate at altitudes from sea level to 12000 feet above sea level.

3.5.6 Shock and Vibration

The receiver processor, antenna, and preamplifier shall be able to withstand shock and vibration encountered in the laboratory and ground vehicle environment. Every reasonable effort will be made by the manufacturer to ruggedize the receiver processor, antenna, preamplifier, cables, and connectors to the best commercial practices to minimize receiver failure due to shock induced either during normal operation or while in transit via a ground vehicle. If required for dependable operation of receiver during cross country transit via a ground vehicle, the manufacturer shall specify and make available the necessary shock mount hardware.

3.6 System Power Requirements

The receiver/system power must be either of the following:

- 115 VAC ±10% @ 60Hz ±3Hz

- 220 VAC ±10% @ 60Hz ±3Hz

The total power consumption of the receiver system will not exceed 500 Watts. Receivers requiring DC voltages, at low power levels, will also be considered.

4.0 ACCEPTANCE TESTING

4.1 Manufacturer Performed Tests

The manufacturer shall perform tests to demonstrate the ability of the receiver carrier and code tracking loops to meet the requirements set forth in Sections 3.1.1.1, 3.1.1.2, and 3.1.1.3. The results of these tests shall be provided to the buyer.

The manufacturer shall perform environmental testing to demonstrate the ability of the receiver to operate under the conditions set forth in Sections 3.5.2 through 3.5.5. The results of these tests shall be provided to the buyer (see Section 3.5.1).

4.2 Buyer Performed Tests

The receiver shall undergo acceptance testing conducted on the buyer's premises. These tests shall verify the operation of the receiver functions as they are described in the manufacturer supplied manuals. The buyer intends to subject the receiver to the following tests:

- All keyboard or front panel commands available to the user will be tested and proper responses must be verified.
- Operation of the serial or parallel data ports shall be demonstrated.
- The receiver antenna shall be set up in a known location and the system position estimate shall fall within the accuracies specified by the manufacturer.

Final acceptance of the receiver shall be contingent upon the success of these acceptance tests.

5.0 DELIVERABLE ITEMS BY THE MANUFACTURER

The receiver manufacturer will provide a comprehensive list of the anticipated deliverable items, be they hardware, software, or support services, plus the corresponding costs/fees for said items. The manufacturer will also provide with this list, the total delivered price of the system.

The manufacturer will also provide, before procurement, a document explaining the deviations of the system design of the receiver from this specification.

5.1 Hardware

A list of hardware components, cables, connectors, and assembly hardware, with the itemized costs, shall be provided prior to the procurement of the receiver.

5.2 Software

The manufacturer shall release software listings of the programs contained within the receiver, knowledge of which will be necessary for the successful integration of the receiver into the DGPS ground system.

These listings shall be adequately documented and commented for ease of comprehension.

If meeting the above implies the release of proprietary material, the buyer will enter into an agreement to protect the manufacturer's proprietary information, if necessary.

5.3 Manuals

A list of user, technical, or service manuals, to accompany the receiver, will be provided by the manufacturer.

These manuals shall be accessible, for review by the buyer, prior to the procurement of the receiver.

5.4 Service/Maintenance

The manufacturer shall provide data indicating the mean time between failures (MTBF) and the mean time to repair (MTTR) for the receiver. The manufacturer shall provide a list of the support of service and/or maintenance to be provided for the receiver after the purchase. This list shall also include the fees for those services.

5.5 Warranty

The manufacturer shall provide documentation explaining the extent of coverage, time span, and conditions of the warranty provided with the receiver.

5.6 Installation

If installation services are required by the manufacturer's trained field technicians, as specified by the manufacturer, the nature and extent of this service and any resulting fees must be explained prior to the procurement of the receiver.

5.7 Equipment Delivery

A mutual agreement will be made as to the delivery date of the receiver. This agreement will be considered binding and, because this system must be built in a timely manner, may involve monetary penalties proportional to the length of delay of the delivery of the working system.

The delivery of the receiver(s) is to be no later than January 24, 1985.

6.0 TECHNICAL CONTACT

If you have any questions pertaining to the technical aspects of this specification, please contact Mr. Daryl L. McCall at (614) 594-6736 or (614) 594-5263.