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Global Positioning System Adaptation
for Balloon Payloads

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) A reliable method of utilizing the Global Positioning System (GPS) for tracking AFGL balloon payloads has been developed at the Oklahoma State University Electronics Research and Development Lab. The system uses the Collins-Rockwell Navcore I GPS receiver and data converter along with some custom designed signal conditioning electronics.					
The airborne package consists of a Navcore I receiver, a data converter and a proper signal conditioning to provide the modulation signal to an S-band telemetry transmitter. This transmitter is to be used for transmission of both the payload's telemetry data and GPS receiver's navigation solution. Two methods (PCM/FM and FM/FM) of transmitting the GPS data, along with the telemetry data are presented. The ground station equipment consists of an S-band receiver, FM discriminator if required, signal conditioning electronics, and IBM PC compatible computer. The computer provides real-time display and recording of the GPS receiver's position (latitude, longitude, and altitude). Additionally, other payload statuses are provided, GPS second of week, speed, heading, (OVER)					
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and vertical velocity. The recorded GPS data -- on the PC's hard disk -- is available for any necessary post-flight processing. Two formats of post-processed information are created, tabular and plotted. Tabular listings are created for flight review. Plots are generated from the tabular listings by using a spreadsheet with graphic display routines, and can be inspected to determine if possible correlations exist between any two parameters.

OSU personnel involved in this project were Paxton Robey, Project Manager; Randy Donahoo, Research Engineer; and Chris Schuermann, Technician.

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1.0 Introduction

The Air Force Geophysics Laboratory conducts high-altitude long duration balloon flights carrying meteorological and other scientific experiments. Flights may go well above a hundred-thirty thousand feet altitude and may remain airborne in excess of several days.

Balloon payloads have typically been tracked by various means including radar, Loran C, and Omega position determining systems. Accuracies for various navigation systems are shown in Table 1.

Navigation System Comparison

System	Position Accuracy (m)	Velocity Accuracy (m/sec)	Range of Operation	Operation
GPS	16 3-Dimensions	0.1	Worldwide	Operational worldwide with 24-hour, all-weather coverage
Loran-C	180	—	U.S. Coast, Continental U.S., Selected Overseas areas	Operational with localized coverage. Limited by skywave interference.
Omega	2,200	—	Near global (90% coverage)	Current operational with localized coverage. System is subject to multipath errors.
INS	1,500 max after 1st hour	0.8 after 2 hours	Worldwide	Operational worldwide with 24-hour all-weather coverage. Degraded performance in polar areas.
TACAN	400	—	Line of sight	Position accuracy is degraded mainly because of azimuth uncertainty which is typically on the order of ± 1.0 degree.
Transit Satellite	200	—	Worldwide	The interval between position fixes is about 90 minutes. For use in slow moving vehicles.

**Table 1.
Standard Navigation System
Comparisons¹**

The Oklahoma State University Electronics Research & Development Laboratory (ERDL) was responsible for interfacing the Global Positioning System (GPS) receiver to balloon-payload telemetry. The existing telemetry transmitter was to be used without drastically increasing the required transmission bandwidth. Additionally, power and size requirements were reviewed.

2.0 GPS Overview

The NAVSTAR Global Positioning System (GPS) is a space-based radio navigation system that will provide 24-hour coverage worldwide. The system will consist of a constellation of 18 satellites, Space Vehicles (SV's), when fully operational. However, the space shuttle disaster delayed the scheduled completion date. According to current plans, the full constellation will be in place within two years after NAVSTAR launches resume in late 1988, aboard the Delta II launch vehicle. At least four GPS space vehicles must be in view for the receiver to compute its 3-dimensional position. If altitude is known, three visible satellites will provide enough information to compute the 2-dimensional position. Using the seven satellites currently operational, the required 4-satellite coverage is available at any locality for only limited intervals (about four hours) within a 24-hour period. This coverage, however, has been adequate for development purposes.

Figure 1 depicts the three major GPS subsystems, called:

- the space segment,
- the control segment, and
- the user segment.

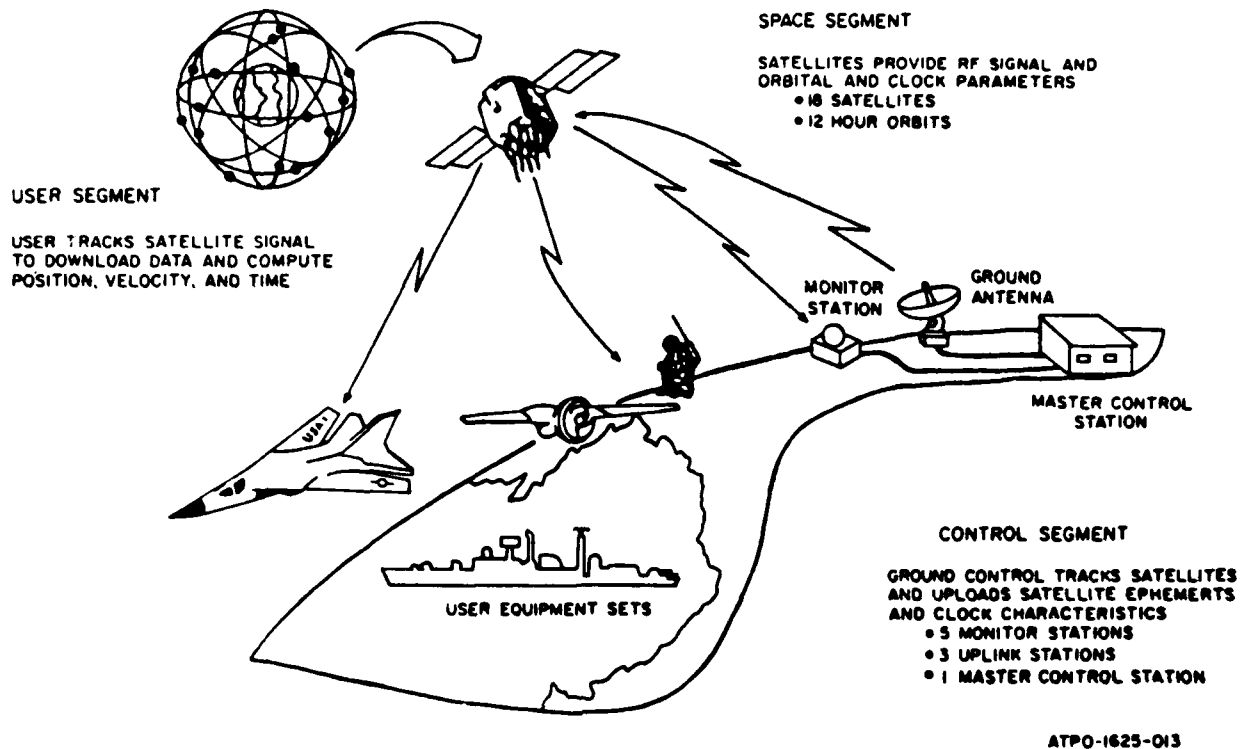
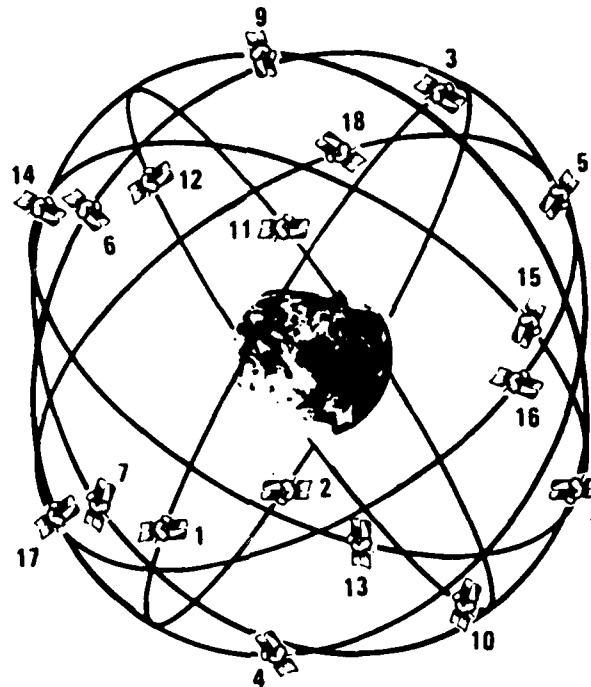


Figure 1
GPS System Diagram²

The space segment, when complete, will consist of 18 space vehicles, satellites, placed into six orbital planes with three satellites per plane. These satellites will be located at an approximate altitude of 20,000 kilometers. At this altitude, the satellites will be in one-half synchronous orbits (2 orbits per day). All satellites will continuously transmit over the same two carrier frequencies: $L_1 @ 1575.42 \text{ MHz}$ and $L_2 @ 1227.6 \text{ MHz}$. Figure 2 represents a diagram of the complete GPS constellation.



18 SHUTTLE-LAUNCHED NAVSTAR SATELLITES
~20,000 KM ABOVE THE EARTH

Figure 2
Planned GPS Satellite Constellation³

The control segment consists of five monitor stations located in Hawaii, Ascension Island, Colorado Springs, Diego Garcia, and Kwajalein. Each is an unmanned data collection center that continuously measures the pseudo-range of the space vehicles visible to it. The data collected is sent to the Master Control Station at the Consolidated Space Operations Center in Colorado Springs, Colorado. With this current information, new ephemeris data is computed and uploaded to each SV on a daily basis.

The user segment -- GPS receiver -- will typically consist of two major sections:

- RF receiver, and
- computer.

In the coarse/acquisition mode, the RF receiver must be able to receive the L₁ carrier (1575.42 MHz). This carrier frequency is modulated with both a 1.023 MHz clock rate Coarse/Acquisition (C/A) code and a 10.23 MHz Precise (P) code unique to each satellite. In addition to these codes, a 50 baud, 1500 bit long navigation message is transmitted. If better precision is required, the receiver must receive and decode the P-code signal transmitted on both the L₁ and L₂ carrier frequencies. For the application developed at OSU, only the C/A code on the L₁ carrier is used to determine the payloads position. Therefore, the GPS receiver chosen, Collins-Rockwell NAVCORE I, need only receive and decode information transmitted over the L₁ carrier to derive its 3-dimensional position, velocity and precise time output. This receiver does not make use of the more precise P-code.

The computer controls the entire operation of the receiver as well as any interactions between the user and the receiver. The computer performs all functions necessary for the acquisition and tracking of the satellite signals and arithmetic operations necessary for computing the position, velocity and time. Data required for these computations is contained in the 50 baud navigation message. This data message of 1500 bits in length consists of system time, space vehicle ephemerides, Space Vehicle clock offsets, transmitter status information, and the C/A to P code handover information. With this data and the difference between signal transmission and receiver reception, the user can successfully navigate with the Global Positioning System.

The difference between the time of reception and transmission of

the signal is used to calculate the radius (x) between the satellite and receiver. The value obtained for the radius is actually known as the pseudo-range since it contains a "user-clock" error. This error occurs because the frequency standard (clock) in the receiver is not directly synchronized with those on-board the satellites. This error, however, is eliminated in the 4-satellite solution for x, y, z position and time.

The receiver is located on the surface of a sphere determined for each satellite. The point of intersection of all these spheres determines the receiver's location which is represented in an earth-centered earth-fixed (ECEF) coordinate system. These ECEF coordinates can be converted to a local level coordinate system (latitude, longitude, and altitude) by using an earth model such as the World Geodetic System 1972 (WGS-72).

3.0 Hardware

Several manufacturers produce GPS receivers capable of being used for navigation and survey operations. After looking at the capabilities and post-flight processing facilities provided by several of these manufacturers, the Collins-Rockwell NAVCORE I GPS receiver was decided upon as being the best in the field of choice. This selection was also based upon factors other than post-flight processing software. These included

- user-friendliness of receiver operation,
- signal reception/acquisition at low elevation angles (5 degrees above the horizon), and
- a the high degree of system flexibility of this unit.

3.1 NAVCORE I Receiver

The NAVCORE I GPS C/A receiver is a single channel, self-contained unit. This receiver uses the commercially available C/A code transmitted from the NAVSTAR GPS satellites to derive three-dimensional position, velocity and time. Two mechanical configurations, standard and low-profile, are available from Collins as well as two basic functional versions. One version outputs standard navigation data while the other precise time. OSU selected Collin's standard mechanical and standard navigation unit, part number 622-7693-001.

The standard navigation unit was designed to provide optimum performance for the user. A complete GPS navigation system based upon this receiver consists of the following items:

- Navcore I GPS C/A Receiver
- Control/Display Unit
- GPS Navigation Antenna/Preamplifier
- DC Block (optional).

If a preamplifier is not used, a DC block must be placed between the antenna and receiver's RF input. This DC block is required because the preamplifier obtains its power from the center conductor of the coaxial cable. Therefore, the DC block is a protection device for both the receiver and the antenna.

Once again, the DC block is required in system installations that do not include a preamplifier and the antenna dc resistance is less than 10 K-ohms.

3.1.2 NAVCORE I GPS Receiver Specifications

The following specifications were obtained from the equipment user manuals provided by Collins-Rockwell.

Performance

Position Accuracy:

25 meters spherical error probability

Velocity Accuracy:

0.5 meters per second on each axis

Time Accuracy:

100 nanoseconds

Time to First Position Solution:

Warm Start: Less than 5 minutes

Cold Start: Less than 20 minutes

Maximum Velocity:

600 knots

Maximum Acceleration:

1 g.

Environmental

Temperature:

Operating: -20 to +55 degrees C.

Storage: -55 to +85 degrees C.

Humidity:

95% noncondensing

Shock:

6 G.

Altitude (nominal):

-100 to 55,000 feet.

Vibration:

0.0005 G/Hz, 10-500 Hz

-3 dB/Octave, 500-2000 Hz

Interface Requirements

Antenna RF Input:

-162.0 to -137.0 dBW.

Handheld Control Terminal I/O:

RS-232C, 9600 baud

Data Transmission I/O:
RS-232C, 9600 baud

Timing Signal Output:
1 PPS: 20-50 ns rise time; 20 us pulse width; 1 us fall time.

Physical Characteristics

Size:
7.4" W, 4.8" H, 7.7" D (196 mm W, 122 mm H, 197 mm D)

Weight:
8 lb. (3.6 kg)

Power Requirements:
10 TO 40 Vdc, 30 watts

3.1.2 NAVCORE I Output Data

The NAVCORE I receiver outputs the following standard data:

- satellites tracked and signal strength,
- test satellite tracked and signal strength,
- current ECEF navigation solution,
- time correction data,
- UTC time once per second,
- current navigation solution in local level coordinates,
(based upon WGS-72)
- satellite selection criteria.

This data is output over the high-speed data channel in the form of data blocks. Each data block is identified with a particular label; a set of two consecutively transmitted identical hexadecimal values (A0A0-A9A9). A brief description for each data block is contained in the Appendix.

3.2 Data Converter

The Collins Data converter filters data coming from the high-speed data port on the GPS receiver. This filtering provides a means of reducing the amount of data transmitted to the ground station thereby reducing the baud rate required send the navigation solution block, labeled A6A6. This data block is normally

provided to the user at 9600 baud. The baud rate reduction alleviates any likelihood of interference between GPS and PCM data. The reduced baud rate is switch selectable to either 300 or 1200 baud.

3.2.1 Data Converter Specifications

Input:

RS-232C, 9600 baud

Output:

RS-232C, switch selectable 300, 1200, 9600 baud

Data Format of output switch selectable:

Latitude, Longitude, Checksum

Latitude, Longitude, Altitude

Complete A6 block and ASCII features

Any of the above can be selected to be output at a variable rate based upon the speed of the object being tracked.

Vehicle Speed

Output Block Rate

< 1 km/hr	1 every 15 sec
1 km/hr - 2 km/hr	1 every 12 sec
2 km/hr - 4 km/hr	1 every 10 sec
4 km/hr - 8 km/hr	1 every 8 sec
8 km/hr - 16 km/hr	1 every 6 sec
16 km/hr - 32 km/hr	1 every 4 sec
32 km/hr - 64 km/hr	1 every 2 sec
> 64 km/hr	1 every second

Primary Power:

22-28 V dc

Weight:

2 lb (0.9 kg)

Dimensions:

10 x 7 x 2 (inches)

3.3 Transmission Method

Several techniques are available for transmission of the balloon-borne GPS receiver's navigation solution. The techniques considered were:

- FM/FM multiplexing,
- FM/PCM mixing,
- direct mixing of RS-232 NRZ and PCM data, and
- insertion of the GPS data blocks directly into the PCM bit stream.

In view of keeping positional information bandwidth requirements to a minimum, the method selected, directly mixing the GPS data with the balloon telemetry PCM data stream, has been determined to be the best possible solution. This method has been proved successful by ERDL in airborne telemetry packages designed to work with the TRADAT tracking system. With this system, a data stream is transmitted to the payload and retransmitted to the ground station over the existing telemetry link. One must remember, however, the other methods mentioned might fit into your telemetry needs better than the one selected.

3.3.1 PCM - RS-232 Mix

This method of mixing GPS and PCM data requires that the PCM data be presented in a bi-phase format. By using a bi-phase format, we can take advantage of the fact that very little of the signal's energy lies in its lower frequencies (a factor of 10 below its clock rate).

The PCM and GPS RS-232 data are filtered with pre-modulation filters (low-pass filters) to eliminate high frequency components contained in the rising and falling edges of the data stream.

The GPS receiver's RS-232 data channel is filtered with a 6th order Butterworth low-pass filter with a cutoff frequency of 10 KHz. The outputs of each pre-modulation filter are mixed together and the level adjusted to modulate the transmitter. This system shown in Figure 3 was tested on the bench under various conditions.

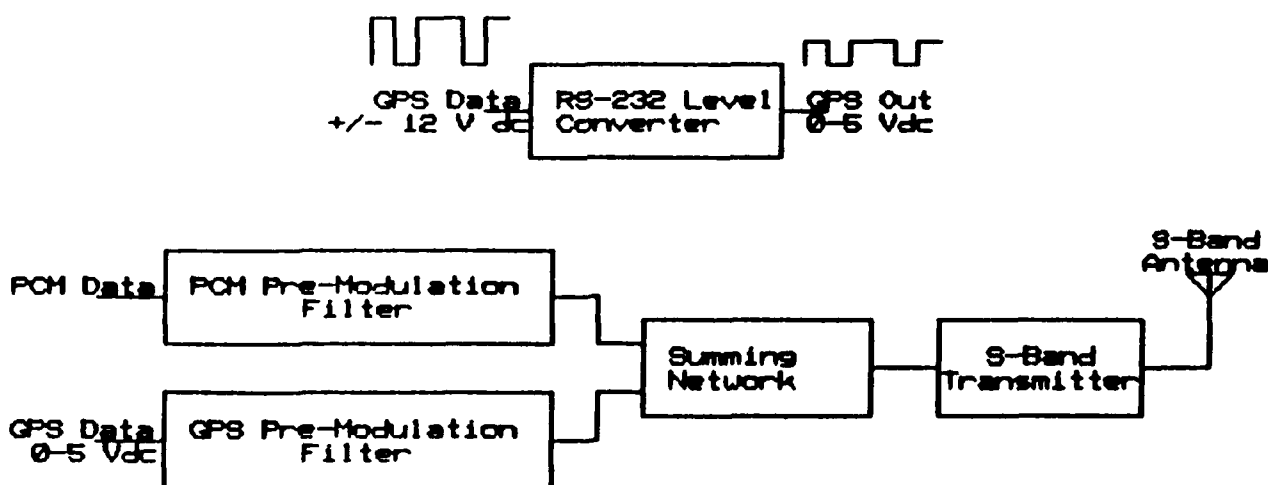


Figure 3.
Block Diagram of GPS and PCM
Transmission System

The modulation indexes for both the PCM and GPS bit stream were adjusted so the combined signal would not over-modulate the S-band transmitter. Proper adjust was verified by lowering the transmitted signal strength until one or both of the data channels

started to show signs of dropout, frame sync loss on the PCM channel and parity, framing, or overflow errors on the RS-232 channel. If properly adjusted, both the PCM and RS-232 data streams would start showing bit dropouts at the same S-band receiver S/N ratio. If not, the modulation index of the channel still intact would be lowered or the other channel's index would be raised but always keeping in mind not to over-modulate the transmitter. Once the bench test configuration was properly adjusted, no detectable data dropouts were noticeable on either the PCM or GPS channel until the ground station S-band receiver's S/N ratio was 15 dB.

With this system, the NAVCORE I GPS receiver's 9600 baud RS-232 data channel can be transmitted error-free with a PCM channel having a bit rate greater than 64,000 bits/second. To reconstruct both the PCM and RS-232 data, the following ground station equipment is required:

- Bit synchronizer,
- Decommutator
- Low-pass filter
- RS-232 driver circuit.

The bit synchronizer which contains internal filtering alleviates the requirement of first externally filtering the S-band receiver's video output with an external high-pass filter. Therefore, the bit synchronizer alone can restore the PCM bit stream. Proper restoration can be verified with a PCM decommutator. The resultant bit stream can be recorded on magnetic tape for permanent storage.

The GPS bit stream is reconstructed by filtering the S-band receiver's video out with a 6th-order Butterworth low-pass filter with a 10 KHz cutoff frequency. This filtering process removes any of the PCM channel's high frequency components. The filtered output is converted to RS-232C signal levels with a RS-232C driver (i.e. LM1488, MAX-232). This data reconstruction technique is illustrated in Figure 4.

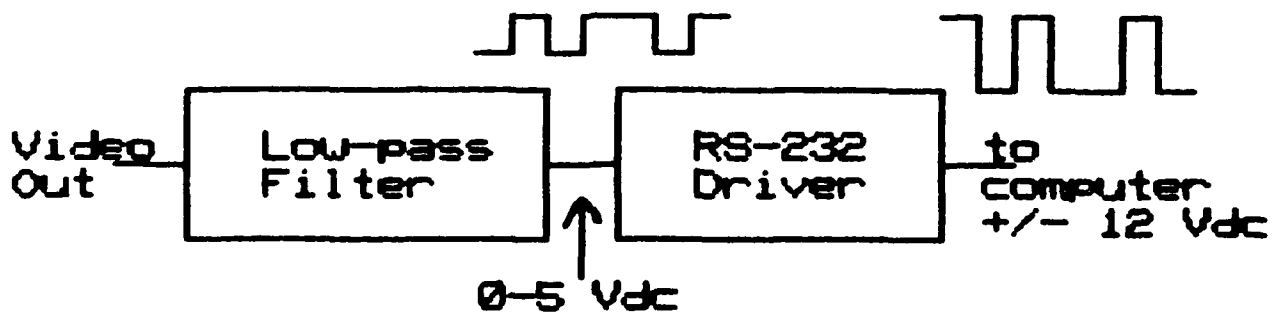


Figure 4
Block Diagram of RS-232 Recovery Circuit

3.4 Ground Station

The ground station equipment consists of the following:

- an S-band telemetry receiver,
- proper signal conditioning hardware for the particular transmission method used, and
- a PC compatible computer with
 - * 8087 math coprocessor,
 - * Hercules compatible graphics card,
 - * monochrome monitor,
 - * hard disk drive, and
 - * RS-232C serial port.

The received GPS bit stream will either consist of all the GPS receiver's available block types, A0 thru A9, requiring 9600 baud transmission channel; or if a Collins data converter is placed in-between the GPS receiver and S-band transmitter, the data transmitted will only consist of the local level navigation solution (A6 block) at a lower baud rate (300 or 1200). Nevertheless by using a lower baud rate, valuable information pertaining to satellite tracking status and system accuracy is lost.

The received position data is stored on the PC's hard disk drive and at the same time presented in a user readable format on the computer monitor. The recorded GPS data -- on the PC's hard disk -- is available for any necessary post-flight processing.

Two presentation formats are available for post-processed information studies, tabular and plotted. Tabular listings are created for flight review. Graphic plots generated with these listings can be inspected to determine if possible correlations exist between any two parameters.

4.0 Software

A short description of the capabilities and operation of the Collins-Rockwell provided GPS software is presented in the following sections. Each section provides an overview of the programs usage for pre-, during, and post-flight ground station operations for payload tracking. For further details, reference the Appendix for complete software documentation as provided by Collins-Rockwell.

4.1 SATVIS - Satellite Visibility

The SATVIS program provides the user with important information pertaining to the available times that the GPS system can be used for navigational tracking of a balloon payload. This program will show the user the times that four of the six currently available satellites will be properly oriented to allow the GPS to be used as a three-dimensional positioning system. This program can be very helpful in determining launch windows when GPS is used for providing payload position information. The program can show the user the geometric dilution of precision (GDOP), horizontal dilution of precision (HDOP), vertical dilution of precision (VDOP). These values allow the user to determine how well the calculated position can be trusted to indicate the payloads actual position.

4.2 RECORD - NAVCORE I Data Recorder

The RECORD program is used to store raw GPS data into a DOS file. This program allows the user to input the name of the data file and provides the user with a display showing the number of parity,

and framing errors that have occurred in the received RS-232 serial bit stream and the amount of space available on the destination drive for storage purposes. If only data storage is required, this program works; but if any real-time position display is desired the next program, DISP_REC, should be used.

4.3 DISP_REC - Real-time Display Data Recorder

DISP_REC like RECORD stores the GPS data blocks being transmitted over the telemetry link onto the PC's storage medium; be it floppy disk, hard disk, or RAM disk. As opposed to the RECORD program, one additional feature has been added. The recorded data blocks can be observed in decoded ASCII on the computer display in real-time. The user can select which particular data blocks he/she would prefer to see. Although only selected blocks are being displayed, all raw data blocks are being stored. The selection of the displayed blocks can also be changed during a record session without having to exit from the program. Therefore, no loss of valuable payload position data occurs.

4.4 DECODER - Post-flight Data Decoder

The DECODER program is used to convert the raw data into an ASCII file. The data stored in the decoded files will be in a tabular form that can be imported into almost all spreadsheet programs. An example of this form is shown in Table 2. Printouts of the decoded data can be obtained by simply typing:

```
type XXXXXX.XXS >prn:
```

This command will re-route the standard output to the printer device connected to the PC's parallel printer port. The

destination does not have to be 'prn' but may be any of the devices in the PC's present configuration.

<u>TIME</u>	<u>LATITUDE</u>	<u>LONGITUDE</u>	<u>ALTITUDE</u>	<u>SPEED</u>	<u>DIRECTION</u>	<u>VSPEED</u>
507118	36.10645797	-97.15598716	2346.31	146.91	109.3867	1.18
507120	36.10621963	-97.15511367	2349.50	147.93	108.0371	1.30
507122	36.10599346	-97.15420642	2353.94	151.97	107.2422	1.12
507124	36.10579415	-97.15324779	2356.56	156.34	106.2012	0.66
507126	36.10560688	-97.15230471	2359.44	160.05	105.0488	0.44
507128	36.10542912	-97.15135695	2357.50	162.84	103.7715	0.37
507130	36.10529719	-97.15039308	2356.19	163.89	101.9082	0.58
507132	36.10515054	-97.14948705	2354.19	165.22	101.0645	0.75
507134	36.10501665	-97.14850577	2355.00	166.64	101.6953	0.83
507136	36.10479626	-97.14747710	2360.25	167.84	102.5000	0.96
507138	36.10457094	-97.14641700	2362.31	168.62	102.6582	1.09
507140	36.10439514	-97.14538760	2362.06	169.54	102.5449	1.13
507142	36.10421336	-97.14431990	2363.94	171.60	103.0039	1.04
507144	36.10401507	-97.14327800	2367.56	174.29	102.7051	1.01
507146	36.10381564	-97.14221271	2368.56	176.90	102.2891	0.91
507148	36.10364860	-97.14114986	2370.13	179.14	101.9590	0.91
507150	36.10344293	-97.14003914	2372.63	180.02	101.3613	1.06
507152	36.10330700	-97.13895652	2374.69	181.19	100.8516	1.20
507154	36.10310835	-97.13783390	2379.13	186.61	101.2695	0.67
507156	36.10294335	-97.13667745	2378.19	189.74	100.2441	-0.01
507158	36.10278403	-97.13554441	2374.38	192.48	98.5078	-0.23
507160	36.10273651	-97.13441337	2371.56	193.94	96.4453	-0.11
507162	36.10262512	-97.13316201	2374.88	195.87	94.9922	0.28
507164	36.10255465	-97.13193801	2375.00	197.13	93.7910	0.58

Table 2.
Example DECODER Output

If the decoded output is to be imported into a spreadsheet, one peculiarity of most ASCII import routines needs to be understood. Most spreadsheets compute the importation field sizes by generating a template from the import file's first line. DECODER places column headings and whitespace (spaces and tabs) in this line. It is this whitespace which confuses the ASCII importation routine's template generation code; therefore, before importing

the numerical data from any decoded file, its column description line should be removed.

5.0 Test Flight

ERDL has designed, constructed, and flown a fully configured airborne GPS navigation system. The test-flight was conceived to verify proper operation of the GPS telemetry downlink hardware. The unit constructed for this test was a battery-powered, self-contained GPS navigation system requiring no input from the user once satellite acquisition was confirmed. An FM/FM transmission technique was used rather than the PCM/FM system described in Section 3.3.1. A channel 18 subcarrier oscillator (70 KHz) was used for re-transmission of TRADAT's 3.9 KHz PCM bit stream, and a channel 7 subcarrier oscillator (2.3 KHz) was used for transmitting the 300 baud GPS navigation solution. This setup was flown on-board a Cessna Skyhawk 172 and proved to be quite successful. The S-band transmitting antenna was located on the baggage compartment door along with the TRADAT uplink receiving antenna (550 MHz). The GPS antenna was mounted on top of the airplane on a special mounting bracket placed over the emergency transponder beacon antenna. This position provided a location with minimal to no GPS satellite signal blockage during maneuvering while in flight.

5.1 System Description

The test system consisted of the following items:

- NAVCORE I GPS receiver
- Collins Data converter
- RS-232C to 0-5 Vdc level converter
- Channel 7 +/- 7.5% proportional-bandwidth VCO
(used for GPS 300 baud A6 block data transmission)
- Channel 18 +/- 7.5% proportional-bandwidth VCO
(used for OSU TRADAT ranging system)
- Vector Series T102S 2251.5 MHz S-band transmitter
- Quanta R104N-150/12 550 MHz TRADAT ranging uplink receiver
- 2 28 V dc batteries

Personnel on-board the aircraft were the pilot and a lab engineer; the engineer as passenger was provided with the NAVCORE I receiver's control/display terminal and a power distribution control panel designed specifically for this application. The power distribution panel provided the passenger with a means of powering the GPS receiver and S-band transmitter independently of one another. This power distribution panel also allowed the operator to monitor the battery voltage for each piece of equipment (GPS receiver/data converter, and S-band transmitter).

During the preliminary test flight, GPS data was being stored on magnetic tape and the PC's hard drive. The program executed to perform data storage on the PC was a modified version of the DISP_REC program. The program, as provided by Collins, only allowed for storage of the high-speed (9600 baud) data port on the GPS receiver not the 300 baud data output from the data converter.

Since the source code was not available from Collins, a few hours of debugging resulted in locating and modifying the RS-232 baud rate selection routine. The section of code to be modified is

located at CS:1B0416. This line of code determines the number of times to shift right the value C00016. Once the value has been shifted by $(nn - 84 + 1)_{16}$ times that value is loaded into the LSB and MSB of the baud rate selection divisor latches. The line of code is:

```
CS:1B02 B18F      MOV CL,nn
```

The value of 8F16 for nn will select 9600 baud, and the value 8A16 will select 300 baud operation. Replacing the value of nn allows one to select from several baud rates. The list below shows the value of nn required to obtain the any one of the listed baud rates:

Value of nn	Baud Rate
8F	9600
8E	4800
8D	2400
8C	1200
8B	600
8A	300

The modified version is called DISP_300, while the unmodified version is named DISP_96.

5.2 Presentation of Results

The recorded data was decoded with DECODER to obtain ASCII files for all A6 data blocks received during the flight. This data was imported into a spreadsheet to obtain various data plots:

- Latitude vs. Longitude
- Speed vs. Time
- Vertical Speed vs. Time
- Altitude vs. Time

These plots are shown in Figures 5 - 8.

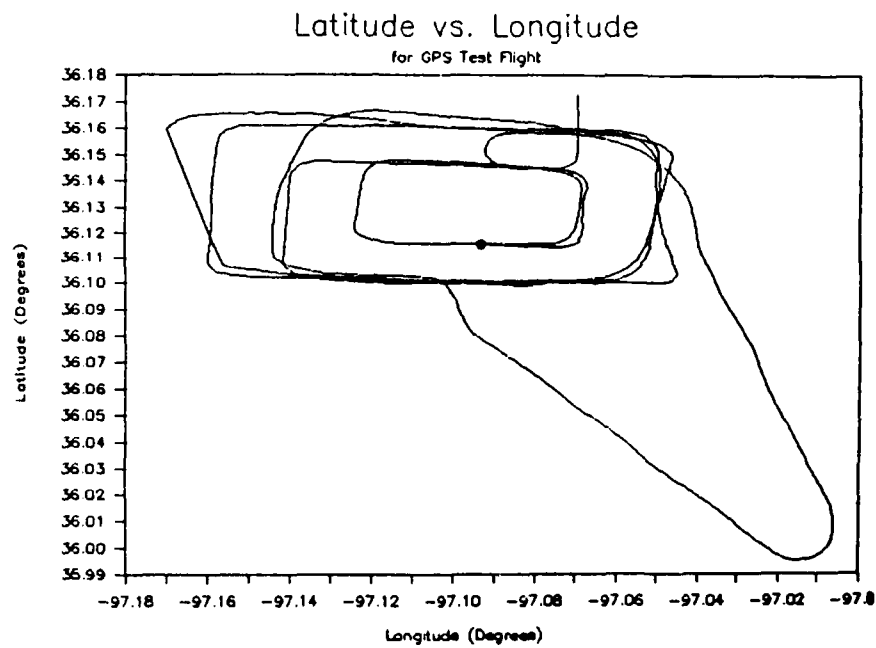


Figure 5.

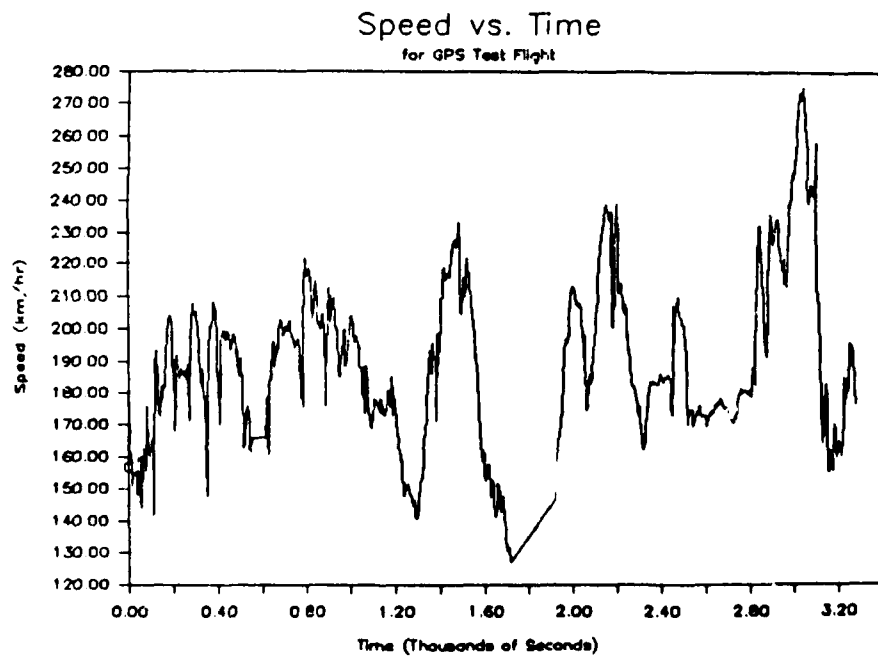


Figure 6.

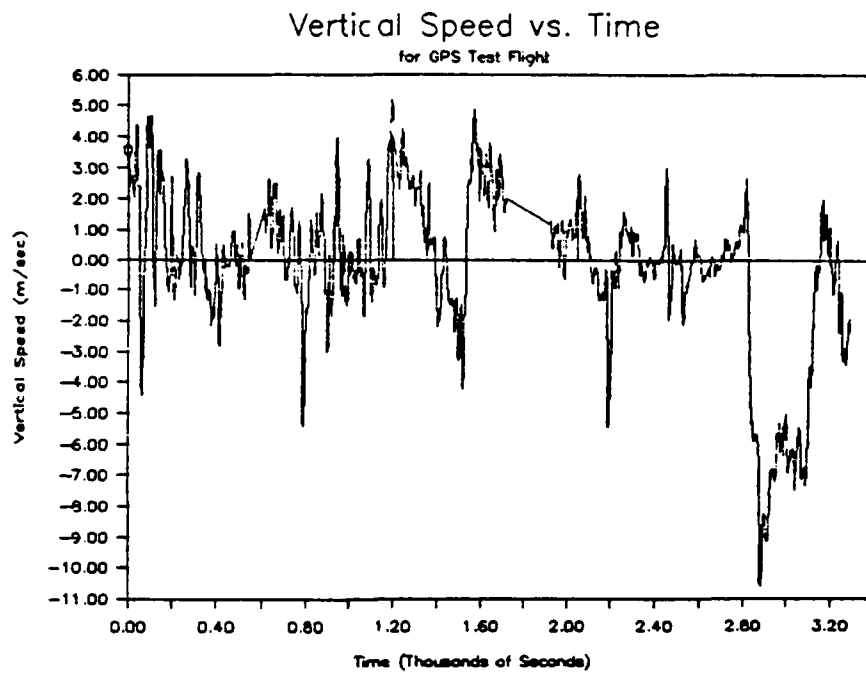


Figure 7.

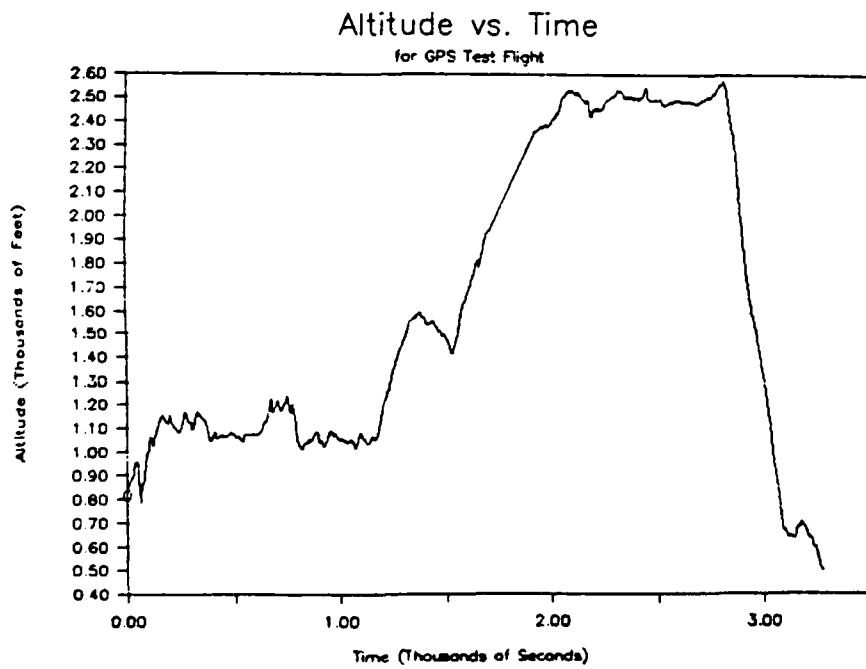


Figure 8.

The discontinuities observed in these figures are the result of data lost during the time required to change tape reels on the recorder during the flight.

6.0 System Limitations

The main limitation of using the present GPS system arises from the fact that the complete constellation of 18 satellites is not in place. This results in a daily coverage period of 4 to 6 hours for using the GPS system for 3-dimensional location determination. The hours of coverage might not occur during the time of the scheduled event or might not last long enough for use during the entire flight. Secondly, increased solar activity perturbs the ionosphere causing the signals transmitted by each SV to experience larger and unpredictable delays as they travel through the earth's ionosphere. As a result, the calculated position will become less accurate. On days of high ionospheric activity, these errors may be on the order of 30 meters or more.⁴

ENDNOTES

¹Collins NAVCORE I Global Positioning System Equipment, Rockwell International Publication No. 074-3862-000.

²Collins NAVCORE™ I GPS C/A Receiver Instruction Manual, Collins Air Transport Division Publication No. 523-0774061-002111, Cedar Rapids, Iowa, 1 Aug 1986, pg. 4-3.

³J.J. Spilker, Jr., "GPS Signal Structure and Performance Characteristics", Global Positioning System, Volume 1, The Institute of Navigation, Washington D.C., 1980, pg. 31.

⁴B.G. Glazer, "GPS Receiver Operation", Global Positioning System, Volume I, The Institued of Navigation, Washington D.C., 1980, pg. 86.

REFERENCES

- Collins NAVCORE™ I GPS C/A Receiver Instruction Manual, Collins Air Transport Division Publication No. 523-0774061-002111, Cedar Rapids, Iowa, 1 Aug 1986, pg. 4:3.
- J.J. Spilker, Jr., "GPS Signal Structure and Performance Characteristics", Global Positioning System, Volume I, The Institute of Navigation, Washington D.C., 1980, pp. 29-54.
- A.J. Van Dierendonck et al., "GPS Navigation Message", Global Positioning System, Volume I, The Institute of Navigation, Washington D.C., 1980, pp. 55-73.
- B.G. Glazer, "GPS Receiver Operation", Global Positioning System, Volume I, The Institute of Navigation, Washington D.C., 1980, pp. 81-86.
- Stiglitz, Martin R., "The Global Positioning System", Microwave Journal, April 1986, pp. 34 ff.
- Eastwood, Raymond A., "Early Applications of Civil GPS", Reprinted from PLANS '84 by Magnavox, Publication No. MX-TM 3393-84, November 1984.

APPENDIX

PROGRAM INSTRUCTION MANUALS

SATVIS
DISPLAY/RECORD
DECODER
CONV-A5

NAVCORE I RECEIVER INTERFACE WIRING DIAGRAM

NAVCORE I DATA BLOCK SUMMARY

SATVIS, DECODER, and CONV-A5 program instructions are provided courtesy Rockwell International Corp. Collins Air Transport Division Cedar Rapids, Iowa.

INSTRUCTIONS FOR USING SATVIS ON IBM PC PROVIDED BY COLLINS-ROCKWELL INTERNATIONAL

The program SATVIS is a system for generating visibility data for the NAVSTAR GPS satellites. Operating on an IBM Personal Computer with 256K of memory and an 8087 coprocessor, the program takes as input the users latitude, longitude, altitude, a mnemonic name for the location, date for calculations and optionally time zone offset from UTC. The SATVIS program provides several optional formats for the output data.

- 1 - Tabular az/el listing. Azimuth and elevation, for each satellite, at 20 minute intervals over the entire day.
- 2 - Polar graphic plot. The same data as (1) above in graphical form.
- 3 - Bar chart of number visible vs. time.
- 4 - Times of rise/set for each satellite.
- 5 - Tabular GDOP vs. time listing. For each twenty minute interval the values of GDOP PDOP TDOP HDOP etc. are listed. This can be for all possible combinations of 4 SV's or for the 3 combinations with the best GDOP
- 6 - Graphic plot of GDOP for a specific set of 4 SV's. Optionally you can select that all combinations be plotted. (Note. This can produce a lot of data!)

The tabular data (1,3,4, and 5 above) can be displayed on the screen, sent to an EPSON FX-80/100 printer or routed to a file. Only the EPSON printer is supported. Other printers have different control sequences and therefore will not produce the proper page formats for the outputs. Graphic data (2 and 6 above) can be displayed on the screen in IBM PC's equipped with the HERCULES graphics card. Graphics data can also be routed to the EPSON printer. Again, other printers or graphics hardware will not necessarily work. The control of routing for output data is by means of a command line argument. Examples of this are:

```
SATVIS -oprn           (Route output to printer)
SATVIS -osavefile.sat (Route output to the file
                      savefile.sat)
SATVIS                (Output goes to the screen)
```

A batch file called PREDICT.BAT is also included on the disk. Rather than entering SATVIS -oprn, the command PREDICT can be used to route the output to the printer.

There is a second command line option possible. The data on the satellite orbits is contained in the file ALMANAC.DAT. Most users need not be concerned with this file.

If, however, you wish to generate data for some other configuration of satellites, or to use an older/newer version of the almanac data then you can specify this by including -afile.ext on the command line. The program will then read the almanac data from the specified file rather than ALMANAC.DAT from the actual satellites. The accuracy of this data tends to degrade with time and this file needs to be updated periodically. When you run SATVIS the date of the almanac will on the az/el tabular listing as -REF WEEK. The date of computation is also shown as GPS WEEK. The data produced will be less accurate for larger differences in these values. This is not normally a problem until the difference is larger than 15 or 20 weeks. Updates of ALMANAC.DAT will usually be available ever 6 or 8 weeks and whenever new satellites are launched or other constellation changes occur. This file is available from the Rockwell VSRBBS (remote bulletin board system).

To aid users who frequently generate data for a specific location, a table of common locations is included. This table may be added to or modified by the individual user. Initially the program will ask if you want to use Cedar Rapids, IA as the user location. Answering no (N) will cause the other options to be displayed. If the desired location is not in the table you can enter the necessary data manually. In that case the data will not be saved permanently. To change the table permanently you need to modify the file USER_POS.DAT. Using an editor you can modify this file as described below. WORDSTAR is not recommended for this purpose, If you must use WORDSTAR be sure to use the non-document mode. To add a location (the maximum number is 48) just edit the file USER_POS.DAT to add the data for the new location. The format for each line in the file is:

Name/Description of location @ latitude, longitude, altitude where:

Name/Description can be up to 39 characters (A-Z,0-9,+,-,.,space or comma). is the delimiter for the end of the string.

Latitude and longitude format is hdd-mm-ss.s where:

h	= N,S,E,or W	dd	= degrees
mm	= minutes of arc	ss.ss	= seconds of arc.

Altitude is in meters.

No blank lines are allowed in the file.

After the program begins execution, answer the various prompts in the formats shown. When entering the date, only two digits are required for the year. Entering the full 4 digit year is also valid. If you use the 2 digit form, any year less than '80 will be interpreted as the next century.

e.g. 1-JAN-79 means January 1, 2079. Month names are only checked to the first 3 characters so Feb, February and Febuary all do the same thing.

When asked if you wish to display times as UTC, if you answer no (N), you enter the offset for the time zone of the location chosen. Remember time zone offsets are positive to the east of Prime Meridian and negative to the west. For example CST is -6 hours while most of Europe is at +1 hours. Don't forget to allow for day light savings time. The time zone offsets must be an integer number of hours, so places like India (at +5 hrs 30 min) can not be specified exactly. Unless you are hopelessly parochial it is probably best to do everything in UTC anyway - this completely eliminates the problems with time zones, day light savings time and various dates of change-over.

Currently there are some minor problems associated with answering the questions which require only a single character input. Collins personel have not been consistent as to whether or not a carriage return (the ENTER key) is required following the input. Don't type too fast or you may be surprised.

Another problem is possible if your printer runs out of paper or for some other reason the program is unable to talk to the printer while in the middle of a graphics printout. In this case the screen will be left in the graphics mode while DOS is trying to display an error message on the text page. You will not be able to see this message. The effect is that the system seems to die or do all sorts of funny things. The best way out is to reboot and start over after you find out why the printer is not talking to the IBM pc.

GPS Display / Record Program Instructions

To start displaying and/or recording GPS data, from the DOS prompt load the program (C:\GPS\)\DISP_REC. Enter the name of the data file to hold the received data. If two streams of GPS data are to be received, enter the other filename when asked for name of COM2: data storage file else just press the return key.

Keyboard Commands

Type 'D' to enter blocks of data that you wish to see displayed on the screen. Enter the blocks separated by a space, i.e. A6 A7 A9. All blocks will be recorded regardless of whether or not they are being displayed, if you have the record function turned on. You can change the blocks that are being displayed at any time by typing 'D'. This will not interrupt the recording process.

To start recording data to the disk press the 'S' key. You are then asked to enter the time at which you want the recording to start, or just press 'ENTER' to start recording immediately.

To stop recording data to the disk type 'E'. You are asked to enter the time you want the recording to stop or just press 'ENTER' to immediately stop recording.

COLLINS NAVCORE G P S Data Recorder, V2.10 29-Sep-1986
Recording started at 14:13:00

COM1 Data file: gps.dat Errs (P F O) = 0 0 0 Blks: 0/17172

Enter labels to be displayed: A6 A7 A9 A0
Press "X" to eXit to DOS

A typical display screen with actual GPS data would look something like the following:

COLLINS NAVCORE G P S Data Recorder, V2.10 29-Sep-1986
Not Recording Data

```
COM1 Data file: gps.dat      Errs (P F O) = 0 0 0 Blks: 5/17172
A6:511672.200 W97 05'01.47" N36 02'58.71" 309.01 .2 77.97 .03
A7:511672.200 132.9      9.4      9.4  4 -6 -9 -11 -13
                87.1      37.4      13.6
                250.5     326.4     233.5
A9:511670.813 191      79666     1987   1  4 6 11 9 13      13  0.0
A0:511671.353   6       132
A1:511671.560  11       138
```

Press "X" to eXit back to DOS

Briefly - the data blocks contain the following information:

- A6 - the longitude, latitude, altitude, speed, heading, and vertical speed.
- A7 - error information, best satellites to track, elevation and azimuth angles of the best satellites available.
- A9 - the day of year, seconds of the day, year, and the actual satellites that are being tracked.
- A0-A3 - signal strength of the satellites being tracked.
- A4 - used only when testing the receiver
- A5 - location and X, Y, & Z velocities in earth-centered, earth-fixed (ECEF) coordinates.

A6, A7, and A9 usually contain all of the information that is needed.

See the Collins NAVCORE receiver operating manual for more detail on these data blocks.

Description of Program DECODER v 1.2

0.0 Revision History

Doc Rev	Doc Date	DECODER Ver	DECODER Date
-	1 Oct 85	0.0	7 Sep 85
A	7 Jan 85	1.0	16 Dec 85
B	16 Apr 86	1.1	19 Apr 86
C	19 Jun 86	1.2	19 Jun 86

1.0 Program Scope.

Program DECODER retrieves NAVCORE instrumentation data records of user selected types from a DOS binary files. The data from each set of records of one selected type are interpreted into ASCII format and tabulated in DOS text files. While DECODER v1.2 recognizes all of these record types, it can interpret only the following record types:

A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AB
C9 CA
E1 E2 E3 E6
F3

DECODER can operate with command-line-only user input. DECODER also provides a means for examining and modifying binary instrumentation data in RAM.

2.0 User's Guide to DECODER.

2.1 Host Computer Requirements.

DECODER is to be used on an IBM PC or compatible configured as follows:

- (1) DOS version 2.0 or higher.
- (2) CONFIG.SYS contains the line FILES=20.
- (3) A disk drive or virtual disk drive identified as drive C:.. (optional)

The default directory on drive C: is the default target for program output. If drive C: does not exist, program will direct output to default drive/directory.

2.2 DECODER Input.

DECODER uses at input a DOS binary file created by program RECORD, DISP_REC et al. This file contains all instrumentation data produced by one NAVCORE unit during a given time interval. The

instrumentation file is an accumulation of instrumentation records as they are produced; so the records occur in roughly chronological order by time tags. The format and content of the various types of instrumentation records are shown in the data block summary contained at the end of this appendix.

2.3 DECODER Output.

The primary output of DECODER is a set of DECODER created DOS output files, each of which is a table of the information contained in the instrumentation data records of one selected record type. In general, each line of an output file corresponds to one instrumentation data record.

Output files are named as follows:

< drive / directory path >< filename >< extension >

where < drive / directory path > is a character string specified in the command line, < filename > is the filename portion of the instrumentation data file specification, and < extension > is a string comprising '.', the hex value of one byte record label, and segment identifier. If not specified in the command line, < drive / directory path > is set to default directory on drive C:.

2.4 Invoking DECODER from DOS.

DECODER may be invoked from DOS by typing the character string "decoder", followed by an optional list of parameter fields (character strings) separated by blanks, and a carriage return. The command line parameters are of three types:

- (a) instrumentation data filespec.
- (b) options.
- (c) record type-segment identifiers (section 2.5.1).

Option parameters are designated by a "-" as the first character of the parameter string. Two option types are recognized. These are designated by the character "o" or "l" in the second position of the parameter string.

Option "-o" identifies the path specification to be used for the output file names. The character string used for this path specification is the command line parameter string itself, less the initial "-o".

Option "-l" specifies a file which contains a list of record type-segment identifiers. The character string used for the file specification is the command line parameter string itself, less the initial "-l".

DECODER supports the DOS output pipeline facility. Specification of a destination device/file at the end of the command line will redirect to this destination most information normally output to the screen. Exceptions are:

- (1) Prompts for input.
- (2) Output of of input buffer upper bound position.
- (3) Output associated with manual editor.

2.5 DECODER Operation.

DECODER performs four tasks:

- (a) Data retrieval job specification. (section 2.5.1)
- (b) Data retrieval. (section 2.5.2)
- (c) Edit. (section 2.5.3)
- (d) Program mode control. (section 2.5.4)

2.5.1 Data Retrieval Job Specification.

DECODER enters this mode upon being invoked from DOS. In this mode DECODER obtains the following specifications:

- (a) the name of the DOS binary file from which DECODER is to extract records. (section 2.5.1.1)
- (b) the types of records DECODER is to retrieve. (2.5.1.2)

2.5.1.1 Instrumentation Data File Specification.

If the first command line parameter is not an option parameter (section 2.4), then it is used as the input file pathname specification. If no command line parameters are supplied, or if the first parameter is an option, the DECODER runstream will prompt the user for input of a valid filename.

2.5.1.2 Specification of Record Types to be Retrieved.

DECODER offers four methods by which record types may be selected for retrieval from the instrumentation data file:

- (1) Explicit command line specification of the types of records to be retrieved.
- (2) Command line specification of a file containing the types of records to be retrieved.
- (3) Runstream specification of a file containing the types of records to be retrieved.
- (4) Explicit runstream specification of the types of records to be retrieved.

DECODER scans the command line to find option parameters. If no "-l" option is found, DECODER will attempt to interpret all remaining command line parameters as record type-segment identifiers. Only those which correspond to legitimate record types will be used.

If no "-l" option is found and no legitimate record type-segment identifier is found in the command line, DECODER will prompt the user for the specification of a valid file containing record type-segment identifiers. A <CR> response to this prompt will cause DECODER to prompt the user for explicit input of record type-segment identifiers from the runstream. (Keyboard i.e. a6,a5)

For each selected record type DECODER will, in general, create one output file containing the information extracted from all records of that type found in the instrumentation data file. Certain types of records contain more data per record than can be tabulated in an 80-column text file with the desired clarity and precision. For these record types, which are listed in Table 2-1, DECODER creates two or more output files, each containing one segment of the record data in table form.

DECODER may be directed to retrieve either one segment or all segments of each selected record type. The program user decides this issue individually for each selected record type.

At any of the above described input sites, the user designates a record type via a "record type-segment identifier", which has the following format:

XXS

where XX is the hex value of one byte of the record label, and S is a single numeric digit which designates the segment to be extracted.

If the S field is '0', empty, non-numeric, or numerically greater than the number of segments allocated for the associated record type, DECODER will extract and output all data segments for that record type.

2.5.1.3

DECODER permits the user to limit record retrieval/decode to those records (of the select types) whose time tags fall within a user specified time tag window.

This time tag window is specified via the -b and -k option fields in the command line. The -b and -k option fields specify minimum and maximum endpoints, respectively, of this window.

The -b option has the form "-b#####" , a string without blanks, where ##### is a floating point value. A record whose time tag is less than this value will not be retrieved. If the -b option is not specified, DECODER uses -1E+38 as the minimum criterion on record time tag.

The -k option has the form "-k#####" , a string without blanks, where ##### is a floating point value. A record whose time tag is greater than this value will not be retrieved. If the -k option is not specified, DECODER uses +1E+38 as the maximum criterion on record time tag.

2.5.1.4 Output file pathmane specification

As described in section 2.5.1.1, DECODER will create one or more DOS output file(s) as the destination for the data retrieved and decoded from each selected instrumentation record type. The format of the file specification for each of these output file is

path\filename.ext

The -character DOS filename for each of these output files is the same as that of the input instrumentation data file.

The 3-character DOS extension for each of these output files has the form

XXS

where XX is the hex value of one byte of the record label, and S is a single numeric digit. If the record type is one of those whose contents are decoded into a single output file, then this S digit is '0'. If the record thpe is one of those listed in Table 2-1, whose contents are decoded into more than one output file, then this S digit identifies the segment of record data stroed in that file.

The path specification is determined via one of the following ways.

If the -o option is not invoked in the command line and the C: drive exists, then the path specification of each of these output files is the default directory of drive C:.

If the -o option is not invoked in the command line, and the C: drive does not exist, then the path specification of each of these output files is the default directory of the default drive.

If the -o option is invoked in the command line, then this command line string, less the initial "-o", is the DOS path used for each of the output files.

2.5.2 Data Retrieval.

The data retrieval mode accomplishes the primary objective of DECODER,

- * retrieval from the instrumentation data file of data records of the designated types and with time tags in the designated window.
- * decode of binary formatted data to ASCII format.
- * tabular presentation, in ASCII formatted DOS files, of the data extracted from the set of records of each type.

2.5.2.1 Byte Scan.

The first two bytes of an instrumentation data record are identical and comprise the record label. The record label identifies the record type.

DECODER scans the contents of the instrumentation data file, one byte at a time, to find the start of a record. DECODER continues to scan until two identical bytes are found. DECODER then tests whether this pair of identical bytes corresponds to NAVCORE instrumentation data record type. If so, DECODER either skips or decodes the appropriate number of subsequent bytes, depending upon whether or not that particular record type is selected for retrieval. After this record is skipped or decoded, DECODER anticipates the start of a new record at the next byte. If the first two bytes following the end of the previous record do not correspond to a legitimate record type, DECODER enters editor mode, described in section 2.5.3.

DECODER decodes the time tag field of all "found" records, whether or not the record is of a type selected for retrieval.

2.5.2.2 Input Buffer.

DECODER does not read individual bytes directly from disk. Rather, DECODER reads 1K blocks of data from the instrumentation file into a 4K RAM input buffer and then scans this buffer -- one byte at a time -- to find, skip, or decode records. A buffer pointer indicates the byte currently being scanned. While DECODER is searching for the start of a record, input from the instrumentation data file is regulated to maintain the upper bound of the input buffer 2K-3K ahead of the buffer pointer. When DECODER is in one of its edit modes (section 2.5.3), the position of the input buffer with respect to the instrumentation file is held static, and the buffer pointer may be positioned anywhere within the bounds of the buffer.

2.5.3 Editor.

DECODER has a limited edit capability which permits the user

- (1) to examine the portion of the instrumentation file currently resident in the input buffer.
- (2) to overwrite the input buffer at any desired point with a valid record label.

DECODER enters its editor when, in the data retrieval processing, the beginning of a record is expected but not found -- i.e., the byte identified by the buffer pointer is not identical to the next byte, or the two bytes together, e.g., 47 47, do not comprise a legitimate record label. The DECODER editor cannot be entered by user command.

The DECODER editor features two modes, manual and automatic. These are selected via the DECODER program mode control procedure, described in section 2.5.4.

2.5.3.1 Manual Editor.

The manual editor permits the user to view a sixteen byte window anywhere within the input buffer. The window comprises the block of sixteen bytes whose starting byte is currently identified by the buffer pointer. Viewing other portions of the input buffer is accomplished by scrolling the buffer pointer up and down value via the <HOME>, <LEFT ARROW> and <RIGHT ARROW> keys. Control <LEFT/RIGHT ARROW> scrolls eight bytes at a time: <LEFT/RIGHT ARROW> scrolls one byte at a time. <HOME> returns the buffer pointer to its initial position at entry to the editor.

The manual editor also permits the user to overwrite one byte in the input buffer with a keyboard entered value. Typing any alphanumeric character during a manual edit session initiates specification of a two-character string which determines this value. This two-character string is displayed on the screen and may be edited or deleted with the BACKSPACE key. If, upon exit from the editor, this string is interpretable as the hex representation of a value between 0 and 255, DECODER will overwrite the input buffer byte at the current input buffer pointer position with this value.

The Manual editor is exited by pressing <CARRIAGE RETURN>, at which time DECODER resumes its scan of the data in the input buffer from the position currently identified by the buffer pointer. If, at editor exit, the optional character string entered by the user during edit is interpretable as the hex representation of a number between 0 and 255, the bytes at <buffer pointer> and at <buffer pointer+1> will be overwritten with this number. If this number corresponds to a legitimate instrumentation data record label, as described in section

2.5.2.1, DECODER would find that record label at <buffer pointer> immediately upon exit from the editor.

2.5.3.2 Automatic Editor.

The automatic editor performs a series of tests upon instrumentation data bytes in the vicinity of the buffer pointer. These tests are ones that the program user, via the manual editor, might reasonably apply to identify and "resurrect" a damaged record.

The following sequence of test steps performed are:

- (1) The four bytes corresponding to the time tag of the expected record -- at <buffer pointer+2> thru <buffer pointer+5> -- are decoded as a 4-byte integer field. This decoded value is interpreted as a time tag, TTnew, and is compared to the time tag, TTold, of the immediately previous record.

If $TTnew < TTold$ or $TTnew \geq (TTold + \text{one hour})$, then Automatic Editor proceeds to Step #2; otherwise, Automatic Editor skips to Step #3.
- (2) DECODER exits Automatic Editor, resumes record label search starting at <buffer pointer-L+1>, where L is the length of the previous record. All remaining steps of this test sequence are skipped.
- (3) The value, nn, of the first byte of the expected record label, at <buffer pointer>, is compared against the list of legal record types.

If "nn nn" corresponds to a legal record type -- the odds of this happening are 38/256 -- then Automatic Editor proceeds to Step #4; otherwise, Automatic Editor skips to Step #6.
- (4) Automatic Editor examines the pair of bytes at <buffer pointer+N> and at <buffer pointer+N+1>, where N is the length of record type nn, and tests whether or not this byte pair corresponds to a legal record type, as described in section 2.5.2.1.

If this byte pair corresponds to a legal record type, then Automatic Editor proceeds to Step #5; otherwise, Automatic Editor skips to Step #6.
- (5) Automatic Editor overwrites the bytes at <buffer pointer> and at <buffer pointer> with value nn. DECODER then exits Automatic Editor and resumes record label search at <buffer pointer>.

- (6) Automatic Editor performs the equivalent of Steps #3, #4 and #5 for the second byte of the expected record label, at <buffer pointer+1>.

2.5.4 DECODER Program Mode Control.

The program mode control procedure of DECODER allows the user

- (a) to select/deselect Editor mode and
- (b) to control the volume of auxiliary info DECODER writes to the standard output device during its execution.

Users can invoke the program mode control procedure any time during DECODER execution by pressing and holding the "h" key.

The mode control procedure allows the user to select one of three levels, MIN, NORM, and MAX, of program output to the standard output device.

The mode control procedure allows the user to select manual (MAN) or automatic (AUTO) Editor mode, or to inhibit entry to Editor (OFF). If OFF is selected, DECODER does not enter Editor upon the "record label expected but not found" condition described in section 2.5.2.1; instead, DECODER searches for a new record label, resuming byte scan at <buffer pointer+1>.

3.0 DECODER Organization.

To be supplied.

Table 2-1
Number of DOS Output Files Created by DECODER v1.2
for each NAVCORE Instrumentation Data Record Type

Record Label	Number of Output Files (segments)
A0	1
A1	1
A2	1
A3	1
A4	1
A5	2
A6	1
A7	1
A8	1
A9	1
AA	1
AB	1
AC	1
C9	2
CA	1
E1	1
E2	1
E3	2
F3	1

Program to reduce navigation solution data from a NAVCORE type A5 instrumentation file.

Data reduction task includes:

- (1) Computation of navigation error w.r.t. a reference position.
- (2) Transformation of error vector from ECEF to local tangent plane.
- (3) Computation of error statistics.

Program uses three DOS files for I/O:

- (1) INPUT data file, an type .A51 instrumentation data file produced by DECODER.
- (2) OUTPUT data file.
- (3) An input file containing default values for user set position, earth model, etc. This can be the DGPS-A5.DEF defaults file used by program DGPS-A5.

DOS pathnames for these three files may be specified on the DOS command line, in the order shown. Pathnames may be up to 80 characters in length.

If an INPUT file pathname is not supplied on the command line or if the specified INPUT file does not exist, CONV-A5 will prompt user to enter a pathname until a valid DOS file is found and opened.

If an OUTPUT file pathname is not supplied on the command line, CONV-A5 will prompt user to enter one.

If a DEFAULTS file pathname is not supplied on the command line, CONV-A5 will use the 'DGPS-A5.DEF' as the pathname spec. If the specified DEFAULTS file does not exist, will prompt user to enter a pathname until a valid DOS file is found and opened for input.

Program can use as input:

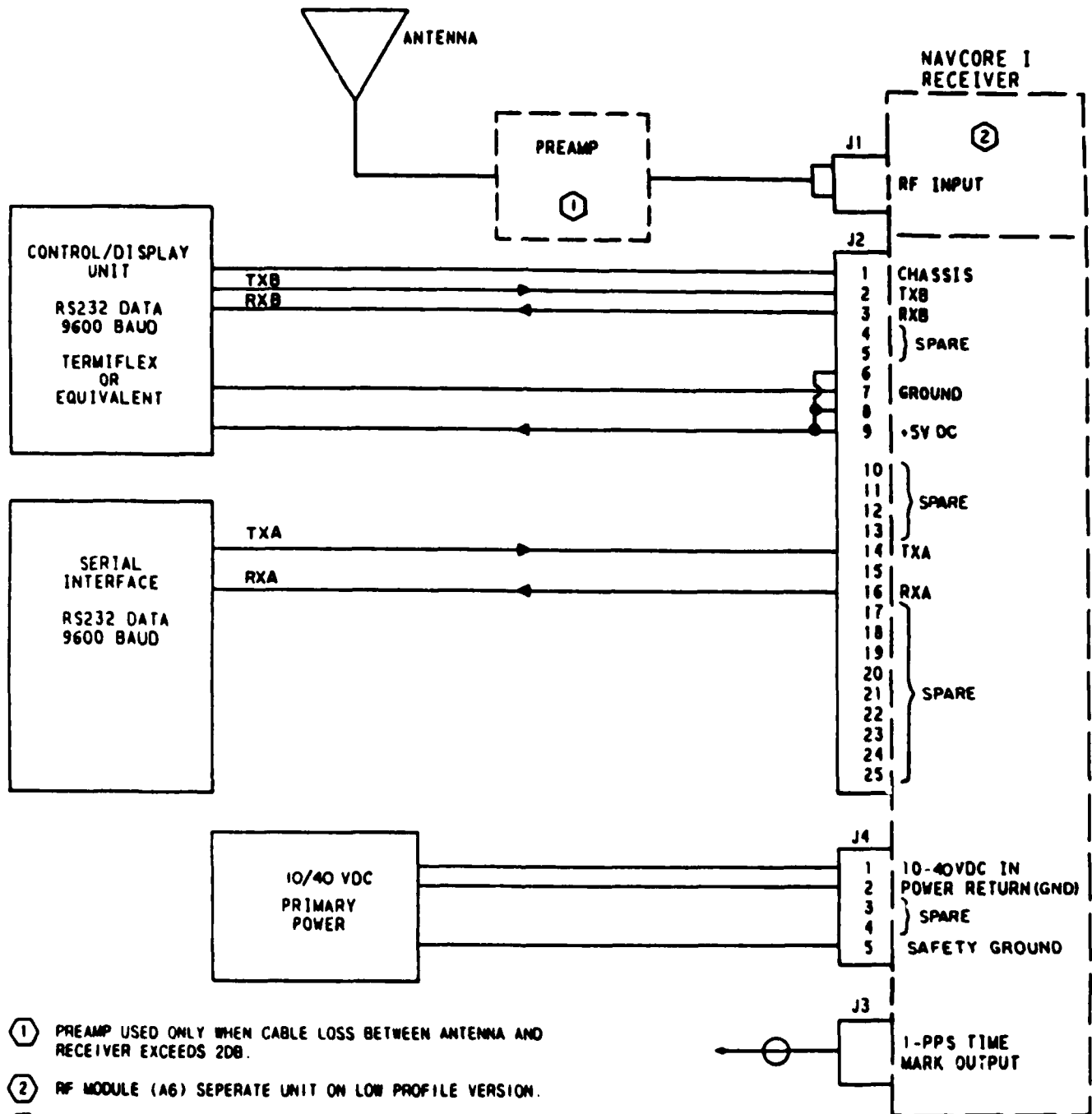
- (1) Type A5 file created by DECODEH.EXE.
- (2) Type A5 file created by DECODER.COM.

NOTE: CONV-A5 always assumes that the input data are in ECEF. It converts these to LTP coordinates.

Program output is spreadsheet importable.

While reading and processing the data, CONV-A5 annunciates the current number of 'good' data points on the PC console screen. This not only alleviates boredom for the user also allows the run to be terminated by <Ctrl-Brk>.

NAVCORE I INTERFACE WIRING DIAGRAM from NAVCORE I User's Manual



- ① PREAMP USED ONLY WHEN CABLE LOSS BETWEEN ANTENNA AND RECEIVER EXCEEDS 20DB.
- ② RF MODULE (A6) SEPERATE UNIT ON LOW PROFILE VERSION.
- ③ A DC BLOCK IS REQUIRED WHEN A PREAMPLIFIER IS NOT USED. HOWEVER, A DC BLOCK MAY NOT BE USED WITH A PREAMPLIER. THE DC BLOCKING DEVICE IS REQUIRED IF THE ANTENNA RESISTANCE IS LESS THAN 10K OHMS.

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NAVCORE 1
DATA BLOCK SUMMARY
from NAVCORE 1 User's Manual

	A0A0- A3A3	A4A4	A5A5	A6A6	A7A7	A8A8	A9A9
BLOCK SIZE (BYTES)	10	10	54	34	212	60	28
LABEL FIELD	116 2 BYTES	116 2 BYTES	116 2 BYTES	116 2 BYTES	116 2 BYTES	116 2 BYTES	116 2 BYTES
TIME MARK (SET TIME)	1 32 4 BYTES	1 32 4 BYTES	1 32 4 BYTES	1 32 4 BYTES	1 32 4 BYTES	1 32 4 BYTES	1 32 4 BYTES
TEXT	SV NO . 116 (2 BYTES)	SV NO . 116 (2 BYTES)	MODE . (2 BYTES)	E LONG . F40 (6 BYTES)	USER ERROR. F24 (4 BYTES)	UTC BIAS. F40 (6 BYTES)	DAY 116 (2 BYTES)
	CARRIER LEVEL . 116 (2 BYTES)	CARRIER LEVEL . 116 (2 BYTES)	SET TIME AT SOLUTION F40 (6 BYTES)	N LAT . F40 (6 BYTES)	NAV GDOP. F24 (4 BYTES)	UTC DRIFT F40 (6 BYTES)	TIME . 1 32 (4 BYTES)
			ECEF X POSITION. F40 (6 BYTES)	WGS72 ALTITUDE. F24 (4 BYTES)	BEST GDOP F24 (4 BYTES)	SET DELAY F40 (6 BYTES)	YEAR. 116 (2 BYTES)
			ECEF Y POSITION. F40 (6 BYTES)	SPEED. F24 (4 BYTES)	VISIBLE SATELLITE. 116 (2 BYTES)	WEEK NO . 116 (2 BYTES)	MODE/ NUMBER. (2 BYTES)
			ECEF Z POSITION. F40 (6 BYTES)	DIRECTION. 24 (4 BYTES)	SATELLITE ID 116 (24 BYTES)	WEEK STAT. 116 (2 BYTES)	SV NO (S) (8 BYTES)
			RANGE BIAS. F40 (6 BYTES)	VERTICAL SPEED. F24 (4 BYTES)	SATELLITE SOURCE DATA 116 (24 BYTES)	ALTITUDE DIFFERENCE 116 (2 BYTES)	GDOP 116 (2 BYTES)
			ECEF X VELOCITY. F24 (4 BYTES)		SATELLITE ELEVATION ANGLE. F24 (48 BYTES)	TIME OF VALIDITY F40 (6 BYTES)	USER ERROR 116 (2 BYTES)
			ECEF Y VELOCITY. F24 (4 BYTES)		SATELLITE AZIMUTH COS. F24 (48 BYTES)	RESERVE (24 BYTES)	
			ECEF Z VELOCITY. F24 (4 BYTES)		SATELLITE AZIMUTH SINE. F24 (48 BYTES)		
			RANGE DRIFT. F24 (4 BYTES)				

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