# LV1b SRAM Packet Definitions

**Version Tracking**

| Date | Notes |
|---|---|
| 10/04/00 | Created as separate document from the Downlink packets. |

## *Discussion*

LV1b has 1MB (1,048,576 bytes) of SRAM (static RAM) that is backed up by a small 3.3V Lithium battery. This SRAM is specifically meant to capture the raw data from the IMU for later analysis on the ground, specifically for high accuracy INS simulations. The data stored in the SRAM is exactly like the data packets sent down the 900MHz downlink, with a few subtle changes such as no CRC and the IMU data packets are raw samples (they aren't digitally low pass filtered).

Note that the first 256 bytes of the SRAM are reserved for Flight Computer state storage and restoration; thus all packets start at address 0x00100 or greater in SRAM.

## *SRAM Packet Types*

There are 5 packet types, some with packet subtypes (note there is no null packets):

```
0x10    GPS Packet
0x20    Status Packet
0x30    INS Packet (NOT IMPLEMENTED)
0x4n    Message packet, where n is the number of message 0x0 - 0xF corresponding to 1 - 16 messages.
0x5n    Raw IMU data packet, where n = 0 is the full 12bit data and n = 2 is delta encoded data
```

## *SRAM Packet Structure*

All packets have the following structure (note no CRC bytes):

```
0x00    Packet Header
PT      Packet Type: 0x10 - 0x60
<D>     Data (length dependent on Packet Type)
0xFF    Footer
```

## *SRAM Packet Frequencies*

Just like the downlink, some packets are isochronous (come at regular intervals in time). We can expect every second will consist of 1 GPS packet, 10 Status packets, 0 message packets (that's not exact because messages do occur, but it's rare on the second to second time scale), and 10 full IMU packets send after the 10 status packets. That's:

1x74 + 10x26 + 10x17 = 504 bytes / second

Now we also know that the FCOS interrupt, which samples the sensors, occurs at 2.5KHz and we save the IMU data every sample. That gives:

| | |
|---|---|
| 2,500 samples per second * 10 bytes/delta encoded IMU packet = | 25,000 bytes per second |
| 2,500 samples per second * 17 bytes/full IMU packet = | 42,500 bytes per second |

This gives a range of 25,504 - 42,704 bytes per second stored in the SRAM. That gives

(1MB - 256) / (25, 504bytes per second) = 41.1 seconds
(1MB - 256) / (42,704 bytes per second) = 24.5 seconds

The reality should be very close to the only delta encoded IMU packets (41.1 seconds) because the sample rate is so high that the sensors simply don't have time to change very much in 400us since they're low pass filtered on the IMU board to much less than the Nyquist rate (<< 1.25KHz).

So, we can expect about 35 - 40 seconds of SRAM recording time.

### *SRAM Calibration Mode*

In "SRAM Calibration Mode" - when pin RA3 is held low - several changes occur to the packet stored in SRAM:

- Only IMU packets (full and delta encoded) are sent down the downlink (all other packets are turned off)
- The FCF_Rec2RAM bit is set on Startup, causing the FC to immediately begin writing packets to SRAM

When in calibration mode, the SRAM packet storage becomes:

10 samples per second * 17 bytes per full encoded IMU packet = 170 bytes per second
2,490 samples per second * 10 bytes per delta encoded IMU packet = 24,900 bytes per second

The total storage time becomes:

(1MB - 256) / 25,070 bytes per second = 41.8 seconds

## *SRAM Packet Type 1: GPS Data (1Hz, 74 bytes long, No encoding)*

| Byte # | GPS Word # | Name | Units | Range | Res. |
|---|---|---|---|---|---|
| 0 | - | Packet Header 0x00 | - | - | -) |
| 1 | - | Packet Type (1) + No Encoding (0) | - | - | - |
| 2 | 1000.22 | UTC Hours | hours | 0 - 23 | |
| 3 | 1000.23 | UTC Minutes | minutes | 0 - 59 | |
| 4 | 1000.24 | UTC Seconds | seconds | 0 - 59 | |
| 5 | 1000.10&11 | Navigation Solution Validity and Type:<br>4.0 Soln Inv - Altitude used<br>4.1 Soln Type - Propagated Solution<br>4.2 Soln Inv - Not Enough Sat.s<br>4.3 Soln Inv - Exceeded Maximum EHPE<br>4.4 Soln Inv - Exceeded Maximum EVPE<br>4.5 Soln Type - Altitude Used | (Bits) | 1 = True | |
| 6 | 1000.12 | Number of Measurements Used in Solution | | 0 - 12 | # sat? |
| 7 | 1000.27.B0 | Latitude0 | radians | +- 0 - PI/2 | 10e-8 |
| 8 | 1000.27.B1 | Latitude1 | radians | +- 0 - PI/2 | 10e-8 |
| 9 | 1000.28.B0 | Latitude2 | radians | +- 0 - PI/2 | 10e-8 |
| 10 | 1000.28.B1 | Latitude3 | radians | +- 0 - PI/2 | 10e-8 |
| 11 | 1000.29.B0 | Longitude0 | radians | +- 0 - PI/4 | 10e-8 |
| 12 | 1000.29.B1 | Longitude1 | radians | +- 0 - PI/4 | 10e-8 |
| 13 | 1000.30.B0 | Longitude2 | radians | +- 0 - PI/4 | 10e-8 |
| 14 | 1000.30.B1 | Longitude3 | radians | +- 0 - PI/4 | 10e-8 |
| 15 | 1000.31.B0 | Height0 | meters | +- 0 - 40000 | 10e-2 |
| 16 | 1000.31.B1 | Height1 | meters | +- 0 - 40000 | 10e-2 |
| 17 | 1000.32.B0 | Height2 | meters | +- 0 - 40000 | 10e-2 |
| 18 | 1000.32.B1 | Height3 | meters | +- 0 - 40000 | 10e-2 |
| 19 | 1009.10.B0 | ECEF Position - X0 | meters | +- 0 - 9000000 | 10e-2 |
| 20 | 1009.10.B1 | ECEF Position - X1 | meters | +- 0 - 9000000 | 10e-2 |
| 21 | 1009.11.B0 | ECEF Position - X2 | meters | +- 0 - 9000000 | 10e-2 |
| 22 | 1009.11.B1 | ECEF Position - X3 | meters | +- 0 - 9000000 | 10e-2 |
| 23 | 1009.12.B0 | ECEF Position - Y0 | meters | +- 0 - 9000000 | 10e-2 |
| 24 | 1009.12.B1 | ECEF Position - Y1 | meters | +- 0 - 9000000 | 10e-2 |
| 25 | 1009.13.B0 | ECEF Position - Y2 | meters | +- 0 - 9000000 | 10e-2 |
| 26 | 1009.13.B1 | ECEF Position - Y3 | meters | +- 0 - 9000000 | 10e-2 |
| 27 | 1009.14.B0 | ECEF Position - Z0 | meters | +- 0 - 9000000 | 10e-2 |
| 28 | 1009.14.B1 | ECEF Position - Z1 | meters | +- 0 - 9000000 | 10e-2 |
| 29 | 1009.15.B0 | ECEF Position - Z2 | meters | +- 0 - 9000000 | 10e-2 |
| 30 | 1009.15.B1 | ECEF Position - Z3 | meters | +- 0 - 9000000 | 10e-2 |
| 31 | 1009.16.B0 | ECEF Velocity - X0 | meters/sec | +- 0 - 1000 | 10e-2 |
| 32 | 1009.16.B1 | ECEF Velocity - X1 | meters/sec | +- 0 - 1000 | 10e-2 |
| 33 | 1009.17.B0 | ECEF Velocity - X2 | meters/sec | +- 0 - 1000 | 10e-2 |
| 34 | 1009.17.B1 | ECEF Velocity - X3 | meters/sec | +- 0 - 1000 | 10e-2 |
| 35 | 1009.18.B0 | ECEF Velocity - Y0 | meters/sec | +- 0 - 1000 | 10e-2 |
| 36 | 1009.18.B1 | ECEF Velocity - Y1 | meters/sec | +- 0 - 1000 | 10e-2 |
| 37 | 1009.19.B0 | ECEF Velocity - Y2 | meters/sec | +- 0 - 1000 | 10e-2 |
| 38 | 1009.19.B1 | ECEF Velocity - Y3 | meters/sec | +- 0 - 1000 | 10e-2 |
| 39 | 1009.20.B0 | ECEF Velocity - Z0 | meters/sec | +- 0 - 1000 | 10e-2 |
| 40 | 1009.20.B1 | ECEF Velocity - Z1 | meters/sec | +- 0 - 1000 | 10e-2 |
| 41 | 1009.21.B0 | ECEF Velocity - Z2 | meters/sec | +- 0 - 1000 | 10e-2 |
| 42 | 1009.21.B1 | ECEF Velocity - Z3 | meters/sec | +- 0 - 1000 | 10e-2 |
| 43 | 1000.40 | EHPE0 | meters | 0 - 320000000 | 10e-2 |
| 44 | 1000.40 | EHPE1 | meters | 0 - 320000000 | 10e-2 |
| 45 | 1000.41 | EHPE2 | meters | 0 - 320000000 | 10e-2 |
| 46 | 1000.41 | EHPE3 | meters | 0 - 320000000 | 10e-2 |
| 47 | 1000.42 | EVPE0 | meters | 0 - 250000 | 10e-2 |
| 48 | 1000.42 | EVPE1 | meters | 0 - 250000 | 10e-2 |
| 49 | 1000.43 | EVPE2 | meters | 0 - 250000 | 10e-2 |
| 50 | 1000.43 | EVPE3 | meters | 0 - 250000 | 10e-2 |
| 51 | 1000.44 | ETE0 | meters | 0 - 300000000 | 10e-2 |
| 52 | 1000.44 | ETE1 | meters | 0 - 300000000 | 10e-2 |
| 53 | 1000.45 | ETE2 | meters | 0 - 300000000 | 10e-2 |
| 54 | 1000.45 | ETE3 | meters | 0 - 300000000 | 10e-2 |
| 55 | 1000.46 | EHVE0 | meters/sec | 0 - 10000 | 10e-2 |
| 56 | 1000.46 | EHVE1 | meters/sec | 0 - 10000 | 10e-2 |
| 57 | 1000.47 | Clock Bias 0 | meters | +- 0 - 9000000 | 10e-2 |
| 58 | 1000.47 | Clock Bias 1 | meters | +- 0 - 9000000 | 10e-2 |
| 59 | 1000.48 | Clock Bias 2 | meters | +- 0 - 9000000 | 10e-2 |
| 60 | 1000.48 | Clock Bias 3 | meters | +- 0 - 9000000 | 10e-2 |
| 61 | 1000.49 | Clock Bias SD 0 | meters | +- 0 - 9000000 | 10e-2 |
| 62 | 1000.49 | Clock Bias SD 2 | meters | +- 0 - 9000000 | 10e-2 |
| 63 | 1000.50 | Clock Bias SD 3 | meters | +- 0 - 9000000 | 10e-2 |
| 64 | 1000.50 | Clock Bias SD 4 | meters | +- 0 - 9000000 | 10e-2 |
| 65 | 1000.51 | Clock Drift 0 | meters/sec | +- 0 - 1000 | 10e-2 |
| 66 | 1000.51 | Clock Drift 1 | meters/sec | +- 0 - 1000 | 10e-2 |
| 67 | 1000.52 | Clock Drift 2 | meters/sec | +- 0 - 1000 | 10e-2 |
| 68 | 1000.52 | Clock Drift 3 | meters/sec | +- 0 - 1000 | 10e-2 |
| 69 | 1000.53 | Clock Drift SD 0 | meters/sec | +- 0 - 1000 | 10e-2 |
| 70 | 1000.53 | Clock Drift SD 1 | meters/sec | +- 0 - 1000 | 10e-2 |
| 71 | 1000.54 | Clock Drift SD 2 | meters/sec | +- 0 - 1000 | 10e-2 |
| 72 | 1000.54 | Clock Drift SD 3 | meters/sec | +- 0 - 1000 | 10e-2 |
| 73 | | Packet Footer 0xFF | | | |

## *SRAM Packet Type 2: Status (10Hz, 26 bytes long, No Encoding)*

| Byte # | Name | Value(s), Description & Units |
|---|---|---|
| 0 | Header | 0x00 |
| 1 | Packet Type (2) + No Encoding (0) | 0x20 |
| 2 | FCS (Flight Computer Status) | 0x00 = NOT_ARMED<br>0x01 = ARMED<br>0x02 = LAUNCH<br>0x04 = FLIGHT<br>0x08 = APOGEE<br>0x16 = RECOVERY |
| 3 | Local Clock Hours | 00 - 23 (if GPS, it's the GPS' hours) |
| 4 | Local Clock Minutes | 00 - 60 (if GPS, it's the GPS' minutes) |
| 5 | Local Clock seconds | 00 - 60 (if GPS, it's the GPS' seconds) |
| 6 | Local Clock tenths of seconds | Incremented on 10HzClk |
| 7 | FCFlg0 | Flight Computer Flag Byte (8 bit flags) |
| 8 | FCFlg1 | Flight Computer Flag Byte (8 bit flags) |
| 9 | FCFlg2 | Flight Computer Flag Byte (8 bit flags) |
| 10 | FCFlg3 | Flight Computer Flag Byte (8 bit flags) |
| 11 | FCFlg4 | Flight Computer Flag Byte (8 bit flags) |
| 12 | FCFlg5 | Flight Computer Flag Byte (8 bit flags) |
| 13 | FCFlg6 | Flight Computer Flag Byte (8 bit flags) |
| 14 | FCFlg7 | Flight Computer Flag Byte (8 bit flags) |
| 15 | FCFlg8 | Flight Computer Flag Byte (8 bit flags) |
| 16 | FCFlg9 | Flight Computer Flag Byte (8 bit flags) |
| 17 | Atmospheric Pressure High Byte | 0x00 - 0x0F |
| 18 | Atmospheric Pressure Low Byte | 0x00 - 0xFF in k*kPa (12bit value) |
| 19 | Separation Igniter Resistance | 0x00 - 0xFF: ADC conversion value (01 - 06 = ok) |
| 20 | Shroud Igniter Resistance | 0x00 - 0xFF: ADC conversion value (01 - 06 = ok) |
| 21 | IMU Temperature High Byte | 0x00 - 0x03 |
| 22 | IMU Temperature Low Byte | 0x00 - 0xFF in k*° (10bit value) |
| 23 | External Temperature High Byte | 0x00 - 0x03 |
| 24 | External Temperature Low Byte | 0x00 - 0xFF in k*° (10bit value) |
| 25 | Footer | 0xFF |

## NOT IMPLEMENTED: Packet Type 3a: INS (1Hz, 39 bytes long, Full data)

| Byte # | Name | Value | Units | Range | Res. |
|---|---|---|---|---|---|
| 0 | Header | 0x00 | - | - | - |
| 1 | Packet Type (3) + Full data (0) | 0x30 | - | - | - |
| 2 | X position 3 | | | | |
| 3 | X position 2 | | | | |
| 2 | X position 1 | | | | |
| 3 | X position 0 | | | | |
| 4 | Y position 3 | | | | |
| 5 | Y position 2 | | | | |
| 6 | Y position 1 | | | | |
| 7 | Y position 0 | | | | |
| 8 | Z position 3 | | | | |
| 9 | Z position 2 | | | | |
| 10 | Z position 1 | | | | |
| 11 | Z position 0 | | | | |
| 12 | Phi Attitude 3 | | | | |
| 13 | Phi Attitude 2 | | | | |
| 14 | Phi Attitude 1 | | | | |
| 15 | Phi Attitude 0 | | | | |
| 16 | Psy Attitude 3 | | | | |
| 17 | Psy Attitude 2 | | | | |
| 18 | Psy Attitude 1 | | | | |
| 19 | Psy Attitude 0 | | | | |
| 20 | Theta Attitude 3 | | | | |
| 21 | Theta Attitude 2 | | | | |
| 22 | Theta Attitude 1 | | | | |
| 23 | Theta Attitude 0 | | | | |
| 24 | X Velocity 3 | | | | |
| 25 | X Velocity 2 | | | | |
| 26 | X Velocity 1 | | | | |
| 27 | X Velocity 0 | | | | |
| 28 | Y Velocity 3 | | | | |
| 29 | Y Velocity 2 | | | | |
| 30 | Y Velocity 1 | | | | |
| 31 | Y Velocity 0 | | | | |
| 32 | Z Velocity 3 | | | | |
| 33 | Z Velocity 2 | | | | |
| 34 | Z Velocity 1 | | | | |
| 35 | Z Velocity 0 | | | | |
| 36 | Status? | | | | |
| 37 | Status? | | | | |
| 38 | Footer | 0xFF | - | - | - |

## NOT IMPLEMENTED: Packet Type 3b: INS (10Hz, 22 bytes long, Δ encoding)

| Byte # | Name | Value | Units | Range | Res. |
|---|---|---|---|---|---|
| 0 | Header | 0x00 | - | - | - |
| 1 | Packet Type (3) + Delta encoding (2) | 0x32 | - | - | - |
| 2 | X position H | | | | |
| 3 | X position L | | | | |
| 4 | Y position H | | | | |
| 5 | Y position L | | | | |
| 6 | Z position H | | | | |
| 7 | Z position L | | | | |
| 8 | Phi Attitude H | | | | |
| 9 | Phi Attitude L | | | | |
| 10 | Psy Attitude H | | | | |
| 11 | Psy Attitude L | | | | |
| 12 | Theta Attitude H | | | | |
| 13 | Theta Attitude L | | | | |
| 14 | X Velocity H | | | | |
| 15 | X Velocity L | | | | |
| 16 | Y Velocity H | | | | |
| 17 | Y Velocity L | | | | |
| 18 | Z Velocity H | | | | |
| 19 | Z Velocity L | | | | |
| 20 | Status? | | | | |
| 21 | Status? | | | | |
| 22 | Footer | 0xFF | - | - | - |

## SRAM Packet Type 4: Messages (Unknown Frequ., 5 - 20 bytes long, Encoding = # of Messages)

| Byte # | Name | Value | Units | Range | Res. |
|---|---|---|---|---|---|
| 0 | Header | 0x00 | - | - | - |
| 1 | Packet Type: 0x40 \| (# messages 0 - F) | - | - | 0x40 - 0x4F | - |
| 2 | Serial # (incremental for new pkts) | - | - | 0x00 - 0xFF | |
| 3 | Message #00 | - | - | 0 - 255 | - |
| { 4} | Message #01 (Optional) | - | - | 0 - 255 | - |
| { 5} | Message #02 (Optional) | - | - | 0 - 255 | - |
| { 6} | Message #03 (Optional) | - | - | 0 - 255 | - |
| { 7} | Message #04 (Optional) | - | - | 0 - 255 | - |
| { 8} | Message #05 (Optional) | - | - | 0 - 255 | - |
| { 9} | Message #06 (Optional) | - | - | 0 - 255 | - |
| {10} | Message #07 (Optional) | - | - | 0 - 255 | - |
| {11} | Message #08 (Optional) | - | - | 0 - 255 | - |
| {12} | Message #09 (Optional) | - | - | 0 - 255 | - |
| {13} | Message #10 (Optional) | - | - | 0 - 255 | - |
| {14} | Message #11 (Optional) | - | - | 0 - 255 | - |
| {15} | Message #12 (Optional) | - | - | 0 - 255 | - |
| {16} | Message #13 (Optional) | - | - | 0 - 255 | - |
| {17} | Message #14 (Optional) | - | - | 0 - 255 | - |
| {18} | Message #15 (Optional) | - | - | 0 - 255 | - |
| 4 {19} | Footer | 0xFF | - | - | - |

## SRAM Packet Type 5a IMU (10Hz and as necessary, 17 bytes long, Full data)

| Byte # | Name | Value(s), Description & Units |
|---|---|---|
| 0 | Header | 0x00 |
| 1 | Packet Type (5) + Full Data (0) | 0x50 |
| 2 | X axis accelerometer High Byte | 0x00 – 0x0F |
| 3 | X axis accelerometer Low Byte | 0x00 – 0xFF k*g |
| 4 | Y axis accelerometer High Byte | 0x00 – 0x0F |
| 5 | Y axis accelerometer Low Byte | 0x00 – 0xFF k*g |
| 6 | Z axis accelerometer High Byte | 0x00 – 0x0F |
| 7 | Z axis accelerometer Low Byte | 0x00 – 0xFF k*g |
| 8 | Q axis accelerometer High Byte | 0x00 – 0x0F |
| 9 | Q axis accelerometer Low Byte | 0x00 – 0xFF k*g |
| 10 | Phi (pitch) axis accelerometer High Byte | 0x00 – 0x0F |
| 11 | Phi (pitch) axis accelerometer Low Byte | 0x00 – 0xFF k*°/s |
| 12 | Psi (yaw) axis accelerometer High Byte | 0x00 – 0x0F |
| 13 | Psi (yaw) axis accelerometer Low Byte | 0x00 – 0xFF k*°/s |
| 14 | Theta (roll) axis accelerometer High Byte | 0x00 – 0x0F |
| 15 | Theta (roll) axis accelerometer Low Byte | 0x00 – 0xFF k*°/s |
| 16 | Footer | 0xFF |

## SRAM Packet Type 5b IMU (2.5KHz, 10 bytes long, Δ encoded)

| Byte # | Name | Value(s), Description & Units |
|---|---|---|
| 0 | Header | 0x00 |
| 1 | Packet Type (5) + Delta Encoding (2) | 0x52 |
| 2 | X axis accelerometer Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*g |
| 3 | Y axis accelerometer Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*g |
| 4 | Z axis accelerometer Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*g |
| 5 | Q axis accelerometer Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*g |
| 6 | φ axis rate gyroscope Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*°/s |
| 7 | ψ axis rate gyroscope Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*°/s |
| 8 | θ axis rate gyroscope Δ encoding | 0x00 – 0xFF: 0x7F (127) to 0x80 (–128) k*°/s |
| 9 | Footer | 0xFF |

## *Appendix: Rockwell GPS Message Information*

Here are the GPS packet formats that come directly from the Rockwell Jupiter GPS board (which are then parsed into the regular FCOS GPS Packets (type 0x10) in the FCOS GPS routines). Yellow rows are data parsed into the FCOS GPS Packets.

| Message ID | Rate | Message Length |
|---|---|---|
| 1000 | Variable (1Hz) | 55 Words |

| Word Num. | Name | Typ | Units | Range | Resolution |
|---|---|---|---|---|---|
| 1-4 | Message Header | | | | |
| 5 | Header Checksum | | | | |
| 6-7 | Set Time (1) | UDI | 10ms ticks | 0 - 4294967295 | |
| 8 | Sequence Number (2) | I | | 0 - 32767 | |
| 9 | Satellite Measurement Sequence Number (3) | I | | 0 - 32767 | |
| 10.0 | Solution Invalid - Altitude Used (4) | Bit | | 1 = True | |
| 10.1 | Solution Invalid - No Differential GPS (4) | Bit | | 1 = True | |
| 10.2 | Solution Invalid - Not Enough Sat.s in Track (4) | Bit | | 1 = True | |
| 10.3 | Solution Invalid - Exceeded Maximum EHPE (4) | Bit | | 1 = True | |
| 10.4 | Solution Invalid - Exceeded Maximum EVPE (4) | Bit | | 1 = True | |
| 10.5-10.15 | Reserved | | | | |
| 11.0 | Solution Type - Propagated Solution (5) | Bit | | 1 = Propagated | |
| 11.1 | Solution Type - Altitude Used | Bit | | 1 = Alt. Used | |
| 11.2 | Solution Type - Differential | Bit | | 1 = Differential | |
| 11.3-11.15 | Reserved | | | | |
| 12 | Number of Measurements Used in Solution | UI | | 0 - 12 | # sat? |
| 13 | Polar Navigation | Bit | | 1 = True | |
| 14 | GPS Week Number | UI | weeks | 0 - 32767 | |
| 15-16 | GPS Seconds From Epoch | UDI | seconds | 0 - 604799 | |
| 17-18 | GPS Nanoseconds From Epoch | UDI | nseconds | 0 - 999999999 | |
| 19 | UTC Day | UI | days | 1 - 31 | |
| 20 | UTC Month | UI | months | 1 - 12 | |
| 21 | UTC Year | UI | year | 1980 - 2079 | |
| 22 | UTC Hours | UI | hours | 0 - 23 | |
| 23 | UTC Minutes | UI | minutes | 0 - 59 | |
| 24 | UTC Seconds | UI | seconds | 0 - 59 | |
| 25-26 | UTC Nanoseconds From Epoch | UDI | nseconds | 0 - 999999999 | |
| 27-28 | Latitude | DI | radians | +- 0 - PI/2 | 10e-8 |
| 29-30 | Longitude | DI | radians | +- 0 - PI/4 | 10e-8 |
| 31-32 | Height | DI | meters | +- 0 - 40000 | 10e-2 |
| 33 | Geoidal Separation | I | meters | +- 0 - 200 | 10e-2 |
| 34-35 | Ground Speed | UDI | meters/sec | 0 - 1000 | 10e-2 |
| 36 | True Course | UI | radians | 0 - 2PI | 10e-3 |
| 37 | Magnetic Variation | I | radians | +- 0 - PI/4 | 10e-4 |
| 38 | Climb Rate | I | meters/sec | +-300 | 10e-2 |
| 39 | Map Datum (6) | UI | meters | 0-188 & 300-304 | 10e-2 |
| 40 - 41 | Expected Horizontal Position Error (7) | UDI | meters | 0 - 320000000 | 10e-2 |
| 42 - 43 | Expected Vertical Position Error (7) | UDI | meters | 0 - 250000 | 10e-2 |
| 44 - 45 | Expected Time Error (7) | UDI | meters | 0 - 300000000 | 10e-2 |
| 46 | Expected Horizontal Velocity Error (7) | UI | meters/sec | 0 - 10000 | 10e-2 |
| 47 - 48 | Clock Bias (7) | DI | meters | +- 0 - 9000000 | 10e-2 |
| 49 - 50 | Clock Bias Standard Deviation (7) | DI | meters | +- 0 - 9000000 | 10e-2 |
| 51 - 52 | Clock Drift (7) | DI | meters/sec | +- 0 - 1000 | 10e-2 |
| 53 - 54 | Clock Drift Standard Deviation (7) | DI | meters/sec | +- 0 - 1000 | 10e-2 |
| 55 | Data Checksum | | | | |

Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization enabled the processor interrupts. It is not used to derive GPS time but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.

Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.

Note 3: The satellite measurement sequence number relates the position solution data to a particular set of satellite measurements found in binary message 1009 (ECEF Position Output Message).

Note 4: The value of this data item was intially set using the Solution Validity Criteria Message (Message 1217).

Note 5: Bit zero of word 11 does not refer to a solution propagated by the navigation software. This bit is used to indicate if the solution was propagated by the serial I/O manager to generate a 1 Hz output message when no neww navigation state data was available. This is an error condition potentially caused by a shortage of throughput in one cycle. It is unlikely to occur and is self-correcting. Normal state propagation which occurs within the navigation software with or without measurements available for processing does not cause this bit to be set.

Note 6: The table in Appendix E contains map datum codes from 0 to 188. Codes 300 to 304 are user-defined.

Note 7: The data displayed by this field is not valid until the receiver is in navigation mode.

| Message ID | Rate | Message Length |
|---|---|---|
| 1009 | Variable | 22 Words |

| Word Num. | Name | Type | Units | Range | Resolution |
|---|---|---|---|---|---|
| 1-4 | Message Header | | | | |
| 5 | Header Checksum | | | | |
| 6-7 | Set Time (1) | UDI | 10 ms ticks | 0 - 4294967295 | |
| 8 | Sequence Number (2) | I | | 0 - 32767 | |
| 9 | Sat. Measurement Sequence Number (3) | I | | 0 - 32767 | |
| 10 - 11 | ECEF Position - X (4) | DI | meters | +- 0 - 9000000 | 10e-2 |
| 12 - 13 | ECEF Position - Y (4) | DI | meters | +- 0 - 9000000 | 10e-2 |
| 14 - 15 | ECEF Position - Z (4) | DI | meters | +- 0 - 9000000 | 10e-2 |
| 16 -17 | ECEF Velocity - X (4) | DI | meters/sec | +- 0 - 1000 | 10e-2 |
| 18 - 19 | ECEF Velocity - Y (4) | DI | meters/sec | +- 0 - 1000 | 10e-2 |
| 20 - 21 | ECEF Velocity - Z (4) | DI | meters/sec | +- 0 - 1000 | 10e-2 |
| 22 | Data Checksum | | | | |

Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.

Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.

Note 3: The satellite measurement sequence number relates the position solution data to a particular set of satellite measurements found in binary messages 1000 and 1002 (Geodetic Position Status Output Message and Channel Summary Message, respectively).

Note 4: The data displayed by this field is not valid until the receiver is in navigation mode.