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RS-422 INTERFACE PROTOCOL SPECIFICATION
FOR THE
OPERATIONAL VEHICLE PROGRAM
OF THE
INERTIAL REFERENCE UNIT

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Revision History

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1. SCOPE

1.1 Identification.

This Protocol Specification provides information for the RS-422 data link of the Smiths Aerospace LLC Electronic Systems – Grand Rapids Inertial Reference Unit (IRU).

1.2 Introduction.

The IRU RS-422 interface is used for calibrating, testing and normal operational use of the IRU. It supports an RS-422 data link, which is designed to facilitate testing of the Computer Software Configuration Item and characterization of its sensors. Data received via the RS-422 link consists of commands and data. Data provided by the IRU via the RS-422 link consists of the proper response to received RS-422 messages.

2. APPLICABLE DOCUMENTS

2.1 Government Documents.

This paragraph is not applicable to this document.

2.2 Non-Government Documents.

The following documents of the exact issue shown form a part of this document to the extent specified herein. For those documents showing no date of issue, the latest issue applies.

DRAWINGS:

Smiths Aerospace LLC, Electronic Systems – Grand Rapids

202041-001	Interface Control Document for the RS-422 Interface of the Position/Navigation Unit

STANDARDS:

The Institute of Electrical and Electronics Engineers, Inc.

ANSI/IEEE Std 754	IEEE Standard for Binary Floating-Point Arithmetic

OTHER PUBLICATIONS:

Electronic Industries Association

RS-422A	Electrical Characteristics of Balanced Voltage Digital Interface Circuits

3. REQUIREMENTS

This describes the requirements for the two RS-422 serial input and output channels.

The RS-422 serial Input/Output (I/O) is a message-oriented protocol with input and output messages each consisting of exactly eight 16-bit words. The IRU RS-422 channels are configured as follows:

1. Channel A
   a. Full Duplex
   b. One Start Bit
   c. 8 Bits
   d. No Parity
   e. 1 Stop Bit
   f. Baud Rate – Selectable (default = 19200)
2. Channel B
   a. Full Duplex
   b. One Start Bit
   c. 8 Bits
   d. No Parity
   e. 1 Stop Bit
   f. Baud Rate – Selectable (default = 19200)

The default baud rate for each channel is configurable in the EEPROM coefficient area of the IRU.

For messages received by the IRU, the Most Significant Byte (MSByte) of each word is received first and the Least Significant Byte (LSByte) second. This is opposite of the messages sent from the IRU, where the LSByte is sent first. The Least Significant Bit of each byte is always sent or received first.

All messages shall conform to the format illustrated in Table 1 below.

Table 1. RS-422 Input and Output Message Format

XXXX[a]	Header Word
XXXX	Data Word
XXXX	Data Word
XXXX	Data Word
XXXX	Data Word
XXXX	Data Word
XXXX	Data Word
XXXX	Checksum[b] Word

[a]XXXX - Placeholder for 16-bit Hexadecimal value
[b]Checksum - Result of exclusive-OR of the header word and all 6 data words

Each header word shall consist of a command identifier (the least significant byte). The command identifier is an 8-bit value that is copied from the input message to the message identifier of following output messages from the IRU. This field may be used to associate output messages with a specific input message. Note that for IRU input messages that do not affect the output messages, the message identifier from the input message will not be used for subsequent output messages if output messages are currently being sent.

The value for the command identifier shall determine the message type as indicated in Table 2. Values for the command identifier may range from 0 to 255. Those values not listed in Table 2 are invalid command identifier values and will result in an invalid action request flag being set in the Built-In Test (BIT) error message buffers. A value of 0 is a special case of the invalid command identifier, and will have a separate error reporting bit set in the BIT error message buffers.

Table 2. Message Command Identifier Summary

COMMAND ID	NOTE [a]	DESCRIPTION
0 (0000h)		Zero Action Indicated
1 (0001h)		Reset system, branch to power-up sequence
2 (0002h)		Stop serial output until new output request is received
3 (0003h)		Perform initiated Built-in Test
4 (0004h)		Clear current accumulated BIT error messages
5 (0005h)	RSVD	Perform calibration
6 (0006h)	RSVD	Lock gyros in high rate
7 (0007h)	RSVD	Force gyros into low rate
9 (0009h)		Perform Serial Wraparound Test
10 (000Ah)	RSVD	Modify Calibration EEPROM areas
11 (000Bh)		Display latitude and longitude from the IRU
12 (000Ch)		Set RS-422 baud rate
13 (000Dh)	RSVD	Set RS-422 Port B output mode
14 (000Eh)	RSVD	Modify Contiguous Calibration EEPROM areas
15 (000Fh)		Display residual heading
16 (0010h)		Display odometer scale factor
17 (0011h)		Set Latitude/Longitude position
18 (0012h)	RSVD	Modify RAM
19 (0013h)		Set the True Heading
20 (0014h)	RSVD	Modify I/O Region 0 Location
21 (0015h)	RSVD	Modify I/O Region 1 Location
22 (0016h)	RSVD	Display calibration EEPROM data
23 (0017h)		Set ETI Number
24 (0018h)		Display ETI Number
25 (0019h)	RSVD	Display Vehicle Velocities
26 (001Ah)	RSVD	Display RAM Data
27 (001Bh)	RSVD	Display ROM Region 0 Data
28 (001Ch)	RSVD	Display ROM Region 1 Data
29 (001Dh)	RSVD	Display ROM Region 2 Data
30 (001Eh)	RSVD	Display ROM Region 3 Data
32 (0020h)	RSVD	Display Calibration Data (start packet header = 0020h)
33 (0021h)	RSVD	Display Calibration Data (start packet header = 0021h)
34 (0022h)	RSVD	Display Calibration Data (start packet header = 0022h)
35 (0023h)	RSVD	Display Calibration Data (start packet header = 0023h)
36 (0024h)	RSVD	Display Calibration Data (start packet header = 0024h)
37 (0025h)	RSVD	Display Calibration Data (start packet header = 0025h)
38 (0026h)	RSVD	Display Calibration Data (start packet header = 0026h)
39 (0027h)	RSVD	Display Temperatures
40 (0028h)	RSVD	Display Raw Sensor Data
41 (0029h)	RSVD	Display Compensated Sensor Data
42 (002Ah)		Display Latitude/Longitude, Sin of Pitch, Sin of Roll
43 (002Bh)		Display Latitude, True Heading, GC Variance
44 (002Ch)		Display Base Motion Comp. (BMC) GC Heading, Status
45 (002Dh)	RSVD	Turn OFF Sensor Data Accumulation
46 (002Eh)	RSVD	Turn ON Sensor Data Accumulation
51 (0033h)	RSVD	Turn OFF Attitude Integration

COMMAND ID	NOTE [a]	DESCRIPTION
52 (0034h)	RSVD	Turn ON Attitude Integration
56 (0038h)		Display Target Coordinates
61 (003Dh)		Display BIT Words 1 through 6
62 (003Eh)		Display BIT Words 7 through 12
63 (003Fh)		Display BIT Words 13 through 18
64 (0040h)		Display BIT Words 19 through 24
65 (0041h)	RSVD	Set Spin Motors 5% Slow
66 (0042h)	RSVD	Set Spin Motors to Normal Speed
67 (0043h)	RSVD	Set Temporary Rotor Offsets
68 (0044h)	RSVD	Set Temporary Loop Gain
69 (0045h)		Set Waypoint Position Latitude/Longitude
70 (0046h)		Set Waypoint Position MGRS
71 (0047h)		Display Waypoint Position Latitude/Longitude
72 (0048h)		Display Waypoint Position MGRS
73 (0049h)		Display Range and Bearing to Waypoint
74 (004Ah)	RSVD	Display Loop Gain Cal Data
75 (004Bh)	RSVD	Initiate Loop Gain Cal Process
76 (004Ch)	RSVD	Perform Rotation Movement
77 (004Dh)	RSVD	Set Temporary Spin Speeds
78 (004Eh)	RSVD	Modify Memory 32 bit addressing
79 (004Fh)	RSVD	Display Memory 32 bit addressing
80 (0050h)		Display Release Date and Part Number Words 1 - 6
81 (0051h)		Display Release Date and Part Number Words 7 - 12
82 (0052h)		Display Release Date and Part Number Words 13 - 18
83 (0053h)		Display Release Date and Part Number Words 19 - 24
84 (0054h)		Display MGRS Coordinate Position
85 (0055h)	RSVD	Display Meridian Convergence
86 (0056h)	RSVD	Set Gyrocompass Residual
88 (0058h)		Set Heading via RS-422
89 (0059h)		Set MGRS Position
90 (005Ah)		Set Datum via RS-422
91 (005Bh)		Set IRU Azimuth, Pitch, and Roll Alignment
92 (005Ch)		Set IRU KOD Scale Factor
93 (005Dh)		Set IRU Mode
94 (005Eh)		Set IRU Vertical Navigation Pitch Alignment
95 (005Fh)		Display IRU Navigation Alignment Data
96 (0060h)		Set Elevation
97 (0061h)		Display Elevation
98 (0062h)		Display Heading and Attitude
99 (0063h)		Display IVC Data
100 (0064h)	RSVD	Set Attitude via RS-422
101 (0065h)		Set IVC Start and Finish Positions
102 (0066h)		Display IVC Calculated Calibration Parameters
104 (0068h)		Display Attitude Data
105 (0069h)		Display Lat/Long Position
106 (006Ah)		Display Attitude and Rates
107 (006Bh)		Set 3D Position
108 (006Ch)		Display PLGR OR DAGR Status

COMMAND ID	NOTE [a]	DESCRIPTION
109 (006Dh)		Display PLGR OR DAGR Status
113 (0071h)		PLGR OR DAGR Setup Data Message 1
114 (0072h)		PLGR OR DAGR Setup Data Message 2
115 (0073h)		PLGR OR DAGR Setup Data Message 3
116 (0074h)		PLGR OR DAGR Setup Data Message 4
119 (0077h)		Display NFM Status (Degrees)
120 (0078h)		Display Position in Degrees
121 (0079h)		Display NFM Status (Radians)
122 (007Ah)		Display Position in Radians
123 (007Bh)	RSVD	Transmit simulation data
124 (007Ch)	RSVD	Receive simulation data
125 (007Dh)		Display 3D Position
126 (007Eh)		Display NFM Status
127 (007Fh)	RSVD	Display I/O Region 0 Data
128 (0080h)	RSVD	Display I/O Region 1 Data
138 (008Ah)		Display IVC Start Position
139 (008Bh)		Display IVC Finish Position
140 (008Ch)		Display Datum
141 (008Dh)		Set IVC Start and Finish Positions, 0.1m Elevation
142 (008Eh)		Set Position in Specified Format
143 (008Fh)		Display Position in Specified Format
146 (0092h)		Set Waypoint Position in Specified Format
147 (0093h)		Display Waypoint Position in Specified Format
[a]RSVD – Reserved for Factory Use		

Every message shall have a header word and shall be followed by six data words and a checksum word. The last word of an input or output message shall be the checksum word. The contents of the checksum word shall be the result of the exclusive-OR of the message header and all six data words.

3.1 RS-422 Input.

RS-422 serial input data is collected from either of two full duplex channels. The channels operate independently and may be used simultaneously.

The IRU RS-422 serial input procedure detects the start of a message by keeping track of intermessage idle time. This is the time between any two consecutive bytes received. The idle time necessary to indicate that the byte just received is the first byte of a new message is approximately equal to 8 character times. Any time this intermessage idle time is encountered, the next byte received is handled as the beginning of a new message. Any partial message that is received is discarded. The IRU can support successive input messages up to 30Hz.

Checksum verification is performed by the message processing procedure. Failure of the checksum validation procedure results in the message being ignored, as well as a checksum failure being recorded in the BIT error message output buffer.

NOTE: It is assumed that the MSByte of each word is received first and the LSByte second. This is opposite of the output from the IRU, where the LSByte is sent first.

Many of the input messages contain address offsets. These are 16-bit values that are an offset from a base address. (The message command identifier implies the base address.) The IRU RS-422 protocol has been kept as similar as possible to the POS/NAV protocol described in its Interface Control Document, 202041-001. For this reason, an adjustment is made to each address offset value that is placed into a message. This adjustment may be considered to be an addition of the value of 8000h to each offset, or as the subtraction of the value of 8000h from each offset, or as the negation of the most significant bit of each offset.

The address base values depend upon the message region being accessed by the specific command, and are defined in Table 3 below:

Table 3. Memory Region Base Address

MEMORY REGION	BASE ADDRESS
EEPROM memory	0001_0000
RAM memory	0104_0000
ROM 0 memory	0200_0000
ROM 1 memory	0201_0000
ROM 2 memory	0202_0000
ROM 3 memory	0203_0000
I/O 0 memory	0300_0000
I/O 1 memory	0108_0000

3.2 Serial Output Handling.

A process executed at a 61-Hz rate will handle the Serial Output. The 61-Hz output handler will send the data to the output message buffer on the following schedule:

1. Every time it executes when the baud rate is 38400 or 19200 baud (61 messages per second)
2. Every second time at 9600 baud (30 messages per second)
3. Every fourth time at 4800 baud (15 messages per second).

The process of performing the serial output function shall be as follows:

1. Pick up the address of the message buffer (SER_OUT_BUFF).
2. Return if the pointer to the message buffer is zero.
3. Get Header Word from message buffer, add word to checksum, and transfer this word to the serial output FIFO.
4. Get message data word 1, add word to checksum, and transfer this word to the serial output FIFO.
5. Get message data word 2, add word to checksum, and transfer this word to the serial output FIFO.
6. Get message data word 3, add word to checksum, and transfer this word to the serial output FIFO.
7. Get message data word 4, add word to checksum, and transfer this word to the serial output FIFO.
8. Get message data word 5, add word to checksum, and transfer this word to the serial output FIFO.
9. Get message data word 6, add word to checksum, and transfer this word to the serial output FIFO.
10. Transfer checksum word to the serial output FIFO.

Each word transferred to the serial output FIFO will first be picked up from memory as a 16-bit word and then sent to the FIFO as two bytes. The LSByte of the data word is sent first, the MSByte of the data word is sent second.

Each message sent out by the serial output function shall be of fixed length of eight 16-bit words identified by the buffer pointed to by the variable SER_OUT_BUFF pointer. The format of this buffer shall be as shown in Figure 1. Note that the checksum word does not occupy a physical location in the serial output buffer. It is computed from the message data and sent to the serial output FIFO as the last word.

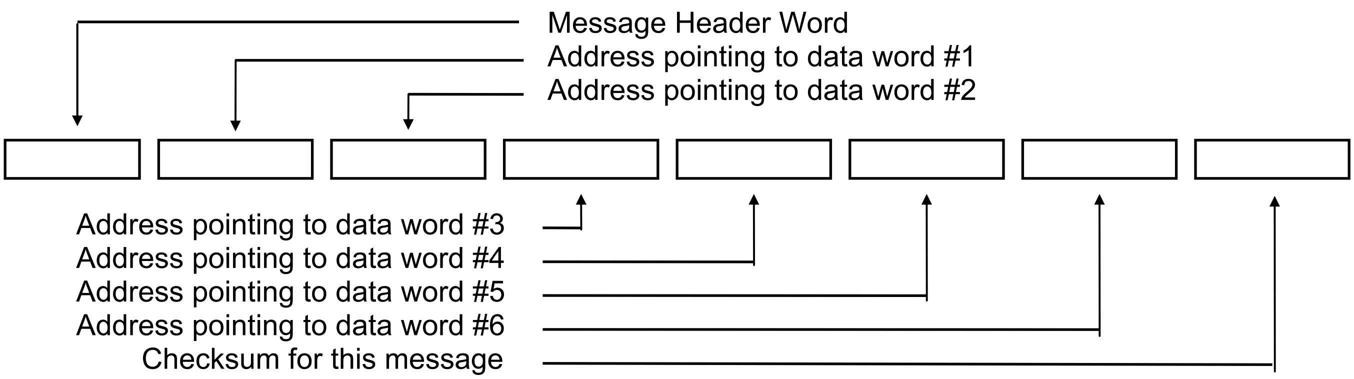

Figure 1. Serial Output Buffer Data Format

Attitude data will be updated at a rate of 61Hz, and is relative to 3 milliseconds before the start of the message transfer. Position data will be updated at a rate of 20Hz, and is relative to 4.5 milliseconds before the start of the message transfer.

3.2.1 *RS-422 Output.*

Outputs will be messages sent out by the IRU through the RS-422 serial line. Each output message can be identified from the value contained in the message header. These header values correspond to those of the input message headers.

Serial output shall be implemented using a buffer containing a header word and an array of pointers as illustrated in Figure 1. All pointers in this buffer will point to the memory locations of the data to be sent. Data pointed to by these locations will be sent from the 61 Hz process until the addresses at these locations are changed via a new input command to the IRU. When a “Stop Serial Output” command is sent to the IRU, all output will stop. The Serial Wrap Around Test (SWAT) shall echo the first seven words of the serial input message. When a memory dump is requested, a memory dump buffer shall be loaded with the appropriate addresses of the memory data to be dumped.

3.2.2 *FLOAT_32 Output Definition.*

For any output messages that have data specified as FLOAT_32, the following definition applies to interpreting the data.

Two output data words are used with the first word being the most significant 16 bits and the second word the least significant 16 bits. The 32 bit floating point value is represented as follows (Bit 0 is LSB):

Bits 31 - 8 : A 24 bit mantissa, (normalized so MSB is 0.5) will represent a number between 0.5 and 1.0, (except for the special case of 0.0).

Bit 7 : Sign bit, 0 = positive, 1 = negative.

Bits 6 - 0 : A 7 bit "excess 64" exponent. Subtract 64 from the exponent to get the actual base 2 exponent.

The following formula may be used to convert the SIO FLOAT_32 Message data to a Decimal (Base 10) value:

$$\text{FLOAT\_32(DEC)} = \left(\frac{\text{Mantissa(Dec)}}{2^{24}} \right) * 2^{\text{Exponent(Dec)} - 64}$$

Examples: -1.0 = 800000C1 Hex, 0.0 = 00000000 Hex, 1.0 = 80000041 Hex.

3.2.3 *IRU Mode/GPS Status/Moving Definition*

The IRU Mode/GPS Status/Moving Status is presented as follows:

IRU Mode: The IRU Mode is contained in the least significant 4 bits of the most significant byte. The valid modes are as follows:

1 – Power Up Mode
2 – Standby Mode
3 – Gyrocompass Mode (GC)
4 – Gyrocompass Abort Mode (GCABORT)
5 – Initiated BIT Mode
6 – Navigation Mode (NAV)
7 – Reserved
8 – In-Vehicle Calibration Mode (IVC)
9 – Base Motion Compensated Coarse Align (BMCCOARSE)
10 – Base Motion Compensated Fine Align (BMCFINE)
11 – Base Motion Compensated Align Abort (BMCABORT)

GPS Status:

Bit 12: GPS Receiver connected (1 = connected).
Bit 13: GPS Receiver tracking satellites (1 = tracking).
Bit 14: Valid GPS setup data message received (1 = received).

Moving Status:

Bit 15: 0 if IRU not moving, 1 if IRU moving.

3.2.4 *NFM/Target/GPS/Time FOM Definitions*

NFM FOM is the Figure of Merit on the NFM position calculations, presented as a single precision signed integer as shown in Table 4.

Table 4. NFM FOM

NFM FOM	Vehicle Position Error (meters)
1	< 25
2	< 50
3	< 75
4	< 100
5	< 200
6	< 500
7	< 1000
8	< 5000
9	≥ 5000

The Target FOM for the output message is an unsigned 4 bit integer. It is calculated using CEP calculations. The Target FOM represents the RMS error for the target position in meters as shown in Table 5.

Table 5. Target FOM

TargetFOM	Target Position Error (meters)
1	< 20
2	< 40
3	< 60
4	< 80
5	< 100
6	< 120
7	< 140
8	< 160
9	≥ 160

The GPS FOM for the output message is calculated by the PLGR OR DAGR. The GPS FOM represents the vehicle position error in meters as shown in Table 6.

Table 6. GPS FOM

GPS FOM	Vehicle Position Error (meters)
1	< 25
2	< 50
3	< 75
4	< 100
5	< 200
6	< 500
7	< 1000
8	< 5000
9[1]	≥ 5000

The Time FOM for the output message is calculated by the PLGR OR DAGR. The Time FOM represents the Estimated Time Error in seconds as shown in Table 7 and is used in conjunction with the PLGR OR DAGR 1PPS signal or the HAVE QUICK data.

Table 7. Time FOM

TimeFOM Value	ETE with respect to GPS Time (1 sigma)
0	Not used
1	ETE ≤ 1 ns
2	1 ns < ETE ≤ 10 ns
3	10 ns < ETE ≤ 100 ns
4	100 ns < ETE ≤ 1 µs
5	1 µs < ETE ≤ 10 µs
6	10 µs < ETE ≤ 100 µs
7	100 µs < ETE ≤ 1 ms
8	1 ms < ETE ≤ 10 ms
9[2]	10 ms < ETE
10-15	Not Used

[1] A GPS FOM=9 with Nav Converged=False or Nav Data Not Valid set to 1 indicates that there is no position solution, otherwise, a FOM=9 indicates an EPE > 5000 meters.
[2] A Time FOM=9 with Nav Converged=False or Nav Data Not Valid set to 1 indicates that there is no GPS time solution, otherwise, a Time FOM=9 indicates an ETE > 10 ms.

3.3 RS-422 Message Definitions.

Following is a description of each input message accepted by the IRU, and each output message provided in response:

- **0000h**: Zero Action Indicated – This message header is a special value. If this header value is received for a message, no action will be taken.

  Message format to the IRU:
  Word 1: Header = 0000h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0001h**: Branch to Zero – Command total system restart.

  Message format to the IRU:
  Word 1: Header = 0001h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: All output stops when the IRU resets.

- **0002h**: Stop Serial Output – Command to cause serial output to stop. Output will commence again at the next request of data. (This command does not interrupt any output message in mid-stream).

  Message format to the IRU:
  Word 1: Header = 0002h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: All output stops

- **0003h**: Perform Initiated BIT – Initiated BIT (IBIT) begins immediately. (Note: This command resets the processor and it will reboot the same as if power had been cycled off and on.)

  Message format to the IRU:
  Word 1: Header = 0003h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: All output stops

- **0004h**: Clear BIT errors – This command causes the BIT error words in the IRU to be cleared.

Message format to the IRU:
Word 1: Header = 0004h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: – No change in output

- **0005h**: Perform Calibration – This command initiates the calibration algorithm and accumulation in the IRU. The interval of time used for accumulating sensor data is determined from the value in Word 2 of this message. The calibration accumulation time is the number of seconds the IRU shall use to accumulate sensor data during a calibration sequence.

  Message format to the IRU:
  Word 1: Header = 0005h
  Word 2: Calibration accumulation time
  Words 3-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0006h**: Lock High Rate – This command will force the gyros to be locked into one rate as specified by words 2, 3, and 4. This command should be used with care because the gyros heat up rapidly when in 60 or 120 deg/sec rates.

  Message format to the IRU:
  Word 1: Header = 0006h
  Word 2: P gyro rate command
  Word 3: Q gyro rate command
  Word 4: R gyro rate command
  Words 5-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The rate command values for words 2-4 are:
  0 = 15 Deg/Sec
  1 = 30 Deg/Sec
  2 = 60 Deg/Sec
  3 = 120 Deg/Sec

- **0007h**: Force Low Rate – This command causes the gyros in the IRU to be unlocked and returned to their normal rate.

  Message format to the IRU:
  Word 1: Header = 0007h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

- **0009h**: Serial Wrap Around – This command will cause the IRU to echo the data received in this message in the output message of the RS-422.

  Message format to the IRU:
  Word 1: Header = 0009h
  Word 2: Data word 1 to be echoed
  Word 3: Data word 2 to be echoed
  Word 4: Data word 3 to be echoed
  Word 5: Data word 4 to be echoed
  Word 6: Data word 5 to be echoed
  Word 7: Data word 6 to be echoed
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 0009h
  Word 2: Data word 1 of input message
  Word 3: Data word 2 of input message
  Word 4: Data word 3 of input message
  Word 5: Data word 4 of input message
  Word 6: Data word 5 of input message
  Word 7: Data word 6 of input message
  Word 8: 16-bit checksum for this message

- **000Ah**: Modify Calibration EEPROM – This command is used for modifying single locations within the calibration Electrically Erasable Programmable Read-Only Memory (EEPROM) area of the IRUs memory space.

  Message format to the IRU:
  Word 1: Header = 000Ah
  Word 2: Offset 1 (+ 8000h)
  Word 3: Data to write to EEPROM base + Offset 1
  Word 4: Offset 2 (+ 8000h), or Zero
  Word 5: Data to write to EEPROM base + Offset 2
  Word 6: Offset 3 (+ 8000h), or Zero
  Word 7: Data to write to EEPROM base + Offset 3
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **000Bh**: Display Latitude and Longitude from the IRU.

  Message format to the IRU:
  Word 1: Header = 000Bh
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 000Bh
Words 2-3: Latitude
Words 4-5: Longitude
Word 6: True Heading
Word 7: Malfunction BIT (Least Significant Byte (LSByte))
Word 7: IRU Mode/GPS Status/Moving (Most Significant Byte (MSByte))
Word 8: 16-bit checksum for this message

Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 2-3 = ((IRU Latitude, in radians) / PI) * 2^{30}
Words 4-5 = ((IRU Longitude, in radians) / PI) * 2^{30}

Words 2 and 4 contain the most significant portion of Latitude and Longitude, respectively. Words 3 and 5 contain the least significant portions of Latitude and Longitude, respectively.

True Heading is presented as an integer value in this message. It is derived from the IRUs True Heading and transformed to a 16-bit unsigned integer as follows:

Word 6 = TRUE HEADING (Degrees) * 100.0

The Malfunction word is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

- **000Ch**: Set RS-422 baud rate – This command will force the baud rate of the IRU RS-422 ports to the baud rate designated in words 2 and 3 of the message. The possible baud rates are 4800, 9600, and 19200. A Zero (0) will leave the baud rate as is.

Message format to the IRU:

Word 1: Header = 000Ch
Word 2: Baud Rate for Channel A
Word 3: Baud Rate for Channel B
Words 4-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

- **000Dh**: Set RS-422 Port B output mode – This command will set the operating mode of the NFM port B to any of the modes possible in the application specific coefficient file.

Message format to the IRU:

Word 1: Header = 000Dh
Word 2: RS-422 Port B mode word
Words 3-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output for ports A, C, D. Port B output will be as specified by the mode word.

RS-422 Port B mode word values:

0 - Port B output is standard YV protocol with continuous response output.
1 - Port B output is NMEA message map output at 1 Hz
2 - Port B output is standard YV protocol with single response output.

- **000Eh**: Modify Contiguous EEPROM areas – write five consecutive words in calibration EEPROM. The first word is the offset from the base address of the calibration EEPROM memory and the remaining five words are the data words to be written.

  Message format to the IRU:

  Word 1: Header = 000Eh
  Word 2: Offset (+ 8000h)
  Word 3: 1st value to be written
  Word 4: 2nd value to be written
  Word 5: 3rd value to be written
  Word 6: 4th value to be written
  Word 7: 5th value to be written
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **000Fh**: Display Residual Heading

  Message format to the IRU:

  Word 1: Header = 000Fh
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:

  Word 1: Header = 000Fh
  Word 2: Box Azimuth alignment
  Word 3: Gyrocompass residual
  Word 4: Gyrocompass state
  Word 5: Gyrocompass time remaining
  Word 6: Moving status
  Word 7: 0000h
  Word 8: 16-bit checksum for this message

  IRU LRU alignment is presented as an integer value in this message. It represents the misalignment between the IRU box and the vehicle. It is transformed to a 16-bit integer as follows:

  IRU alignment = IRU ALIGNMENT (Degrees) * 100.0

  Gyrocompass residual is presented as an integer value in this message. It is a factory calibration constant. It is transformed to a 16-bit integer as follows:

Gyrocompass residual = GYROCOMPASS RESIDUAL (Degrees) * 100.0

The gyrocompass state represents the current step of a sequence of operations during a gyrocompass operation. The states are defined as follows:

0 – CHECK_IF_VALID_TO_GC
1 – FIRST_SETTLE_AT_0
2 – FIRST_COLLECT_DATA_AT_0
3 – MOVE_0_TO_180
4 – STOP_AT_180
5 – SETTLE_AT_180
6 – FIRST_COLLECT_DATA_AT_180
7 – SECOND_COLLECT_DATA_AT_180
8 – MOVE_FROM_180_TO_0
9 – STOP_AT_0
10 – SETTLE_AT_0
11 – SECOND_COLLECT_DATA_AT_0
12 – COMPUTE_FIRST_HEADING_EST
13 – GYRO_COMPASS_FAIL
14 – END_GYRO_COMPASS
15 – RETRY_MOVE_0_TO_180
16 – RETRY_MOVE_180_TO_0
17 – MOVE_TO_0_NOW
18 – RESTART_GYRO_COMPASS
19 – ESTIMATE_R_GYRO_BIAS
20 – ITERATE_HEADING_ESTIMATE

The gyrocompass time remaining is an estimate of the amount of time remaining until the gyrocompass operation is complete. This estimate may change due to events such as retry operations. The units are seconds * 61.

The moving status word has a value of 0 if the IRU is not moving, or a value of 1 if motion has been detected in approximately the last 10 seconds. A gyrocompass operation cannot be initiated if motion has been detected.

- **0010h**: Display odometer scale factor

Message format to the IRU:
Word 1: Header = 0010h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0010h
Word 2: IRU KOD Scale Factor
Words 3-7: 0000h
Word 8: 16-bit checksum for this message

Word 2 = IRU KOD SCALE FACTOR * 10000

- **0011h**: Set Latitude/Longitude position.

  Message format to the IRU:
  Word 1: Header = 0011h
  Words 2-3: Latitude
  Words 4-5: Longitude
  Words 6-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The new Latitude and Longitude must be scaled before being sent to the IRU. The scaling must be as follows:

  Words 2-3 = ((New Latitude, in Radians)/PI)* 2^{30}
  Words 4-5 = ((New Longitude, in Radians)/PI)* 2^{30}

  Words 2 and 4 contain the most significant portion of Latitude and Longitude, respectively. Words 3 and 5 contain the least significant portions of Latitude and Longitude, respectively. Latitude is limited to ± 90 degrees and Longitude is limited to ± 180 degrees.

- **0012h**: Modify Random Access Memory (RAM) – For these commands, the six data words will contain both offsets and data. The offsets will represent the offset into the RAM area of the location to be changed. The data is the data to write to the new location. The offsets must be in words 2, 4, and 6, with the corresponding new values that are to be written to these locations in words 3, 5, and 7. If fewer than 3 addresses are to be modified, the remaining input message data words must contain zero values. If the base word of the RAM is to be modified (indicated by a zero offset), it must be specified in word 2 of the message; otherwise it will be interpreted as the end of the "MODIFY RAM MEMORY" specifications within the data words. There will always be at least one location modified by this command; if all data words are zero, the base word of the corresponding memory will be set to whatever value is in word 3 of this message.

  Message format to the IRU:
  Word 1: Header = 0012h
  Word 2: Offset 1 (+ 8000h)
  Word 3: Data to write to location BASE + Offset 1
  Word 4: Offset 2 (+ 8000h), or Zero
  Word 5: Data to write to location BASE + Offset 2
  Word 6: Offset 3 (+ 8000h), or Zero
  Word 7: Data to write to location BASE + Offset 3
  Word 8: 16-bit checksum for this message

  Message format from the IRU: – No change in output

- **0013h**: Set True Heading.

  Message format to the IRU:

Word 1: Header = 0013h
Word 2: True Heading (0-3599)
Words 3-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

(Note: The IRU will establish the new heading according to the following:
New True heading = Word 2 * 0.1;)

- **0014h**: Modify I/O Region 0 Location – The first word of this message must be the offset from the base location of the I/O region 0. The second word of this message is the actual data to be written to this location.

  Message format to the IRU:
  Word 1: Header = 0014h
  Word 2: Offset 1 (+ 8000h)
  Word 3: Data value to write to I/O region 0 base + Offset 1
  Word 4: Offset 2 (+ 8000h), or Zero
  Word 5: Data value to write to I/O region 0 base + Offset 2
  Word 6: Offset 3 (+ 8000h), or Zero
  Word 7: Data value to write to I/O region 0 base + Offset 3
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0015h**: Modify I/O Region 1 Location –The first word of this message must be the offset from the base location of the I/O region 1. The second word of this message is the actual data to be written to this location.

  Message format to the IRU:
  Word 1: Header = 0015h
  Word 2: Offset 1 (+ 8000h)
  Word 3: Data value to write to I/O region 1 base + Offset 1
  Word 4: Offset 2 (+ 8000h), or Zero
  Word 5: Data value to write to I/O region 1 base + Offset 2
  Word 6: Offset 3 (+ 8000h), or Zero
  Word 7: Data value to write to I/O region 1 base + Offset 3
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0016h**: Display Calibration EEPROM Data – Display the contents of six locations of Calibration EEPROM Data. Each data word of this message will be interpreted as an offset from the base of the Calibration EEPROM memory of the values to be sent out on the RS-422. This command will always cause six values to be sent out.

  Message format to the IRU:
  Word 1: Header = 0016h

Word 2: Offset 1 (+ 8000h)
Word 3: Offset 2 (+ 8000h)
Word 4: Offset 3 (+ 8000h)
Word 5: Offset 4 (+ 8000h)
Word 6: Offset 5 (+ 8000h)
Word 7: Offset 6 (+ 8000h)
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0016h
Word 2: Data value at offset 1
Word 3: Data value at offset 2
Word 4: Data value at offset 3
Word 5: Data value at offset 4
Word 6: Data value at offset 5
Word 7: Data value at offset 6
Word 8: 16-bit checksum for this message

- **0017h**: Set Elapsed Time Indicator (ETI)

Message format to the IRU:
Word 1: Header = 0017h
Word 2: Most significant word of New ETI
Word 3: Least significant word of New ETI
Words 4-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The ETI value is the number of 6-minute periods that the IRU unit has been operating.

- **0018h**: Display Elapsed Time Indicator

Message format to the IRU:
Word 1: Header = 0018h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0018h
Word 2: Most significant word of ETI
Word 3: Least significant word of ETI
Words 4-7: 0000h
Word 8: 16-bit checksum for this message

The ETI value is the number of 6-minute periods that the IRU unit has been operating.

- **0019h**: Display Vehicle Velocities

Message format to the IRU:
Word 1: Header = 0019h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0019h
Words 2-3: FLOAT_32(Vehicle Forward Velocity, Meters/Sec)
Words 4-5: FLOAT_32(Vehicle Right Velocity, Meters/Sec)
Words 6-7: FLOAT_32(Vehicle Down Velocity, Meters/Sec)
Word 8: 16-bit checksum for this message

- **001Ah**: Display RAM Data – Return the contents of six locations of RAM Data. Each data word of this message will be interpreted as an offset from the base of the RAM memory of the values to be sent out on the RS-422. This command will always cause six values to be sent out. Each offset must be specified as a hexadecimal value as follows:

  offset = (offset of desired location) + 8000h.

  Message format to the IRU:
  Word 1: Header = 001Ah
  Word 2: Offset 1 (+ 8000h)
  Word 3: Offset 2 (+ 8000h)
  Word 4: Offset 3 (+ 8000h)
  Word 5: Offset 4 (+ 8000h)
  Word 6: Offset 5 (+ 8000h)
  Word 7: Offset 6 (+ 8000h)
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 001Ah
  Word 2: Data value at offset 1
  Word 3: Data value at offset 2
  Word 4: Data value at offset 3
  Word 5: Data value at offset 4
  Word 6: Data value at offset 5
  Word 7: Data value at offset 6
  Word 8: 16-bit checksum for this message

- **001Bh**: Display ROM Region 0 Data – Return the contents of six locations of ROM Data. Each data word of this message will be interpreted as an offset from the base of the ROM memory region 0. Each offset must be specified as a hexadecimal value as follows:

  offset = (offset of desired location) + 8000h.

  This command will always cause six values to be sent out.

  Message format to the IRU:

Word 1: Header = 001Bh
Word 2: Offset 1 (+ 8000h)
Word 3: Offset 2 (+ 8000h)
Word 4: Offset 3 (+ 8000h)
Word 5: Offset 4 (+ 8000h)
Word 6: Offset 5 (+ 8000h)
Word 7: Offset 6 (+ 8000h)
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 001Bh
Word 2: Data value at offset 1
Word 3: Data value at offset 2
Word 4: Data value at offset 3
Word 5: Data value at offset 4
Word 6: Data value at offset 5
Word 7: Data value at offset 6
Word 8: 16-bit checksum for this message

- **001Ch** Display ROM Region 1 Data – Return the contents of six locations of ROM Data. Each data word of this message will be interpreted as an offset from the base of the ROM memory region 1. Each offset must be specified as a hexadecimal value as follows:

  offset = (offset of desired location) + 8000h.

  This command will always cause six values to be sent out.

  Message format to the IRU:
  Word 1: Header = 001Ch
  Word 2: Offset 1 (+ 8000h)
  Word 3: Offset 2 (+ 8000h)
  Word 4: Offset 3 (+ 8000h)
  Word 5: Offset 4 (+ 8000h)
  Word 6: Offset 5 (+ 8000h)
  Word 7: Offset 6 (+ 8000h)
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 001Ch
  Word 2: Data value at offset 1
  Word 3: Data value at offset 2
  Word 4: Data value at offset 3
  Word 5: Data value at offset 4
  Word 6: Data value at offset 5
  Word 7: Data value at offset 6
  Word 8: 16-bit checksum for this message

- **001Dh**: Display ROM Region 2 Data – Return the contents of six locations of ROM Data. Each data word of this message will be interpreted as an offset from the base of the ROM memory region 2. Each offset must be specified as a hexadecimal value as follows:

offset = (offset of desired location) + 8000h.

This command will always cause six values to be sent out.

Message format to the IRU:
Word 1: Header = 001Dh
Word 2: Offset 1 (+ 8000h)
Word 3: Offset 2 (+ 8000h)
Word 4: Offset 3 (+ 8000h)
Word 5: Offset 4 (+ 8000h)
Word 6: Offset 5 (+ 8000h)
Word 7: Offset 6 (+ 8000h)
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 001Dh
Word 2: Data value at offset 1
Word 3: Data value at offset 2
Word 4: Data value at offset 3
Word 5: Data value at offset 4
Word 6: Data value at offset 5
Word 7: Data value at offset 6
Word 8: 16-bit checksum for this message

- **001Eh**: Display ROM Region 3 Data – Return the contents of six locations of ROM Data. Each data word of this message will be interpreted as an offset from the base of the ROM memory region 3. Each offset must be specified as a hexadecimal value as follows:

offset = (offset of desired location) + 8000h.

This command will always cause six values to be sent out.

Message format to the IRU:
Word 1: Header = 001Eh
Word 2: Offset 1 (+ 8000h)
Word 3: Offset 2 (+ 8000h)
Word 4: Offset 3 (+ 8000h)
Word 5: Offset 4 (+ 8000h)
Word 6: Offset 5 (+ 8000h)
Word 7: Offset 6 (+ 8000h)
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 001Eh
Word 2: Data value at offset 1
Word 3: Data value at offset 2

Word 4: Data value at offset 3
Word 5: Data value at offset 4
Word 6: Data value at offset 5
Word 7: Data value at offset 6
Word 8: 16-bit checksum for this message

- **0020h, 0021h, 0022h**, **0023h**, **0024h**, **0025h**, and **0026h**: Display Calibration Data – This command causes the calibration data to be sent from the IRU. The output resulting from this command requires seven messages since the number of data words is too large for one message. The data output from this command will continue to rotate through all of the messages until a new message is received that changes the output data. The calibration data output command may be initiated from any one of the seven header values. The first message sent out following the interpretation of the input command will be the one that matches the header of the input message header. The output will begin sequencing through the output messages from that point. For example, if a message is received with a header value of 0022h, the output messages would have header values in the following order: 0022h, 0023h, 0024h, 0025h, 0026h, 0020h, 0021h, 0022h, 0023h, 0024h. If a message was received with a header value of 0026h, the output messages would have header values in the following order: 0026h, 0020h, 0021h, 0022h, 0023h, 0024h, 0025h, 0026h, 0020h, 0021h, 0022h, 0023h, 0024h, ... and so forth.

  Message format to the IRU:
  Word 1: Header = 0020h – 0026h
  Words 2-7: Not significant
  Word 8: Checksum for this message

  Message format from the IRU:
  Word 1: Header = 0020h
  Word 2: Most significant 16 bits of the summed up raw Z accelerometer values
  Word 3: Least significant 16 bits of the summed up raw Z accelerometer values
  Word 4: Most significant 16 bits of the summed up compensated Z accelerometer values
  Word 5: Least significant 16 bits of the summed up compensated Z accelerometer values
  Word 6: Total accumulation time being used
  Word 7: Accumulation time counter used by the IRU
  Word 8: Checksum for this message

  Message format from the IRU:
  Word 1: Header = 0021h
  Word 2: Most significant 16 bits of the summed up raw YAW redundant gyro values
  Word 3: Least significant 16 bits of the summed up raw YAW redundant gyro values
  Word 4: 0000h
  Word 5: 0000h
  Word 6: Total accumulation time being used
  Word 7: Accumulation time counter used by the IRU
  Word 8: Checksum for this message

Word 1: Header = 0022h
Word 2: Most significant 16 bits of the summed up raw X accelerometer values
Word 3: Least significant 16 bits of the summed up raw X accelerometer values
Word 4: Most significant 16 bits of the summed up compensated X accelerometer values
Word 5: Least significant 16 bits of the summed up compensated X accelerometer values
Word 6: Total accumulation time being used
Word 7: Accumulation time counter used by the IRU
Word 8: Checksum for this message

Word 1: Header = 0023h
Word 2: Most significant 16 bits of the summed up raw Y accelerometer values
Word 3: Least significant 16 bits of the summed up raw Y accelerometer values
Word 4: Most significant 16 bits of the summed up compensated Y accelerometer values
Word 5: Least significant 16 bits of the summed up compensated Y accelerometer values
Word 6: Total accumulation time being used
Word 7: Accumulation time counter used by the IRU
Word 8: Checksum for this message

Word 1: Header = 0024h
Word 2: Most significant 16 bits of the summed up raw ROLL gyro values
Word 3: Least significant 16 bits of the summed up raw ROLL gyro values
Word 4: Most significant 16 bits of the summed up compensated ROLL gyro values
Word 5: Least significant 16 bits of the summed up compensated ROLL gyro values
Word 6: Total accumulation time being used
Word 7: Accumulation time counter used by the IRU
Word 8: Checksum for this message

Word 1: Header = 0025h
Word 2: Most significant 16 bits of the summed up raw PITCH gyro values
Word 3: Least significant 16 bits of the summed up raw PITCH gyro values
Word 4: Most significant 16 bits of the summed up compensated PITCH gyro values
Word 5: Least significant 16 bits of the summed up compensated PITCH gyro values
Word 6: Total accumulation time being used
Word 7: Accumulation time counter used by the IRU
Word 8: Checksum for this message

Word 1: Header = 0026h
Word 2: Most significant 16 bits of the summed up raw YAW gyro values
Word 3: Least significant 16 bits of the summed up raw YAW gyro values
Word 4: Most significant 16 bits of the summed up compensated YAW gyro values

Word 5: Least significant 16 bits of the summed up compensated YAW gyro values
Word 6: Total accumulation time being used
Word 7: Accumulation time counter used by the IRU
Word 8: Checksum for this message

- **0027h**: Display Temperatures – This command initiates output of sensor temperature data.

  Message format to the IRU:
  Word 1: Header = 0027h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 0027h
  Word 2: Yaw gyro temperature
  Word 3: Accelerometer mount temperature
  Word 4: Pitch and Yaw gyro estimated magnet temperature
  Word 5: Pitch gyro temperature
  Word 6: Roll gyro temperature
  Word 7: Roll gyro estimated magnet temperature
  Word 8: 16-bit checksum for this message

  The temperature values sent out of the IRU are translated from the value in the message to a temperature in degrees Celsius according to the following formula:

  XX = Temperature value from message.

  Temperature (degree C) = XX / 100

- **0028h**: Display Raw Sensor Data – This command initiates output of the raw sensor data which provides a “snapshot” of the data being used by the IRU for input to the sensor compensation function.

  Message format to the IRU:
  Word 1: Header = 0028h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 0028h
  Word 2: Raw X accelerometer value
  Word 3: Raw Y accelerometer value
  Word 4: Raw Z accelerometer value
  Word 5: Raw ROLL gyro value
  Word 6: Raw PITCH gyro value
  Word 7: Raw YAW gyro value
  Word 8: 16-bit checksum for this message

The output data for both accelerometers and gyros is a 16 bit integer.

For the accelerometers, the Least Significant Bit represents 9.80388992e-6 Meters/Second. The full scale range is then approximately +/- 0.32125 Meters/Second.

For the gyros, the Least Significant Bit represents 2.09439510239e-6 Radians. The full scale range is then approximately +/- 0.068629138715 Radians.

- **0029h**: Display Compensated Sensor Data – This command initiates output of the compensated sensor data which provides a snapshot of the data being used by the IRU for input to the leveling loops.

  Message format to the IRU:
  - Word 1: Header = 0029h
  - Words 2-7: Not significant
  - Word 8: 16-bit checksum for this message

  Message format from the IRU:
  - Word 1: Header = 0029h
  - Word 2: Compensated X accelerometer value
  - Word 3: Compensated Y accelerometer value
  - Word 4: 0000h
  - Word 5: Compensated ROLL gyro value
  - Word 6: Compensated PITCH gyro value
  - Word 7: Compensated YAW gyro value
  - Word 8: 16-bit checksum for this message

  The scaling for this message is the same as for 0028h.

- **002Ah**: Display Latitude and Longitude, True Heading, Grid Heading, Sin of Pitch and Sin of Roll.

  Message format to the IRU:
  - Word 1: Header = 002Ah
  - Words 2-7: Not significant
  - Word 8: 16-bit checksum for this message

  Message format from the IRU:
  - Word 1: Header = 002Ah
  - Word 2: Latitude LSW
  - Word 3: Longitude LSW
  - Word 4: Grid Heading
  - Word 5: True Heading
  - Word 6: Sin of Pitch
  - Word 7: Sin of Roll
  - Word 8: 16-bit checksum for this message

  Words 2 and 3 contain only the least significant word of latitude and longitude, respectively. Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled before sending out according to the following equations:

Word 2 = ((IRU Latitude, in radians) / PI) * 2^{30}
Word 3 = ((IRU Longitude, in radians) / PI) * 2^{30}

Grid Heading is presented as an integer value in this message. It is derived from the IRUs Grid Heading and transformed to a 16-bit signed integer as follows:

Word 4 = GRID HEADING (Degrees) * 100.0

True Heading is presented as an integer value in this message. It is derived from the IRUs True Heading and transformed to a 16-bit signed integer as follows:

Word 5 = TRUE HEADING (Degrees) * 100.0

The Sine of Pitch and Sine of Roll are presented as scaled integer values from the IRU. They are scaled before sending out according to the following equations:

Word 6 = SIN_PITCH * 10,000
Word 7 = SIN_ROLL * 10,000

- **002Bh**: Display Latitude, True Heading, GC Variance.

Message format to the IRU:
Word 1: Header = 002Bh
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 002Bh
Words 2-3: Latitude
Words 4-5: True Heading
Word 6: Heading Variance
Word 7: Estimate of Heading Variance
Word 8: 16-bit checksum for this message

Latitude is presented as a scaled integer value from the IRU. It is scaled according to the following equation:
Words 2-3 = ((IRU Latitude, in radians) / PI) * 2^{30}

True Heading is presented as an integer value in this message. It is derived from the IRUs True Heading and transformed to a 32-bit signed integer as follows:

Words 4-5 = True HEADING (Degrees) * (6400 / 360) * 100

The Heading Variance is the Gyro Compass Kalman filters current heading error estimate as a one sigma value. The Heading Variance is presented as an integer value in this message. It is scaled according to the following equation:

Word 6 = Heading Variance (milliradians) * 100

The Estimate of Heading Variance is the Gyro Compass Kalman filters estimate of the heading error at the end of the Gyro Compass time as a one sigma value. The Estimate of Heading Variance is presented as an integer value in this message. It is scaled according to the following equation:

Word 7 = Estimate of Heading Variance (milliradians) * 100

- **002Ch**: Display Base Motion Comp. (BMC) GC Heading, Status.

Message format to the IRU:
Word 1: Header = 002Ch
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 002Ch
Word 2: True Heading
Word 3: Grid Heading
Word 4: BMC Gyrocompass State
Word 5: BMC Gyrocompass Time Remaining
Word 6: Current Heading Variance
Word 7: Malfunction BIT (Least Significant Byte (LSByte))
Word 7: IRU Mode/GPS Status/Moving (Most Significant Byte (MSByte))
Word 8: 16-bit checksum for this message

True Heading is the unit heading relative to true north and is presented as an integer value in this message. It is transformed to a 16-bit integer as follows:

True Heading = True Heading (Degrees) * 100.0

Grid Heading is presented as an integer value in this message. It is derived from the IRUs Grid Heading and transformed to a 16-bit signed integer as follows:

Grid Heading = Grid Heading (Degrees) * 100.0

The BMC Gyrocompass State represents the current step of a sequence of operations during a BMC gyrocompass operation. The states are defined as follows:

0 – CHECK_IF_VALID_TO_GC
1 – SETTLE_AT_0
2 – FIRST_COLLECT_DATA_AT_0
3 – MOVE_0_TO_180
4 – STOP_AT_180
5 – COLLECT_DATA_AT_180
6 – MOVE_FROM_180_TO_0
7 – STOP_AT_0
8 – SECOND_COLLECT_DATA_AT_0
9 – END_GYRO_COMPASS
10 – MOVE_TO_0_NOW
11 – RESTART_GYRO_COMPASS

The BMC Gyrocompass Time Remaining is an estimate of the amount of time remaining until the gyrocompass operation is complete. The units are seconds * 61.

The Current Heading Variance is the Gyro Compass Kalman filters current heading error estimate as a one sigma value. The Heading Variance is presented as an integer value in this message. It is scaled before sending out according to the following equation:

Current Heading Variance = Heading Variance (miliradians) * 100

The Malfunction word is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

- **002Dh**: Turn Off Sensor Data Accumulation – This command disables the sensor data accumulation task in the IRU.

  Message format to the IRU:
  Word 1: Header = 002Dh
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: All RS-422 output will stop and remain off until sensor data accumulation is turned on and a new output message is requested.

  Note: If the processor deadman timer is enabled, turning off the sensor data accumulation will result in a reset of the IRU.

- **002Eh**: Turn On Sensor Data Accumulation – This command enables the sensor data accumulation task in the IRU.

  Message format to the IRU:
  Word 1: Header = 002Eh
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0033h**: Turn Off Attitude Integration – This command disables the roll and pitch attitude integration into the variables PHI and Theta.

  Message format to the IRU:
  Word 1: Header = 0033h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0034h**: Turn On Attitude Integration – This command enables the roll and pitch attitude integration into the variables PHI and Theta.

  Message format to the IRU:
  Word 1: Header = 0034h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0038h**: Display FTL Target Coordinates – The NFM receives input data of Laser Range, Elevation, Azimuth Lead, and Display Format in this message. Then using the NFM position, heading and attitude information and the input data, the target coordinates are computed and reported in the output message. The exact format of the output message depends upon the Display Format selected.

  Message format to the IRU:
  Word 1: Header 0038h
  Word 2: Elevation input
  Word 3: Azimuth Lead input
  Word 4: Laser Range input
  Word 5: Display Format
  Word 6-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU: (If display format is MGRS)
  Word 1: Header 0038h
  Word 2: MSByte: Target FOM
  Word 2: LSByte: Datum Number (Integer number, Range 1-61)
  Word 3: MSByte: Grid Number (Integer number, Range 1-60)
  Word 3: LSByte: Zone Letter Character (ASCII)
  Word 4: MSByte: Easting Letter (ASCII)
  Word 4: LSByte: Northing Letter (ASCII)
  Word 5: Easting (Integer, LSBit = 10 meters)
  Word 6: Northing (Integer, LSBit = 10 meters)
  Word 7: MSByte: IRU Mode/GPS Status/Moving
  Word 7: LSByte: Malfunction BIT
  Word 8: 16-bit Checksum for this message

  Message format from the IRU: (If display format is Lat/Lon)
  Word 1: Header 0038h
  Word 2: MSByte: Target FOM
  Word 2: LSByte: Datum Number
  Word 3-4: Latitude (32-bit Integer)
  Word 5-6: Longitude (32-bit Integer)
  Word 7: MSByte: IRU Mode/GPS Status/Moving
  Word 7: LSByte: Malfunction BIT
  Word 8: 16-bit Checksum for this message

The Elevation input is the angle between the Line Of Sight (LOS) of the laser range finder and the XY plane of the NFM system with positive defined as the LOS above the XY plane. This input is a 16 bit signed integer with the Least Significant Bit (LSB) equal to 25 microradian.

The Azimuth Lead input is the angle between the Line Of Sight (LOS) of the laser range finder and the NFM system heading with positive defined as the LOS to the right of the NFM heading. This input is a 16 bit signed integer with the Least Significant Bit equal to 25 microradian.

The Laser Range input is the range to the target. This input is a 16 bit signed integer with the LSB equal to 1 Meter.

The Display Format for the input message is defined as follows:

0 – MGRS - Old
1 – MGRS - New
3 or 4 – Lat/Long

The Easting and Northing values are the MGRS easting and northing coordinates with the least significant bit equal to 10 meters.

Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 3-4 = ((IRU Latitude, in radians) / PI) * 2^{30}
Words 5-6 = ((IRU Longitude, in radians) / PI) * 2^{30}

The Malfunction BIT is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word. See Table 5 of 3.2.4 NFM/Target/GPS/Time FOM Definition for a description of the Target FOM definition.

- **003Dh**, **003Eh**, **003Fh**, and **0040h**: Display BIT Words – This command initiates output of all IRU BIT words. Selecting any one of the headers will cause the IRU to rotate through the remaining headers in sequence beginning with the commanded header. Refer to Section 5 of this document for a description of the following words and corresponding bits:

Message format to the IRU:

Word 1: Header = 003Dh
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 003Dh
Word 2: LRU CBIT
Word 3: RESERVED
Word 4: RESERVED
Word 5: RESERVED

Word 6: TEST FAULT → TEST WORD 1
Word 7: TEST FAULT → TEST WORD 2
Word 8: 16-bit checksum for this message

Word 1: Header = 003Eh
Word 2: TEST FAULT → TEST WORD 3
Word 3: TEST FAILURE → TEST WORD 1
Word 4: TEST FAILURE → TEST WORD 2
Word 5: TEST FAILURE → TEST WORD 3
Word 6: TEST ERROR → TEST WORD 1
Word 7: TEST ERROR → TEST WORD 2
Word 8: 16-bit checksum for this message

Word 1: Header = 003Fh
Word 2: TEST ERROR → TEST WORD 3
Word 3: TEST FAULT → DIAGNOSTIC WORD 1
Word 4: TEST FAULT → DIAGNOSTIC WORD 2
Word 5: TEST FAILURE → DIAGNOSTIC WORD 1
Word 6: TEST FAILURE → DIAGNOSTIC WORD 2
Word 7: TEST ERROR → DIAGNOSTIC WORD 1
Word 8: 16-bit checksum for this message

Word 1: Header = 0040h
Word 2: TEST ERROR → DIAGNOSTIC WORD 2
Word 3: CRITICAL DATA R/W FAIL COUNT
Word 4: RESERVED
Word 5: RESERVED
Word 6: RESERVED
Word 7: RESERVED
Word 8: 16-bit checksum for this message

- **0041h**: Set Spin Motors 5% Slow – This command sets the spin motors on both DTG's 5% below the nominal value in the calibration data base for the purpose of determining the rotor offset.

  Message format to the IRU:
  Word 1: Header = 0041h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

- **0042h**: Set Spin Motors to Normal Speed – This command sets the spin motors on both DTG's to the nominal value in the calibration data base.

  Message format to the IRU:
  Word 1: Header = 0042h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

- **0043h**: Set Temporary Rotor Offsets – This command sets the DTG rotor offsets to the values in Words 2-5. The values in the calibration data base are not changed and the system will return to the values in the data base if the power is cycled off and on.

  Message format to the IRU:
    - Word 1: Header = 0043h
    - Word 2: P gyro channel rotor offset
    - Word 3: Q gyro channel rotor offset
    - Word 4: R gyro channel rotor offset
    - Word 5: Redundant channel rotor offset
    - Words 6-7: Not significant
    - Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The rotor offset values are integer values in the range of -128 to +127. Each count is approximately 8 arcseconds of rotor offset.

- **0044h**: Set Temporary Loop Gain – This command sets the DTG servo loop gains to the values in Words 2-4. The values in the calibration data base are not changed and the system will return to the values in the data base if the power is cycled off and on.

  Message format to the IRU:
    - Word 1: Header = 0044h
    - Word 2: P gyro channel loop gain
    - Word 3: Q gyro channel loop gain
    - Word 4: R gyro channel loop gain
    - Words 5-7: Not significant
    - Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The rotor offset values are integer values in the range of 0 to 7. Each count is a gain change of 1/8. Zero represents a gain of 1.0, seven represents a gain of 1.875.

- **0045h**: Set Waypoint Position Latitude/Longitude. - This command sets the selected way point position to the entered latitude and longitude.

  Message format to the IRU:
    - Word 1: Header = 0045h
    - Word 2: Waypoint number (1 to 64)
    - Words 3-4: Waypoint Latitude
    - Words 5-6: Waypoint Longitude
    - Words 7: Not significant
    - Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The new Waypoint Latitude and Waypoint Longitude must be scaled before being sent to the IRU. The scaling must be as follows:

Words 3-4 = ((New Latitude, in Radians)/PI)* 2^{30}
Words 5-6 = ((New Longitude, in Radians)/PI)* 2^{30}

Words 3 and 5 contain the most significant portion of Latitude and Longitude, respectively. Words 4 and 6 contain the least significant portions of Latitude and Longitude, respectively. Latitude is limited to ± 90 degrees and Longitude is limited to ± 180 degrees. Note: Invalid values will be ignored.

- **0046h**: Set Waypoint Position MGRS – This command sets the selected way point position to the entered MGRS coordinate.

Message format to the IRU:
Word 1: Header = 0046h
Word 2: Waypoint number (1 to 64)
Word 3 MSB: Waypoint First Zone Number Character (ASCII)
Word 3 LSB: Waypoint Second Zone Number Character (ASCII)
Word 4 MSB: Waypoint First Zone Letter Character (ASCII)
Word 4 LSB: Waypoint Easting Letter (ASCII)
Word 5 MSB: Waypoint Northing Letter (ASCII)
Word 5 LSB: Not significant
Word 6: New Waypoint Easting Value
Word 7: New Waypoint Northing Value
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The Zone Numbers and Zone Letters specified in this message are validated before allowing a new position to be set. The New Easting Value and New Northing Value in Words 6 and 7, respectively, must be scaled to the nearest 10 meters of desired easting and northing position and must be within the range of $0 \leq \text{Value} \leq 9999$. For example, if the new position is to be 2110 meters East and 44888 meters North, then the values for message Words 6 and 7 would be 211 and 4489, respectively. The IRU uses these words internally according to the following:

New Easting = Word 6 * 10.0
New Northing = Word 7 * 10.0

- **0047h**: Display Waypoint Latitude/Longitude. - This initiates the output of the requested waypoint number Latitude and Longitude.

Message format to the IRU:
Word 1: Header = 0047h
Word 2: Waypoint number (1 to 64)
Words 3-7: Not significant

Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 0047h
Word 2: Waypoint number (1 to 64)
Words 3-4: Waypoint Latitude
Words 5-6: Waypoint Longitude
Word 7: Not significant
Word 8: 16-bit checksum for this message

Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 3-4 = ((IRU Latitude, in radians) / PI) * 2^{30}
Words 5-6 = ((IRU Longitude, in radians) / PI) * 2^{30}

Words 3 and 5 contain the most significant portion of Latitude and Longitude, respectively. Words 4 and 6 contain the least significant portions of Latitude and Longitude, respectively.

- **0048h**: Display Waypoint Position MGRS – This command initiates output of the requested waypoint number position in MGRS form.

Message format to the IRU:

Word 1: Header = 0048h
Word 2: Waypoint number (1 to 64)
Words 3-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 0048h
Word 2: Waypoint number (1 to 64)
Word 3 MSB: First Zone Number Character (ASCII)
Word 3 LSB: Second Zone Number Character (ASCII)
Word 4 MSB: First Zone Letter Character (ASCII)
Word 4 LSB: Easting Letter (ASCII)
Word 5 MSB: Northing Letter (ASCII)
Word 5 LSB: Datum Number/Position Format
Word 6: Easting Value
Word 7: Northing Value
Word 8: 16-bit checksum for this message

The system current Datum Number is output in the least significant 7 bits of Word 5, and the 8^{th} bit is set to 0 for MGRS-old Position Format and 1 for MGRS-new Position Format.

The Northing and Easting values are scaled integers and are converted to their true values by multiplying by 10.0.

- **0049h**: Display Range and Bearing to Waypoint - This command initiates the output of the range and bearing to the requested waypoint number.

Message format to the IRU:
Word 1: Header = 0049h
Word 2: Waypoint number (1 to 64)
Word 3: Driver Waypoint Number (0 to 64)
Words 4-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0049h
Word 2: Waypoint number (1 to 64)
Word 3-4: Range to Waypoint
Word 5: Bearing from current location to waypoint
Word 6: Vehicle True heading
Word 7: Vehicle Grid heading
Word 8: 16-bit checksum for this message

The waypoint number in Word 2 defines the waypoint to be output in the RS-422 output message. The waypoint number in Word 3 defines the waypoint to be displayed on the driver's display. No waypoint data will be displayed on the driver's display when the waypoint number in Word 3 is set to 0.

The range to the waypoint is given as an integer number in meters. Word 3 contains the most significant word and word 4 contains the least significant word.

The Bearing from the current location to the waypoint is the true heading to the waypoint and is presented as an integer value in this message. It is transformed to a 16 bit integer as follows:

Bearing = Integer(Bearing (Degrees) * 100.0)

Vehicle True Heading is the unit heading relative to true north and is presented as an integer value in this message. It is transformed to a 16-bit integer as follows:

Vehicle True Heading = Integer(Vehicle True Heading (Degrees) * 100.0)

Vehicle Grid Heading is presented as an integer value in this message. It is derived from the IRUs Grid Heading and transformed to a 16-bit signed integer as follows:

Vehicle Grid Heading = Integer(Vehicle Grid Heading (Degrees) * 100.0)

- **004Ah**: Display Loop Gain Cal Data – This command displays the results of the Loop Gain Cal Command.

Message format to the IRU:
Word 1: Header = 004Ah
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 004Ah
Word 2: Calibration Step Count
Word 3: P Gyro Loop Gain
Word 4: Q Gyro Loop Gain
Word 5: R Gyro Loop Gain
Word 6: Loop Gain Cal Validity
Word 7: 0000h
Word 8: 16-bit checksum for this message

The calibration step count will increment from 1 to 30 as the Loop Gain Cal Process proceeds. When the process is complete, the step count will return to zero.

The P gyro, Q gyro, and R gyro Loop Gain Values will be a value from 0 through 7. This value is the value that should be entered into coefficient file for the correct Loop Gain calibration of the unit.

The Loop Gain calibration validity is as follows:

Bit 0 (LSB)	:	1 = valid, 0 = invalid, P Gyro Axis
Bit 1	:	1 = valid, 0 = invalid, Q Gyro Axis
Bit 2	:	1 = valid, 0 = invalid, R Gyro Axis
Bit 3	:	1 = valid, 0 = invalid, R' Gyro Axis

- **004Bh**: Initiate Loop Gain Cal Process – This command initiates the automatic Loop Gain Cal process. The process can take up to 4.5 minutes to complete. The results of this process can be monitored with the 004Ah command.

  Message format to the IRU:
  Word 1: Header = 004Bh
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output.

- **004Ch**: Perform Rotator Movement – This command causes the rotator to rotate 180 degrees and then hold the rotator against the stop. This command is for test purposes only.

  Message format to the IRU:
  Word 1: Header = 004Ch
  Words 2: Direction (1 = Clockwise, 0=Counter Clockwise)
  Words 3-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output.

- **004Dh**: Set Frequency Spin Speeds – This command sets the DTG spin speeds to the values in words 2 and 3. The values in the calibration database are not changed. The system will return to the values in the database if the power is cycled off and on.

Message format to the IRU:

Word 1: Header = 004Dh
Words 2: Spin Frequency 1 Count
Words 3: Spin Frequency 2 Count
Words 4-7: Not significant

Message format from the IRU: No change in output.

The spin frequency count must be between 1930 and 2500 to be valid. The spin frequency count is computed as follows:

$$Count = Int\left(\frac{14318100}{48 \cdot Speed}\right)$$

Where: Speed is the desired mechanical speed of the gyro

Spin frequency 1 is the pitch/yaw gyro and Spin frequency 2 is the roll gyro.

- **004Eh**: Modify Memory 32 bit addressing – Modify memory using 32 bit addresses. If words 5 & 6 are zero, only the first address will be written.

  Message format to the IRU:

  Word 1: Header = 004Eh
  Word 2: Most significant word of address 1
  Word 3: Least significant word of address 1
  Word 4: Data to write to address 1
  Word 5: Most significant word of address 2
  Word 6: Least significant word of address 2
  Word 7: Data to write to address 2
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output.

  Valid memory write ranges include all of RAM and all of EEPROM above the loader.

- **004Fh**: Display Memory 32 bit addressing – Display the contents of the 32 bit addresses spedified.

  Message format to the IRU:

  Word 1: Header = 004Fh
  Word 2: Most significant word of address 1
  Word 3: Least significant word of address 1
  Word 4: Most significant word of address 2
  Word 5: Least significant word of address 2
  Word 6: Most significant word of address 3
  Word 7: Least significant word of address 3
  Word 8: 16-bit checksum for this message

  Message format from the IRU:

  Word 1: Header = 004Fh

Word 2: 16 bits of data at address 1
Word 3: 16 bits of data at address 1 + 2
Word 4: 16 bits of data at address 2
Word 5: 16 bits of data at address 2 + 2
Word 6: 16 bits of data at address 3
Word 7: 16 bits of data at address 3 + 2
Word 8: 16-bit checksum for this message

- **0050h**, **0051h**, **0052h**, and **0053h**: Display Release Date and Part Number – This command causes the creation date and the part number of the IRU software to be sent on the RS-422. Selecting any one of the headers will cause the IRU to rotate through the remaining headers in sequence beginning with the commanded message.

Message format to the IRU:
Word 1: Header = 0050h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0050h
Word 2: Characters 1 and 2 of the part number
Word 3: Characters 3 and 4 of the part number
Word 4: Characters 5 and 6 of the part number
Word 5: Characters 7 and 8 of the part number
Word 6: Characters 9 and 10 of the part number
Word 7: Characters 11 and 12 of the part number
Word 8: 16-bit checksum for this message

Word 1: Header = 0051h
Word 2: Characters 13 and 14 of the part number
Word 3: Characters 15 and 16 of the part number
Word 4: Characters 17 and 18 of the part number
Word 5: Characters 19 and 20 of the part number
Word 6: Characters 1 and 2 of the time and date
Word 7: Characters 3 and 4 of the time and date
Word 8: 16-bit checksum for this message

Word 1: Header = 0052h
Word 2: Characters 5 and 6 of the time and date
Word 3: Characters 7 and 8 of the time and date
Word 4: Characters 9 and 10 of the time and date
Word 5: Characters 11 and 12 of the time and date
Word 6: Characters 13 and 14 of the time and date
Word 7: Characters 15 and 16 of the time and date
Word 8: 16-bit checksum for this message

Word 1: Header = 53h
Word 2: Characters 17 and 18 of the time and date
Word 3: Characters 19 and 20 of the time and date
Word 4: Characters 21 and 22 of the time and date

Word 5: Characters 23 and 24 of the time and date
Word 6: Characters 25 and 26 of the time and date
Word 7: Characters 27 and 28 of the time and date
Word 8: 16-bit checksum for this message

- **0054h**: Display Military Grid Reference System (MGRS) Position – This command initiates output of the MGRS coordinates.

  Message format to the IRU:
  Word 1: Header = 0054h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 0054h
  Word 2 MSB: First Zone Number Character (ASCII)
  Word 2 LSB: Second Zone Number Character (ASCII)
  Word 3 MSB: First Zone Letter Character (ASCII)
  Word 3 LSB: Easting Letter (ASCII)
  Word 4 MSB: Northing Letter (ASCII)
  Word 4 LSB: Datum Number/Position Format
  Word 5: Easting Value
  Word 6: Northing Value
  Word 7: Grid Heading
  Word 8: 16-bit checksum for this message

  The system current Datum Number is output in the least significant 7 bits of Word 4, and the 8th bit is set to 0 for MGRS-old Position Format and 1 for MGRS-new Position Format.

The Northing and Easting values are scaled integers and are converted to their true values by multiplying by 10.0. The Grid Heading is a scaled integer and is converted to its true value by dividing by 100.0.

- **0055h**: Display Meridian Convergence.

  Message format to the IRU:
  Word 1: Header = 0055h
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 0055h
  Words 2-3: FLOAT_32(Meridian Convergence in Radians)
  Words 4-7: Not significant
  Word 8: 16-bit checksum for this message

- **0056h**: Set Gyrocompass Residual

  Message format to the IRU:

Word 1: Header = 0056h
Word 2: Gyrocompass Residual
Words 3-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The value specified for a gyrocompass residual in Word 2 must be an integer value 100 times the actual angle, in degrees, to be established. For example, if a new gyrocompass residual were to be set to 2.8 degrees then Word 2 of this input message would need to be 280. The IRU will only accept a value in Word 2 in the range of -400 ≤ Word 2 ≤ 400. The IRU uses the following formula when establishing a new gyrocompass residual:

New Gyrocompass Residual = Word 2 * 0.01

- **0058h**: Set Grid Heading – This command allows a new grid heading to be established in the IRU.

  Message format to the IRU:
  Word 1: Header = 0058h
  Word 2: Grid Heading
  Words 3-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The grid heading value in Word 2 of the input message must be an integer value specified in degrees and be 10 times the desired value. For example, if a new heading of 19.2 degrees is to be established Word 2 would have to be 19.2 * 10 = 192. Therefore, heading can only be set to the nearest 0.1 degrees.

  (Note: The IRU will establish the new heading according to the following:
  New Grid heading = Word 2 * 0.1;)

- **0059h**: Set MGRS Position – This command allows new position to be sent to the IRU for initialization of a new position.

  Message format to the IRU:
  Word 1: Header = 0059h
  Word 2 MSB: First Zone Number Character (ASCII)
  Word 2 LSB: Second Zone Number Character (ASCII)
  Word 3 MSB: First Zone Letter Character (ASCII)
  Word 3 LSB: Easting Letter (ASCII)
  Word 4 MSB: Northing Letter (ASCII)
  Word 4 LSB: Not significant
  Word 5: New Easting Value
  Word 6: New Northing Value
  Word 7: Not significant
  Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The Zone Numbers and Zone Letters specified in this message are validated before allowing a new position to be set. The New Easting Value and New Northing Value in Words 5 and 6, respectively, must be scaled to the nearest 10 meters of desired easting and northing position and must be within the range of $0 \leq \text{Value} \leq 9999$. For example, if the new position is to be 2110 meters East and 44888 meters North, then the values for message Words 5 and 6 would be 211 and 4489, respectively. The IRU uses these words internally according to the following:

New Easting = Word 5 * 10.0
New Northing = Word 6 * 10.0

- **005Ah**: Set Datum – This command allows the datum to be changed in the IRU.

Message format to the IRU:

Word 1: Header = 005Ah
Word 2: Datum Number
Word 3: Position Format
Words 4-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The datum number value specified in Word 2 of this input message is accepted by the IRU if it is a valid datum number value. There is no scaling needed for datum number value.

The Display Format for the output message is defined as follows:

0 – MGRS Old
1 – MGRS New
2 – UTM
3 – Lat/Lon (degrees, minutes)
4 – Lat/Lon (degrees, minutes, seconds)

Note: When the datum is changed, the system will compute the new latitude, longitude, and MGRS position for the new datum and then begin navigating from this new position.

The valid datum values are listed in table 8. If a PLGR is connected, and a datum of 62 or higher is selected, then it will be ignored.

Table 8. List of Valid Datums

No.	**ID**	**Datum**	**Spheroid**	**Alpha MGRS-old**	**Offset MGRS-new**
1	ARF-M	ARC 1950	Clark 1880	10	10
2	ARS	ARC 1960	Clark 1880	10	10
3	AUA	Australian Geo 1966	Australian National	0	0
4	AUG	Australian Geo 1984	Australian National	0	0
5	BOO	Bogota Observatory	International 1924	0	0
6	CAI	Campo Iuchauspe	International 1924	0	0
7	CAP	Cape	Clark 1880	10	10
8	CGE	Carthage	Clark 1880	10	10
9	CHI	Chatham 1971	International 1924	0	0
10	CHU	Chua Astro	International 1924	0	0
11	COA	Correga Alegre	International 1924	0	0
12	EUR-A	European 1950	International 1924	0	0
13	EUR-E	Cyprus	International 1924	0	0
14	EUR-F	Egypt	International 1924	0	0
15	EUR-H	Iran	International 1924	0	0
16	EUR-J	Sicily	International 1924	0	0
17	EUS	European 1979	International 1924	0	0
18	FAH	Oman	Clark 1880	10	10
19	GAA	Gandajika Base	International 1924	0	0
20	GEO	Geo Datum 1949	International 1924	0	0
21	HJO	Hjorsey 1955	International 1924	0	0
22	INF-A	Indian (Thailand)	Everest 1830	10	0
23	IND-I	Indian (Nepal)	Everest 1956	10	0
24	IRL	Ireland 1965	Modified Airy	0	0
25	KEA	Kertau 1948	Everest 1948	0	0
26	LIB	Liberia 1964	Clark 1880	10	10
27	LUZ-A	Luzon	Clark 1866	10	0
28	MAS	Massawa	Bessel 1841	0	10
29	MER	Merchich	Clark 1880	10	10
30	MIN-B	Minna	Clark 1880	10	10
31	NAH-C	Nahrwan	Clark 1880	10	10
32	NAR	North Amer 1983	GRS 80	0	0
33	NAS-C	North Amer 1927 (Conus)	Clark 1866	10	10
34	NAS-D	Alaska	Clark 1866	10	10
35	NAS-E	Canada	Clark 1866	10	10
36	NAS-N	Central America	Clark 1866	10	10
37	OEG	Old Egyptian	Helmert 1906	0	10
38	OGB-M	Ordnance Survey of GB	Airy 1830	0	0
39	OHA-M	Old Hawaiian	Clark 1866	10	10
40	PIT	Pitcairn Astro 1967	International 1924	0	0
41	QAT	Qatar National	International 1924	0	0
42	QUO	Qornoq	International 1924	0	0

Table 8. List of Valid Datums (Continued)

No.	ID	Datum	Spheroid	Alpha MGRS-old	Offset MGRS-new
43	SAN-M	South American 1969	South America 1969	0	0
44	SCK	Schwarzeck	Bessel Namibia 1841	10	10
45	TIL	Timbalai 1948	Everest Brunei	10	0
46	TOY-M	Tokyo	Bessel 1841	0	10
47	WGD	WGS 1984	WGS 1984	0	0
48	WGS	WGS 1972	WGS 1972	0	0
49	ZAN	Sanderij	International 1924	0	0
50	USER1	WGS 1984	WGS 1984	0	0
51	USER2	WGS 1984	WGS 1984	0	0
52	RSVD	WGS 1984	WGS 1984	0	0
53	RSVD	WGS 1984	WGS 1984	0	0
54	RSVD	WGS 1984	WGS 1984	0	0
55	RSVD	WGS 1984	WGS 1984	0	0
56	RSVD	WGS 1984	WGS 1984	0	0
57	RSVD	WGS 1984	WGS 1984	0	0
58	RSVD	WGS 1984	WGS 1984	0	0
59	RSVD	WGS 1984	WGS 1984	0	0
60	RSVD	WGS 1984	WGS 1984	0	0
61	BBOHM	Bessel Bohm	Bessel 1841	0	10
NOTE:The following datums are only valid if using a DAGR					
62	ADI-A	ADINDAN-Ethiopia	Clark 1880	10	10
63	ADI-B	ADINDAN-Sudan	Clark 1880	10	10
64	ADI-C	ADINDAN-Mali	Clark 1880	10	10
65	ADI-D	ADINDAN-Senegal	Clark 1880	10	10
66	ADI-E	ADINDAN-Burkina Faso	Clark 1880	10	10
67	ADI-F	ADINDAN-Cameroon	Clark 1880	10	10
68	ADI-M	ADINDAN-Mean Solution	Clark 1880	10	10
69	AFG	Somalia	Krassovsky 1940	0	0
70	AIA	Antigua Island	Clark 1880	10	10
71	AIN-A	Bahrain Island	International 1924	0	0
72	AIN-B	Saudi Arabia	International 1924	0	0
73	AMA	American Samoa 1962	Clark 1866	10	10
74	ANO	Cocos Islands	Australian National	0	0
75	ARF-A	ARC50-Botswana	Clark 1880	10	10
76	ARF-B	ARC50-Lesotho	Clark 1880	10	10
77	ARF-C	ARC50-Malawi	Clark 1880	10	10
78	ARF-D	ARC50-Swaziland	Clark 1880	10	10
79	ARF-E	ARC50-Zaire	Clark 1880	10	10
80	ARF-F	ARC50-Zambia	Clark 1880	10	10
81	ARF-G	ARC50-Zimbabwe	Clark 1880	10	10
82	ARF-H	ARC50-Burundi	Clark 1880	10	10
83	ARS-A	ARC60-Kenya	Clark 1880	10	10
84	ARS-B	ARC60-Tanzania	Clark 1880	10	10
85	ARS-M	ARC 1960 Mean Solution	Clark 1880	10	10

Table 8. List of Valid Datums (Continued)

No.	ID	Datum	Spheroid	Alpha	Offset
				MGRS-old	MGRS-new
86	ASC	Ascension Island	International 1924	0	0
87	ASM	Montserrat Island	Clark 1880	10	10
88	ASQ	Marcus Island	International 1924	0	0
89	ATF	Astro Beacon E	International 1924	0	0
90	BAT	Djakarta	Bessel 1841	0	10
91	BER	Bermuda 57	Clark 1866	10	10
92	BID	Bissau	International 1924	0	0
93	BUR	Bukit Rimpah	Bessel 1841	0	10
94	CAC	Cape Canaveral	Clark 1866	10	10
95	CAO	Canton Astro	International 1924	0	0
96	CAZ	Camp McMurdo	International 1924	0	0
97	CCD	Czechoslovakia	Bessel 1841	0	10
98	DAL	Dabola	Clark 1880	10	10
99	DID	Deception Island	Clark 1880	10	10
100	DOB	Guadalcanal Island	International 1924	0	0
101	EAS	Easter Island	International 1924	0	0
102	ENW	Marshall Islands	Hough 1960	0	0
103	EST	Estonia	Bessel 1841	0	10
104	EUR-B	Greece	International 1924	0	0
105	EUR-C	Norway	International 1924	0	0
106	EUR-D	Spain	International 1924	0	0
107	EUR-G	England	International 1924	0	0
108	EUR-I	Sardinia	International 1924	0	0
109	EUR-K	United Kingdom	International 1924	0	0
110	EUR-L	Malta	International 1924	0	0
111	EUR-M	Mean	International 1924	0	0
112	EUR-S	Mean Near East	International 1924	0	0
113	EUR-T	Tunisia	International 1924	0	0
114	FLO	Corvo and Flores Islands	International 1924	0	0
115	FOT	Fort Thomas 1955	Clark 1880	10	10
116	GIZ	Gizo Islands	International 1924	0	0
117	GRA	Graciosa Base	International 1924	0	0
118	GSE	Kalimantan	Bessel 1841	0	10
119	GUA	Guam	Clark 1866	10	10
120	HEN	Afghanistan	International 1924	0	0
121	HER	Yugoslavia	Bessel	0	10
122	HIT	Southern Chile	International 1924	0	0
123	HKD	Hong Kong	International 1924	0	0
124	HTN	Taiwan	International 1924	0	0
125	IBE	Bellevue	International 1924	0	0
126	IDN	Indonesia	Indonesian_1974	0	0
127	IND-B	Bangladesh	Everest	10	0
128	IND-P	Pakistan	Everest	0	0
129	IND-S	India	Everest	10	0
130	ING-A	Vietnam	Everest	10	0
131	ING-B	Con Son Island	Everest	10	0

Table 8. List of Valid Datums (Continued)

No.	ID	Datum	Spheroid	Alpha MGRS-old	Offset MGRS-new
132	INH-A	Thailand	Everest	10	0
133	INH-A1	Thailand	Everest	10	0
134	ISG	South Georgia Islands	International 1924	0	0
135	IST	Diego Garcia	International 1924	0	0
136	JOH	Johnston Island	International 1924	0	0
137	KAN	Sri Lanka	Everest	10	0
138	KEG	Kerguelen Island	International 1924	0	0
139	KGS	South Korea	WGS_84	0	0
140	KUS	Kusaie Astro 1951	International 1924	0	0
141	LCF	Cayman Brac Island	Clark 1866	10	10
142	LEH	Ghana	Clark 1880	10	10
143	LUZ-B	Mindanao Island	Clark 1866	10	10
144	MID	Midway Islands	International 1924	0	0
145	MIK	Mahe Island	Clark 1880	10	10
146	MIN-A	Cameroon	Clark 1880	10	10
147	MOD	Sardinia	International 1924	0	0
148	MPO	Gabon	Clark 1880	10	10
149	MVS	Viti Levu Island	Clark 1880	10	10
150	NAH-A	Masirah Island	Clark 1880	10	10
151	NAH-B	United Arab Emirates	Clark 1880	10	10
152	NAP	Trinidad and Tobago	International 1924	0	0
153	NAR-A	Alaska	GRS 80	0	0
154	NAR-B	Canada	GRS 80	0	0
155	NAR-D	Mexico	GRS 80	0	0
156	NAR-E	Aleutian Islands	GRS 80	0	0
157	NAR-H	Hawaii	GRS 80	0	0
158	NAS-A	Eastern United States	Clark 1866	10	10
159	NAS-B	Western United States	Clark 1866	10	10
160	NAS-F	Alberta, British Columbia	Clark 1866	10	10
161	NAS-G	Eastern Canada	Clark 1866	10	10
162	NAS-H	Manitoba, Ontario	Clark 1866	10	10
163	NAS-I	NW Territory, Saskatchewan	Clark 1866	10	10
164	NAS-J	Yukon	Clark 1866	10	10
165	NAS-L	Mexico	Clark 1866	10	10
166	NAS-O	Canal Zone	Clark 1866	10	10
167	NAS-P	Caribbean	Clark 1866	10	10
168	NAS-Q	Bahamas	Clark 1866	10	10
169	NAS-R	San Salvador Island	Clark 1866	10	10
170	NAS-T	Cuba	Clark 1866	10	10
171	NAS-U	Greenland	Clark 1866	10	10
172	NAS-V	Eastern Aleutian Islands	Clark 1866	10	10
173	NAS-W	Western Aleutian Islands	Clark 1866	10	10
174	NSD	Algeria	Clark 1880	10	10
175	OGB-A	England	Airy 1830	0	0
176	OGB-B	Isle of Man, Wales	Airy 1830	0	0

Table 8. List of Valid Datums (Continued)

No.	ID	Datum	Spheroid	Alpha MGRS-old	Offset MGRS-new
177	OGB-C	Scotland	Airy 1830	0	0
178	OGB-D	Wales	Airy 1830	0	0
179	OHA-A	Hawaii	Clark 1866	10	10
180	OHA-B	Kauai	Clark 1866	10	10
181	OHA-C	Maui	Clark 1866	10	10
182	OHA-D	Oahu	Clark 1866	10	10
183	OHI-A	Hawaii	International 1924	0	0
184	OHI-B	Kauai	International 1924	0	0
185	OHI-C	Maui	International 1924	0	0
186	OHI-D	Oahu	International 1924	0	0
187	OHI-M	Hawaii - Mean	International 1924	0	0
188	PHA	Djibouti	Clark 1880	10	10
189	PLN	Canary Islands	International 1924	0	0
190	POS	Porto Santo, Madeira Islands	International 1924	0	0
191	PRP-A	Bolivia	International 1924	0	0
192	PRP-B	Northern Chile	International 1924	0	0
193	PRP-C	Southern Chile	International 1924	0	0
194	PRP-D	Colombia	International 1924	0	0
195	PRP-E	Ecuador	International 1924	0	0
196	PRP-F	Guyana	International 1924	0	0
197	PRP-G	Peru	International 1924	0	0
198	PRP-H	Venezuela	International 1924	0	0
199	PRP-M	South American Mean	International 1924	0	0
200	PTB	Burkina Faso, Niger	Clark 1880	10	10
201	PTN	Congo	Clark 1880	10	10
202	PUK	Russia	Krassovsky 1940	0	0
203	PUR	Puerto Rico	Clark 1866	10	10
204	REU	Mascarene Islands	International 1924	0	0
205	SAE	Espirito Santo Island	International 1924	0	0
206	SAN-A	Argentina	South America 1969	0	0
207	SAN-B	Bolivia	South America 1969	0	0
208	SAN-C	Brazil	South America 1969	0	0
209	SAN-D	Chile	South America 1969	0	0
210	SAN-E	Colombia	South America 1969	0	0
211	SAN-F	Ecuador	South America 1969	0	0
212	SAN-G	Guyana	South America 1969	0	0
213	SAN-H	Paraguay	South America 1969	0	0
214	SAN-I	Peru	South America 1969	0	0
215	SAN-J	Baltra, Galapagos Islands	South America 1969	0	0
216	SAN-K	Trinidad and Tobago	South America 1969	0	0
217	SAN-L	Venezuela	South America 1969	0	0
218	SAO	Sao Miguel, Santa Maria Islands	International 1924	0	0
219	SAP	East Falkland Island	International 1924	0	0
220	SGM	Salvage Islands	International 1924	0	0

Table 8. List of Valid Datums (Continued)

No.	ID	Datum	Spheroid	Alpha MGRS-old	Offset MGRS-new
221	SHB	St. Helena Island	International 1924	0	0
222	SIR	South America	GRS 80	0	0
223	SOA	Singapore	Modified Fischer 1960	0	0
224	SPK-A	Hungary	Krassovsky 1940	0	0
225	SPK-B	Poland	Krassovsky 1940	0	0
226	SPK-C	Czechoslovakia	Krassovsky 1940	0	0
227	SPK-D	Latvia	Krassovsky 1940	0	0
228	SPK-E	Kazakhstan	Krassovsky 1940	0	0
229	SPK-F	Albania	Krassovsky 1940	0	0
230	SPK-G	Romania	Krassovsky 1940	0	0
231	SRL	Sierra Leone	Clark 1880	10	10
232	TAN	Madagascar	International 1924	0	0
233	TDC	Tristan da Cunha	International 1924	0	0
234	TIL-S	Timbalai	Bessel 1841	0	10
235	TOY-A	Japan	Bessel 1841	0	10
236	TOY-B	Korea	Bessel 1841	0	10
237	TOY-B1	Korea	Bessel 1841	0	10
238	TOY-C	Okinawa	Bessel 1841	0	10
239	TRN	Tern Island	International 1924	0	0
240	VOI	Tunisia	Clark 1880	10	10
241	VOR	Algeria	Clark 1880	10	10
242	WAK	Wake Atoll	International 1924	0	0
243	YAC	Uruguay	International 1924	0	0

- **005Bh**: Set IRU Azimuth, Pitch, and Roll Alignment

Message format to the IRU:

Word 1: Header = 005Bh
Word 2: IRU Azimuth Alignment
Word 3: IRU Pitch Alignment
Word 4: IRU Roll Alignment
Words 5-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The value specified for a new IRU Alignment in Words 2-4 must be an integer value 100 times the actual angle in degrees. For example, if a new IRU Azimuth Alignment were to be set to 2.8 degrees, then Word 2 of this input message would need to be 280. The IRU will only accept a value in Word 2 in the range of $-400 \leq$ Word 2 ≤ 400. A positive number entered for the alignment will increase the output of the box by that amount. For example, a value of 2.8 degrees for the Azimuth alignment will take an alignment of 10 degrees and report 12.8. The IRU uses the following formula when establishing a new IRU Alignment:

New IRU Azimuth, Pitch, or Roll Alignment = (Word 2, 3, or 4) * 0.01

- **005Ch**: Set IRU KOD Scale Factor

  Message format to the IRU:
  Word 1: Header = 005Ch
  Word 2: IRU KOD Scale Factor
  Words 3-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The value specified for a new IRU KOD Scale Factor in Word 2 must be an integer value 10000 times the actual scale factor. For example, if a new IRU KOD Scale Factor were to be set to 1.25, then Word 2 of this input message would need to be 12500. The IRU uses the following formula when establishing a new IRU KOD Scale Factor:

  New IRU KOD Scale Factor = Word 2 * 0.0001

- **005Dh**: Set IRU Mode – This command is used to set the mode of the IRU to one of the valid modes shown below.

  Message format to the IRU:
  Word 1: Header = 005Dh
  Word 2: Mode
  Words 3-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU: No change in output

  The valid modes for the IRU are as follows:

  2 – Standby Mode
  3 – Gyrocompass Mode (GC)
  6 – Navigation Mode (NAV)
  8 – In-Vehicle Calibration Mode (IVC)
  9 – Base Motion Compensated Coarse Align Mode (BMCCOARSE)

  All others are invalid mode commands.

  Note: If the system is commanded into the Standby mode, the system cannot be commanded back into Navigation mode. To return to Navigation mode, system power must be cycled.

- **005Eh**: Set IRU Vertical Navigation Pitch Alignment

  Message format to the IRU:
  Word 1: Header = 005Eh
  Word 2: IRU Vertical Navigation Pitch Alignment
  Words 3-7: Not significant

Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The value specified for a new IRU Vertical Navigation Pitch Alignment in Word 2 must be an integer value 100 times the actual angle in degrees. For example, if a new IRU Pitch Alignment were to be set to 2.8 degrees, then Word 2 of this input message would need to be 280. The IRU will only accept a value in Word 2 in the range of -400 ≤ Word 2 ≤ 400. The IRU uses the following formula when establishing a new IRU Pitch Alignment:

New IRU Vertical Navigation Pitch Alignment = Word 2 * 0.01

- **005Fh**: Display IRU Navigation Alignment Data

Message format to the IRU:
Word 1: Header = 005Fh
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 005Fh
Word 2: IRU Azimuth Alignment
Word 3: IRU Pitch Alignment (Vertical Navigation)
Word 4: IRU KOD Scale Factor
Word 5: IRU Pitch Alignment
Word 6: IRU Roll Alignment
Word 7: 0000h
Word 8: 16-bit checksum for this message

IRU Azimuth Alignment is presented as an integer value in this message. It represents the misalignment between the IRU box Azimuth and the vehicle reference Azimuth. The number returned for the Azimuth Alignment represents the amount of correction added to the box azimuth before the box azimuth is reported. It is transformed to a 16-bit integer by the IRU as shown below.

IRU Pitch Alignment (Vertical Navigation) is presented as an integer value in this message. It represents the misalignment between the IRU box Pitch and the vehicle velocity vector. The number returned for the Pitch Alignment represents the amount of correction added to the box pitch before the box pitch is reported. It is transformed to a 16-bit integer by the IRU as follows:

Word 3 = IRU Pitch Alignment (Degrees) * 100

IRU KOD Scale Factor is presented as an integer value in this message. It represents the scale factor for the vehicle odometer as read by the IRU and is nominally 1.0. It is transformed to a 16-bit integer by the IRU as follows:

Word 4 = IRU KOD Scale Factor * 10000

IRU Pitch Alignment is presented as an integer value in this message. It represents the misalignment between the IRU box Pitch and the vehicle reference Pitch. The number returned for the Pitch Alignment represents the amount of correction added to the box pitch before the box pitch is reported. It is transformed to a 16-bit integer by the IRU as follows:

IRU Roll Alignment is presented as an integer value in this message. It represents the misalignment between the IRU box Roll and the vehicle reference Roll. The number returned for the Roll Alignment represents the amount of correction added to the box roll before the box roll is reported. It is transformed to a 16-bit integer by the IRU as follows:

Word 2,5, or 6 = IRU Azimuth, Pitch, or Roll Alignment (Degrees) * 100

- **0060h**: Set Elevation

Message format to the IRU:
    Word 1: Header = 0060h
    Word 2: Vehicle Elevation
    Words 3-7: Not significant
    Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The value specified for the vehicle elevation in Word 2 must be an integer value scaled to the nearest meter referenced to Mean Sea Level for the selected Geoid. Valid Elevation entries are between -500 and 6000 meters.

- **0061h**: Display Elevation

Message format to the IRU:
    Word 1: Header = 0061h
    Words 2-7: Not significant
    Word 8: 16-bit checksum for this message

Message format from the IRU:
    Word 1: Header = 0061h
    Word 2: Vehicle Elevation
    Words 3-7: 0000h
    Word 8: 16-bit checksum for this message

Vehicle elevation is presented as an integer value in this message. It represents the vehicle elevation referenced to Mean Sea Level for the selected Geoid. It is scaled for the least significant bit to be equal to one meter.

- **0062h**: Display Heading and Attitude

Message format to the IRU:
    Word 1: Header = 0062h
    Words 2-7: Not significant

Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 0062h
Word 2: Grid Heading
Word 3: True Heading
Word 4: Pitch
Word 5: Roll
Words 6-7: 0000h
Word 8: 16-bit checksum for this message

Grid Heading, True Heading, Pitch, and Roll are presented as integer values in this message. Grid Heading and True heading are derived from the IRU internal values and converted to 16-bit Unsigned integers; Pitch and Roll are converted to 16-bit signed integers as follows:

Word 2 = GRID HEADING(Degrees) * 100.0
Word 3 = TRUE HEADING(Degrees) * 100.0
Word 4 = PITCH(Degrees) * 100.0
Word 5 = ROLL(Degrees) * 100.0

- **0063h**: Display IVC Data

Message format to the IRU:

Word 1: Header = 0063h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 0063h
Words 2-3: IVC Vehicle Range
Word 4: IVC Azimuth Angle (Grid)
Word 5: IVC Pitch Angle
Word 6-7: IVC Distance Traveled
Word 8: 16-bit checksum for this message

IVC Vehicle Range is presented as a scaled integer. It represents the range from the position the vehicle was in when the IVC mode was entered. It is scaled as follows:

Words 2-3 = (IRU Range in Meters) * 10

Word 2 contains the most significant portion of the range and Word 3 contains the least significant portion.

IVC Azimuth Angle is presented as a scaled integer. It represents the azimuth angle relative to Grid North that the vehicle has traveled since entering IVC mode. Word 4 presents this angle relative to north. It is scaled as follows:

Word 4 = Azimuth angle relative to Grid North(Degrees) * 100.0

IVC Pitch Angle is presented as a scaled integer. It represents the change in elevation over the distance traveled as an angle since entering IVC mode. It is scaled as follows:

Word 5 = Pitch Angle(Degrees) * 100.0

IVC Distance Traveled is presented as a scaled integer. It represents the total distance traveled and is scaled as follows:

Word 6-7 = IRU DISTANCE TRAVELED (METERS) * 10

- **0064h**: Set Attitude. (Used only for factory calibration)

Message format to the IRU:

Word 1: Header = 0064h
Word 2: Sine of PHI (Roll) * 10000
Word 3: Sine of THETA (Pitch) * 10000
Word 4: Gravity Sign (0001h for Normal, FFFFh for Inverted)
Words 5-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

Note: When this message is received, the IRU turns off attitude integration and sets the attitudes to the values received in the message. In this mode of operation, normal navigation or gyrocompass operation will not function.

- **0065h**: Set IVC Start and Finish Positions

Message format to the IRU:

Word 1: Header = 0065h
Word 2: Position number
Word 3-4: Easting
Word 5-6: Northing
Word 7: Elevation
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

Before setting the IVC starting and finishing positions, the system present position must properly set.

Position number is set to 1 for the IVC starting position and 2 for the IVC finish position.

The Easting, Northing and Elevation values must be scaled before being sent to the IRU. The scaling must be as follows:

Word 3-4: Easting in Meters * 10
Word 5-6: Northing in Meters * 10
Word 7: Elevation in Meters

Words 3 and 5 contain the most significant portion of Easting and Northing, respectively. Words 4 and 6 contain the least significant portions of Easting and Northing, respectively.
Note: Both points must be in the same 100 Km Grid. The Easting and Northing values are to contain the ten thousands position through the tenths position; ie if the location to be entered is MGRS:16TFN 54321.0E 65432.1N, then the Easting Value (Words 3&4) would be 0x0008 49EA and the Northing Value (Words 5&6) would be 0x0009 FBF1. If the location to be entered is UTM 16 654321.0E 8765432.1N, then the Easting Value (Words 3&4) would be 0x0008 49EA and the Northing Value (Words 5&6) would be 0x0009 FBF1.

The elevation is referenced to Mean Sea Level for the selected Geoid.

- **0066h**: Display IVC Calculated Calibration Parameters

Message format to the IRU:
Word 1: Header = 0066h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 0066h
Word 2: IVC mode Calculated Azimuth Correction
Word 3: IVC mode Calculated Pitch Correction
Word 4: IVC mode Calculated KOD Scale Factor Correction
Word 5: IVC Azimuth and KOD Scale Factor calculation validity
Word 6: IVC Pitch calculation validity
Word 7: 0000h
Word 8: 16-bit checksum for this message

Calculated Azimuth, Pitch and KOD Scale Factor are the values calculated by the IVC mode based upon the navigation errors measured while driving from point 1 to point 2. These values are scaled as follows:

Word 2 = IRU Azimuth correction (Degrees) * 100
Word 3 = IRU Pitch correction (Degrees) * 100
Word 4 = IRU KOD Scale Factor correction * 10000

If there is any error in the calculation of the Azimuth or KOD Scale Factor errors, the Azimuth and KOD Scale Factor validity word will be set invalid. Similarly, if there is any error in the calculation of the Pitch error, the Pitch validity word will be set invalid. For both validity words, 1 = VALID and 0 = INVALID.

- **0068h**, and **0069h**: Display Attitude Data and Lat/Long Position– This command causes the MGRS position, Elevation, Speed, Attitude and Attitude Rates of the IRU to be sent on the RS-422. The output of this data requires two messages because of the number of data words. Selecting either of the headers will cause the IRU to rotate through the two headers in sequence beginning with the commanded message.

Message format to the IRU:

Word 1: Header = 0068h - 0069h
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:

Word 1: Header = 0068h
Word 2: True Heading
Word 3: Pitch
Word 4: Roll
Word 5: Heading Rate
Word 6: Pitch Rate
Word 7: Roll Rate
Word 8: 16-bit checksum for this message

Word 1: Header = 0069h
Words 2-3: Latitude
Words 4-5: Longitude
Word 6: Elevation
Word 7: Speed
Word 8: 16-bit checksum for this message

True Heading, Pitch, and Roll are presented as scaled integers. True Heading is the IRU heading with respect to true north with positive heading clockwise from north. Pitch is the IRU pitch angle relative to local level with pitch up being a positive pitch angle. Roll is the IRU roll angle about the IRU X axis with roll to the right being a positive roll. The heading, pitch and roll are scaled as follows:

Word 2 = TRUE HEADING (Radians) * 1000.0
Word 3 = PITCH (Radians) * 1000.0
Word 4 = ROLL (Radians) * 1000.0

Heading Rate, Pitch Rate, and Roll Rate are presented as scaled integers. These rates are about the heading, pitch and roll axis, respectively, and scaled as follows:

Word 5 = HEADING RATE (Radians/Sec) * 10000.0
Word 6 = PITCH RATE(Radians/Sec) * 10000.0
Word 7 = ROLL RATE(Radians/Sec) * 10000.0

Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 2-3 = ((IRU Latitude, in radians) / PI) * 2^{30}
Words 4-5 = ((IRU Longitude, in radians) / PI) * 2^{30}

Words 2 and 4 contain the most significant portion of Latitude and Longitude, respectively. Words 3 and 5 contain the least significant portions of Latitude and Longitude, respectively.

Elevation is presented as a scaled integer from the IRU. It is scaled as follows:

Word 6 = IRU Elevation (Meters)

The elevation is referenced to Mean Sea Level for the selected Geoid.

IRU Speed is presented as a scaled integer from the IRU. Speed is the velocity of the vehicle with positive forward and is scaled as follows:

Word 7 = IRU SPEED (Meters/Sec) * 100.0

- **006Ah**: Display Attitude and Rates - This message will cause the NFM to output the attitude and rate data indicated below.

  Message format to the IRU:
  Word 1: Header = 006Ah
  Words 2-7: Not significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 006Ah
  Word 2: True Heading
  Word 3: Pitch
  Word 4: Roll
  Word 5: Heading Rate
  Word 6: Pitch Rate
  Word 7: Roll Rate
  Word 8: 16-bit checksum for this message

  True Heading, Pitch, and Roll are presented as scaled integers. True Heading is the IRU heading with respect to true north with positive heading clockwise from north. Pitch is the IRU pitch angle relative to local level with pitch up being a positive pitch angle. Roll is the IRU roll angle about the IRU X axis with roll to the right being a positive roll. The heading, pitch and roll are scaled as follows:

  Word 2 = TRUE HEADING (Radians) * 1000.0
  Word 3 = PITCH (Radians) * 1000.0
  Word 4 = ROLL (Radians) * 1000.0

  Heading Rate, Pitch Rate, and Roll Rate are presented as scaled integers. These rates are about the heading, pitch and roll axis respectively and scaled as follows:

  Word 5 = HEADING RATE (Radians/Sec) * 10000.0
  Word 6 = PITCH RATE (Radians/Sec) * 10000.0
  Word 7 = ROLL RATE (Radians/Sec) * 10000.0

- **006Bh**: Set 3D Position - This message will set the NFM position to the position indicated in the message.

  Message format to the IRU:
  Word 1: Header = 006Bh
  Words 2-3: Latitude

Words 4-5: Longitude
Words 6-7: Elevation
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

The new Latitude and Longitude must be scaled before being sent to the IRU. The scaling must be as follows:

Words 2-3 = ((New Latitude, in Radians)/PI)* 2^{30}
Words 4-5 = ((New Longitude, in Radians)/PI)* 2^{30}

Words 2 and 4 contain the most significant portion of Latitude and Longitude, respectively. Words 3 and 5 contain the least significant portions of Latitude and Longitude, respectively. Latitude is limited to ± 90 degrees and Longitude is limited to ± 180 degrees.

The new Elevation must be scaled before being sent to the IRU. The scaling must be as follows:

Words 6-7 = (New Elevation, in Meters) * 100

The elevation is referenced to Mean Sea Level for the selected Geoid.

Word 6 contains the most significant portion of the Elevation and Word 7 contains the least significant portion.

- **006Ch**, and **006Dh**: Display PLGR OR DAGR Status – This command causes a portion of the PLGR OR DAGR Status message to be sent on the RS-422. The output of this data requires two messages because of the number of data words. Selecting either of the headers will cause the IRU to rotate through the two headers in sequence beginning with message 006Ch.

Message format to the IRU:
Word 1: Header = 006Ch - 006Dh
Words 2-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 006Ch
Word 2: Malfunction BIT (Least Significant Byte (LSByte))
Word 2: IRU Mode (Most Significant Byte (MSByte))
Word 3: Estimate of Heading Variance
Word 4: Time Reference
Word 5: Hours
Word 6: Minutes
Word 7: Seconds
Word 8: 16-bit checksum for this message

Word 1: Header = 006Dh

Word 2: Day of the Month
Word 3: Month
Word 4: Year
Word 5: GPS FOM
Word 6: Time FOM
Word 7: Elevation Status
Word 8: 16-bit checksum for this message

Message 006C words 2 – 7 are defined as follows:
Word 2, the Malfunction byte is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

LSB Bit 0 - Data Storage Fail
Bit 1 - Correction Computation Fail
Bit 2 - Accelerometer Fail
Bit 3 - Gyro Fail
Bit 4 - Process Fail
Bit 5 - Reserved (always 0)
Bit 6 - Motion While Gyro Compass
MSB Bit 7 - Invalid Gyro Compass

See 3.2.3 for a description of the IRU Mode word. For a definition of GPS FOM and Time FOM, see 3.2.4 NFM/Target/GPS/Time FOM Definition, Table 6 and Table 7, respectively.

The Estimate of Heading Variance is the LNS Kalman filters estimate of the heading error as a one sigma value. The Estimate of Heading Variance is presented as an integer value in this message. It is scaled according to the following equation:

Word 3 = Estimate of Heading Variance (Radians) * 1000
Word 4 = Time Reference (see Table 9)
Word 5 = Hours (0-23), signed integer
Word 6 = Minutes (0-59), signed integer
Word 7 = Seconds (0-60), signed integer

The message 006Dh definitions for words 2 – 6 are listed below.
Word 2 = Day of the Month (1-31), signed integer
Word 3 = Month (1-12), signed integer
Word 4 = Year (0-99), signed integer
Word 5 = GPS FOM (see Table 6)
Word 6 = Time FOM (see Table 7)
Word 7 = Elevation Status: Status of the elevation solution. Possible indications are:
OK (set=0000h)
Held (set=0001h)
Poor VDOP (set=0002h)
Only Valid when NAV CONVERGED is set to true.

Table 9. Time Reference (Allowable Time Zones)

Index	Meaning	Index	Meaning

0	UTC Time (Zulu)	16	Local time, +11 hour offset
1	Local time, 0 hour offset	17	Local time, +12 hour offset
2	Local time, +1 hour offset	18	Local time, +13 hour offset
3	Local time, +2 hour offset	19	Local time, -12 hour offset
4	Local time, +3 hour offset	20	Local time, -11 hour offset
5	Local time, +3.5 hour offset	21	Local time, -10 hour offset
6	Local time, +4 hour offset	22	Local time, -9 hour offset
7	Local time, +4.5 hour offset	23	Local time, -8 hour offset
8	Local time, +5 hour offset	24	Local time, -7 hour offset
9	Local time, +5.5 hour offset	25	Local time, -6 hour offset
10	Local time, +6 hour offset	26	Local time, -5 hour offset
11	Local time, +6.5 hour offset	27	Local time, -4 hour offset
12	Local time, +7 hour offset	28	Local time, -3.5 hour offset
13	Local time, +8 hour offset	29	Local time, -3 hour offset
14	Local time, +9 hour offset	30	Local time, -2 hour offset
15	Local time, +10 hour offset	31	Local time, -1 hour offset

- **0071h, 0072h, 0073h, and 0074h**: PLGR OR DAGR Setup Data Messages - These commands are used to pass PLGR OR DAGR Setup Data to the IRU and then on to the PLGR OR DAGR. In order to insure a consistent data set, all four messages must be received before any data is passed to the PLGR OR DAGR. After the data is sent to the PLGR OR DAGR, all four messages must be received again before any new data is sent to the PLGR OR DAGR. This data is stored in the IRU and should the PLGR OR DAGR be turned off or disconnected and then reconnected to the IRU, the IRU will reinitialize the PLGR OR DAGR with the stored data. However, if the IRU is powered off, all stored initialization data is lost and must be sent to the IRU again. Messages 0071h – 0074h are defined below and the words for each message are defined below the message definitions.

Message format to the IRU:

Word 1: Header 0071h
Word 2: Validity
Word 3: SV Type
Word 4: Coordinate Reference
Word 5: Distance Units
Word 6: Elevation Units
Word 7: Elevation Reference
Word 8: 16-bit checksum for this message

Message format to the IRU:

Word 1: Header 0072h
Word 2: Angular Units
Word 3: North Reference
Word 4: MVAR Type
Word 5: Entered MVAR Word 1
Word 6: Entered MVAR Word 2

Word 7: Navigation Mode
Word 8: 16-bit checksum for this message

Message format to the IRU:

Word 1: Header 0073h
Word 2: Elevation Hold Type
Word 3: Time Reference
Word 4: Error Units
Word 5: Selected Datum
Word 6: Auto off Timer
Word 7: HaveQuick
Word 8: 16-bit checksum for this message

Message format to the IRU:

Word 1: Header 0074h
Word 2: 1PPS
Word 3: Datum Identifier Word 1
Word 4: Datum Identifier Word 2
Word 5: Datum Identifier Word 3
Word 6-7: Not significant
Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

Word definitions for message 0071h:

Word 2: Validity: The validity word is structured as follows:

If bit 15=1, SV TYPE contains valid data.
If bit 14=1, COORDINATE REFERENCE contains valid data.
If bit 13=1, DISTANCE UNITS contains valid data.
If bit 12=1, ELEVATION UNITS contains valid data.
If bit 11=1, ELEVATION REFERENCE contains valid data.
If bit 10=1, ANGULAR UNITS contains valid data.
If bit 9=1, NORTH REFERENCE contains valid data.
If bit 8=1, MVAR TYPE contains valid data.
If bit 7=1, NAVIGATION MODE contains valid data.
If bit 6=1, ELEVATION HOLD TYPE contains valid data.
If bit 5=1, TIME REFERENCE contains valid data.
If bit 4=1, ERROR UNITS contains valid data.
If bit 3=1, SELECTED DATUM contains valid data.
If bit 2=1, AUTO OFF TIMER contains valid data.
If bit 1=1, HAVEQUICK contains valid data.
If bit 0=1, 1PPS contains valid data.

Word 3: SV Type: Commands the RCVR to use SVs that are either

Only Y-code (set=0000h)
Mixed (set=0001h) P-code and Y-code.

Word 4: Coordinate Reference[3]: Specifies the RCVR's coordinate reference system as one of the Position Formats defined below:

[3] Position formats 0001h thru 0004 affect both IRU and PLGR OR DAGR. Position formats 0005h and above affect only the PLGR OR DAGR while leaving the IRU unchanged.

0000h=MGRS-Old
0001h=MGRS-New
0002h=UTM/UPS
0003h=LL-dm
0004h=LL-dms
0005h=BNG
0006h=ITMG
0007h=NZMG
0008h=RT90
4001h=UC1
4002h=UC2
4003h=UC3

Word 5: Distance Units[4]: Specifies the distance units as one of the following:
Metric (set=0000h)
English (set=0001h)
Nautical (set=0002h)

Word 6: Elevation Units[5]: Specifies the elevation units as:
Meters (set=0000h)
Feet (set=0001h)

Word 7: Elevation Reference[6]: Specifies the reference plane for elevation data as either:
Mean Sea Level (set=0000h)
Datum (set=0001h)

Word definitions for message 0072h:

Word 2: Angular Units[7]: specifies the angular units as either:
Mils (set=0000h)
Degrees (set=0001h)
Streck (set=0002h)

Word 3: North Reference[8]: specifies the north reference as one of the following:
True (set=0000h)
Magnetic (set=0001h)
Grid (set=0002h)

Word 4: MVAR Type[9]: Specifies the source of magnetic variation as one of the following:
Calculated by the system (set=0000h)
User entered (set=0001h)
Defined with the current TO navigation waypoint (set=0002h)

Word 5: Entered MVAR Word 1 (see Figure 2 for word format)
Word 6: Entered MVAR Word 2 (see Figure 2 for word format)
Word 7: Navigation Mode[10]: This word contains the operator selected application mode:

[4] This distance unit affects the PLGR OR DAGR display only. The IRU will ignore and use metric format.
[5] This elevation unit affects the PLGR OR DAGR display only. The IRU will ignore and use meters format.
[6] This elevation reference affects the PLGR OR DAGR display only. The IRU will ignore and use mean sea level.
[7] This angular unit affects the PLGR OR DAGR display only, the IRU will use its internal angular units.
[8] This north reference affects the PLGR OR DAGR display only, the IRU will use its north reference.
[9] This magnetic variance affects the PLGR OR DAGR display only, the IRU will ignore.
[10] For proper IRU operation, the PLGR OR DAGR Navigation Mode must be set to 3-D FAST (0002h).

0000h = SLOW
0001h = 2-D FAST
0002h = 3-D FAST
0003h = CUSTOM

Word definitions for message 0073h:

Word 2: Elevation Hold Type[11]: Specifies the elevation hold mode as either:

Automatic (set=0000h)
Manual (set=0001h)

When automatic is chosen, the RCVR will automatically go into elevation hold mode when the conditions are right.

When manual is chosen, the user may enter elevation hold mode when either the number of available satellites has decreased to three or four or more satellites are available but the GDOP is poor.

Word 3: Time Reference[12]: Specifies the time zone index. Refer to Table 9.

Word 4: Error Units[13]: Specifies the format in which position error is displayed as either:

Distance EPE (set=0000h)
Figure of Merit (set=0001h)
Distance EHE (set=0002h)

Word 5: Selected Datum[14]: Specifies the system Datum. Reference Table 8 for a list of datum number and Table 10 for input information

Word 6: Auto off Timer[15]: Specifies the operation mode of the Auto Off Timer as one of the following:

5 minutes (set=0000h)
15 seconds (set=0001h)
20 minutes (set=0002h)
Off (set=0003h)

Word 7: HaveQuick[16]: Controls the operating mode of the HaveQuick output as either:

Off (set=0000h)
On (set=0001h)

Word definitions for message 0074h:

Word 2: 1PPS[17]: Controls the operating mode of the 1PPS mode of the 1PPS output as one of the following:

Off (set=0000h)
UTC (set=0001h)
Time Mark (set=0002h)

Datum Identifier Words 3-5: A six (6) character ASCII string that contains the three (3) to five (5) character Datum Identifier in Table 8 and padded with spaces (ASCII 20h) on the right.

Word 3: Datum Identifier Word 1
Word 4: Datum Identifier Word 2

[11] For proper IRU operation, the PLGR OR DAGR elevation hold must be set to Automatic (0000h).
[12] This time reference affects the PLGR OR DAGR display only, the IRU will ignore this time reference.
[13] This Error Unit affects the PLGR OR DAGR display only, the IRU will ignore and use Figure of Merit.
[14] The IRU will follow all PLGR OR DAGR selected datums except for user defined datums. If a user defined datum is selected the IRU will use the last valid non-user-defined datum.
[15] For proper IRU operation, the PLGR OR DAGR auto off timer must be set to Off (0003h).
[16] The Havequick operating mode is ignored by the IRU.
[17] The 1PPS operating mode is ignored by the IRU.

Word 5: Datum Identifier Word 3

Word 6-7: Not significant

Table 10. Datum Selection Criteria

Datum Number	Datum Identifier	Used by RCVR
If Zero (0)	If Valid**	Datum Identifier
If Zero (0)	If Invalid**	Message Rejected
If Valid*	If Invalid	Datum Number
If Valid*	If Valid**	Datum Identifier
If Valid*	If Invalid**	Message Rejected
* Valid Datum Number are 1-51 and 61		
** See Table 8 for Valid Datum Identifiers.		

The Datum Number corresponds to the three to five character Datum Identifier. When the RCVR sends out position data or the current Datum used (Waypoint, PVT Init, Setup Data, or Current Status messages) the Datum Number and Identifier will both be valid. When the RCVR receives the message that contains position data or the current Datum to use, (Waypoint Init, PVT Init or Setup message), the RCVR will use the data as in Table 10.

1. If the external device wants the RCVR to use the Datum Identifier, Zero should be used as the Datum Number in the input messages.
2. If the Datum Number is Zero the RCVR will check to see if the Datum Identifier is valid. If valid it will use the Datum Identifier. If invalid the input message is rejected.
3. If the Datum Number is Valid the RCVR will use the Datum Number and ignore the Datum Identifier.
4. If the Datum Number is invalid, the RCVR will check to see if the Datum Identifier is valid. If valid, it will use the Datum Identifier. If invalid, the input message is rejected.

```
DATA TYPE  :  CAPS Single Precision Floating-Point (CAPS SPFP)
------------------------------------------------------------------------------
                                 BIT NO.
------------------------------------------------------------------------------
                         WORD 1
                         BYTE 1   -00- LSB
                                  -01-
                                  -02-
                                  -03-       Exponent
                                  -04-
                                  -05-
                                  -06-
                                  -07- MSB

                         BYTE 2   -00- LSB
                                  -01-
                                  -02-
                                  -03-       Mantissa
                                  -04-       LSP
                                  -05-
                                  -06-
                                  -07-
------------------------------------------------------------------------------
                         WORD 2
                         BYTE 1   -00-
                                  -01-
                                  -02-
                                  -03-       Mantissa
                                  -04-       Middle Part
                                  -05-
                                  -06-
                                  -07-

                         BYTE 2   -00-
                                  -01-
                                  -02-
                                  -03-       Mantissa
                                  -04-       MSP
                                  -05-
                                  -06- MSB
                                  -07- Sign  0=Positive, 1=Negative


          Reconstructed Data Type Diagram (does not represent transmission order):

                          W2                                        W1
           Byte  2                 Byte  1             Byte  2              Byte  1
      | 7 6 5 4 3 2 1 0 | 7 6 5 4 3 2 1 0 |     | 7 6 5 4 3 2 1 0 | 7 6 5 4 3 2 1 0 |
        S M  MAN MSP          MAN MP                 MAN LSP   L    M     EXP     L
```

Figure 2. CAPS SPFP Data Type for use in Entered MVARS words 1 and 2

The IRU passes all of this data to the PLGR OR DAGR exactly as it is received.

- **0077h**: Display NFM Status (Degrees)

  Message format to the IRU:

  Word 1: Header 0077h
  Word 2-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU:

  Word 1: Header 0077h

Word 2: Spare
Word 3: NFM FOM
Word 4: Heading Variance
Word 5-6: True Heading
Word 7: Malfunction BIT (Least Significant Byte (LSByte))
Word 7: IRU Mode/GPS Status/Moving (Most Significant Byte (MSByte))
Word 8: 16-bit Checksum for this message

The Heading Variance is the Gyrocompass Kalman filter's current heading error estimate as a one-sigma value. The Heading Variance is presented as an integer value in this message. It is scaled according to the following equation:

Word 4 = Heading Variance (milliradians) * 100

NFM FOM is the Figure of Merit on the NFM position calculations, presented as a single precision signed integer. See 3.2.4, NFM/Target/GPS/Time FOM Definition, for a description of the values of the FOM.

The True Heading is presented in degrees in ANSI/IEEE STD 754 Single Precision Floating Point format.

The Malfunction Word is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

- **0078h**: Display Position in degrees

Message format to the IRU:

Word 1: Header 0078h
Word 2-7: Not Significant
Word 8: 16-bit Checksum for this message

Message format from the IRU:

Word 1: Header 0078h
Word 2-3: Latitude
Word 4-5: Longitude
Word 6-7: Elevation
Word 8: 16-bit Checksum for this message

The latitude is presented in degrees in ANSI/IEEE Std 754 Single Precision Floating Point Format.

The longitude is presented in degrees in ANSI/IEEE Std 754 Single Precision Floating Point Format.

The elevation is presented in meters in ANSI/IEEE Std 754 Single Precision Floating Point Format, and is referenced to Mean Sea Level for the selected Geoid.

- **0079h**: Display NFM Status (Radians)

Message format to the IRU:

Word 1: Header 0079h
Word 2-7: Not Significant
Word 8: 16-bit Checksum for this message

Message format from the IRU:

Word 1: Header 0079h
Word 2: Spare
Word 3: NFM FOM
Word 4: Heading Variance
Word 5-6: True Heading
Word 7: Malfunction BIT (Least Significant Byte (LSByte))
Word 7: IRU Mode/GPS Status/Moving (Most Significant Byte (MSByte))
Word 8: 16-bit Checksum for this message

NFM FOM is the Figure of Merit on the NFM position calculations, presented as a single precision signed integer. See 3.2.4, NFM/Target/GPS/Time FOM Definition, for a description of the values of the NFM FOM.

The Heading Variance is the Gyrocompass Kalman filter's current heading error estimate as a one-sigma value. The Heading Variance is presented as an integer value in this message. It is scaled according to the following equation:

Word 4 = Heading Variance (milliradians) * 100

The True Heading is presented in radians in ANSI/IEEE STD 754 Single Precision Floating Point format.

The Malfunction Word is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

- **007Ah**: Display Position in radians

Message format to the IRU:

Word 1: Header 007Ah
Word 2-7: Not Significant
Word 8: 16-bit Checksum for this message

Message format from the IRU:

Word 1: Header 007Ah
Word 2-3: Latitude
Word 4-5: Longitude
Word 6-7: Elevation
Word 8: 16-bit Checksum for this message

The latitude is presented in radians in ANSI/IEEE Std 754 Single Precision Floating Point Format.

The longitude is presented in radians in ANSI/IEEE Std 754 Single Precision Floating Point Format.

The elevation is presented in meters in ANSI/IEEE Std 754 Single Precision Floating Point Format, and is referenced to Mean Sea Level for the selected Geoid.

- **007Bh**: Transmit simulation data – This message is used to record real time data for future processing and analysis. This message is used by placing the NFM into the continuous output mode, issuing this message once and then using the UIP watch command to monitor the output data.

Message format to the IRU:

Word 1: Header 007Bh
Word 2-7: Not Significant
Word 8: 16-bit Checksum for this message

Message format from the IRU:

Word 1: Max previous PUIT (Least Significant Byte (LSByte))
Word 1: PUIT (Most Significant Byte (MSByte))
Word 2: Raw 61 Hz P gyro data.
Word 3: Raw 61 Hz Q gyro data.
Word 4: Raw 61 Hz R gyro data.
Word 5: Raw 61 Hz X accel data.
Word 6: Raw 61 Hz Y accel data.
Word 7: Rotating 1 Hz data (Least Significant Byte (LSByte))
Word 7: Raw DMU data (Most Significant Byte (MSByte))
Word 8: 16-bit Checksum for this message

The rotating 1 Hz data consists of the following:

Latitude	4 Bytes
Longitude	4 Bytes
Altitude	4 Bytes
Velocity X	4 Bytes
Velocity Y	4 Bytes
Velocity Z	4 Bytes
NFM FOM	2 Bytes
RPU_Fail	1 Byte
Nav_Not_Valid	1 Byte
LT_4	1 Byte
State_3	1 Byte
State_5	1 Byte
Filter_GC	1 Byte
GC_State	1 Byte
Mode	1 Byte
GPS FOM	2 Bytes
Time FOM	2 Bytes

Elev_Status	2 Bytes
Datum_No	2 Bytes
Pos_Format	2 Bytes
P_Gyro_Temp	2 Bytes
Q_Gyro_Temp	2 Bytes
Accel_Temp	2 Bytes

For a description of NFM FOM, GPS FOM and Time FOM, please see 3.2.4, NFM/Target/GPS/Time FOM Definitions.

- **007Ch**: Receive simulation data – This message is currently not implemented and reserved for later use.

  Message format to the IRU:
  Word 1: Header 007Ch
  Word 2-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU: No change in output

- **007Dh**: Display 3D Position -- This message will cause the NFM to output the Latitude, Longitude, and Elevation.

  Message format to the IRU:
  Word 1: Header 007Dh
  Word 2-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU:
  Word 1: Header 007Dh
  Word 2-3: Latitude
  Word 4-5: Longitude
  Word 6-7: Elevation
  Word 8: 16-bit Checksum for this message

  Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

  Words 2-3 = ((IRU Latitude, in radians) / PI) * 2^{30}
  Words 4-5 = ((IRU Longitude, in radians) / PI) * 2^{30}

- **007Eh**: Display NFM Status - This message will cause the NFM to output the NFM status, including the heading variance, NFM FOM, and BIT/Mode data.

  Message format to the IRU:
  Word 1: Header 007Eh
  Word 2-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU:

Word 1: Header 007Eh
Word 2: Heading variance
Word 3: NFM FOM
Word 4-6: 000h
Word 7: Malfunction BIT (Least Significant Byte (LSByte))
Word 7: IRU Mode/GPS Status/Moving (Most Significant Byte (MSByte))
Word 8: 16-bit Checksum for this message

The Heading Variance is the Gyrocompass Kalman filter's current heading error estimate as a one-sigma value. The Heading Variance is presented as an integer value in this message. It is scaled according to the following equation:

Word 2 = Heading Variance (milliradians) * 100

NFM FOM is the Figure of Merit on the NFM position calculations, presented as a single precision signed integer. See 3.2.4, NFM/Target/GPS/Time FOM Definition, for a description of the values of the NFM FOM.

The Malfunction Word is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

- **007Fh**: Display I/O Region 0 Data – Return the contents of six locations of I/O data. Each data word of this message will be interpreted as an offset from the base of the I/O address space 0. Each offset must be specified as a hexadecimal value as follows:

offset = (offset of desired location) + 8000h.

This command will always cause six values to be sent out.

Message format to the IRU:
Word 1: Header = 007F
Word 2: Offset 1 (+ 8000h)
Word 3: Offset 2 (+ 8000h)
Word 4: Offset 3 (+ 8000h)
Word 5: Offset 4 (+ 8000h)
Word 6: Offset 5 (+ 8000h)
Word 7: Offset 6 (+ 8000h)
Word 8: 16-bit checksum for this message

Message format from the IRU:
Word 1: Header = 007F
Word 2: Data value at offset 1
Word 3: Data value at offset 2
Word 4: Data value at offset 3
Word 5: Data value at offset 4
Word 6: Data value at offset 5
Word 7: Data value at offset 6

Word 8: 16-bit checksum for this message

- **0080h**: Display I/O Region 1 Data – Return the contents of six locations of I/O data. Each data word of this message will be interpreted as an offset from the base of the I/O address space 1. Each offset must be specified as a hexadecimal value as follows:

  offset = (offset of desired location) + 8000h.

  This command will always cause six values to be sent out.

  Message format to the IRU:
  Word 1: Header = 0080h
  Word 2: Offset 1 (+ 8000h)
  Word 3: Offset 2 (+ 8000h)
  Word 4: Offset 3 (+ 8000h)
  Word 5: Offset 4 (+ 8000h)
  Word 6: Offset 5 (+ 8000h)
  Word 7: Offset 6 (+ 8000h)
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 0080h
  Word 2: Data value at offset 1
  Word 3: Data value at offset 2
  Word 4: Data value at offset 3
  Word 5: Data value at offset 4
  Word 6: Data value at offset 5
  Word 7: Data value at offset 6
  Word 8: 16-bit checksum for this message

- **008Ah and 008Bh**: Display IVC Start Position and Display IVC Finish Position

  Selecting either of the headers will cause the IRU to rotate through the two headers in sequence beginning with the selected message. Message 008Ah is the start position and message 008Bh is the stop position.

  Message format to the IRU:
  Word 1: Header 008Ah – 008Bh
  Word 2-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU:
  Word 1: Header = 008Ah
  Word 2-3: Easting
  Word 4-5: Northing
  Word 6: Elevation
  Word 7: Not Significant
  Word 8: 16-bit checksum for this message

  Message format from the IRU:
  Word 1: Header = 008Bh

Word 2-3: Easting
Word 4-5: Northing
Word 6: Elevation
Word 7: Not Significant
Word 8: 16-bit checksum for this message

The Easting, Northing and Elevation values are scaled before being sent from the IRU. The scaling is as follows:

Word 2-3: Easting in Meters * 10
Word 4-5: Northing in Meters * 10
Word 6: Elevation in Meters

Words 2 and 4 contain the most significant portion of Easting and Northing, respectively. Words 3 and 5 contain the least significant portions of Easting and Northing, respectively.

The Easting and Northing values are to contain the ten thousands position through the tenths position; ie if the location to be displayed is MGRS:16TFN 54321.0E 65432.1N, then the Easting Value (Words 2&3) would be 0x0008 49EA and the Northing Value (Words 4&5) would be 0x0009 FBF1. If the location to be displayed is UTM 16 654321.0E 8765432.1N, then the Easting Value (Words 2&3) would be 0x0008 49EA and the Northing Value (Words 4&5) would be 0x0009 FBF1.

The elevation is referenced to Mean Sea Level for the selected Geoid.

- **008Ch**: Display Datum Data – This message will cause the NFM to output the Datum and the position format that it is currently using.

  Message format to the IRU:

  Word 1: Header 008Ch
  Word 2-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU:
  Word 1: Header = 008Ch
  Word 2: Datum Number (Integer range 1 – 243)
  Word 3: Position Format
  Words 4-7: Not significant
  Word 8: 16-bit checksum for this message

- **008Dh**: Set IVC Start and Finish Positions, 0.1m Elevation

  Message format to the IRU:
  Word 1: Header = 008Dh
  Word 2: Position number
  Word 3-4: Easting
  Word 5-6: Northing
  Word 7: Elevation
  Word 8: 16-bit checksum for this message

Message format from the IRU: No change in output

Before setting the IVC starting and finishing positions, the system present position must properly set.

Position number is set to 1 for the IVC starting position and 2 for the IVC finish position.

The Easting, Northing and Elevation values must be scaled before being sent to the IRU. The scaling must be as follows:

Word 3-4: Easting in Meters * 10
Word 5-6: Northing in Meters * 10
Word 7: Elevation in Meters * 10

Words 3 and 5 contain the most significant portion of Easting and Northing, respectively. Words 4 and 6 contain the least significant portions of Easting and Northing, respectively.
Note: Both points must be in the same 100 Km Grid. The Easting and Northing values are to contain the ten thousands position through the tenths position; ie if the location to be entered is MGRS:16TFN 54321.0E 65432.1N, then the Easting Value (Words 3&4) would be 0x0008 49EA and the Northing Value (Words 5&6) would be 0x0009 FBF1. If the location to be entered is UTM 16 654321.0E 8765432.1N, then the Easting Value (Words 3&4) would be 0x0008 49EA and the Northing Value (Words 5&6) would be 0x0009 FBF1.

If either elevation is above 3276 meters, then both elevations must be lowered by a common factor before scaling takes place. The elevation is referenced to Mean Sea Level for the selected Geoid.

- **008Eh**: Set Position in Specified Format – The NFM receives input data of the Position Format, and the position specified by that format.

  Message format to the IRU: (If Position format is MGRS)
  Word 1: Header 008Eh
  Word 2: Most significant 4 bits: Position Format
  Word 2: Least significant 12 bits: Not Significant
  Word 3: Packed Zone, Easting, and Northing Letters
  Word 4: MSByte: Grid Number (Integer number, Range 1-60)
  Word 4: LSByte: Most significant 8-bits of Easting Value
  Word 5: Least significant 12 bits of Easting, Most significant 4 bits of Northing
  Word 6: Least significant 16 bits of Northing.
  Word 7: Elevation in Meters
  Word 8: 16-bit Checksum for this message

  Message format to the IRU: (If Position format is Lat/Lon)
  Word 1: Header 008Eh
  Word 2: Most significant 4 bits: Position Format
  Word 2: Least significant 12 bits: Not Significant
  Word 3-4: Latitude (32-bit Integer)

Word 5-6: Longitude (32-bit Integer)
Word 7: Elevation in Meters
Word 8: 16-bit Checksum for this message

Message format to the IRU: (If Position format is UTM)

Word 1: Header 008Eh
Word 2: Most significant 4 bits: Position Format
Word 2: Least significant 12 bits: Not Significant
Word 3: MSByte: Grid Number (Integer number, Range 1-60)
Word 3: LSByte: Zone Letter
Word 4: Most significant 16 bits of Easting Value (Integer, LSBit = 1 meter)
Word 5: MSByte:Least significant 8 bits of Easting value
Word 5: LSByte: Most significant 8 bits of Northing value
Word 6: Least significant 16 bits of Northing value (Integer, LSBit = 1 meter)
Word 7: Elevation in Meters
Word 8: 16-bit Checksum for this message

The Position Format for the input/output message is defined as follows:

0 – MGRS Old
1 – MGRS New
2 – UTM
3 – Lat/Lon (degrees, minutes)
4 – Lat/Lon (degrees, minutes, seconds)

The Position Format for the input message will be encoded in the most significant bits (4 - 7) of the MSByte of the input word 2.

The Elevation is in meters, is not scaled, and is referenced to Mean Sea Level for the selected Geoid.

MGRS Input:
The Zone Letter is encoded in the most significant 5 bits (3 – 7) of the MSByte of Word 3. The Easting Letter is encoded in the least significant 3 bits (0 – 2) of the MSByte of Word 3 and the most significant 2 bits (6 – 7) of the LSByte of Word 3. The Northing letter is encoded in bits 1 - 5 of the LSByte of Word 3. Bit 0 of the LSByte of Word 3 is zero. Each value is the ASCII code of the letter less 64, ie: A (ASCII code 65 (decimal)) would be 1 (decimal), and Z (ASCII code 90 (decimal)) would be 26 (decimal).

The Easting value's most significant 8 bits are stored in the LSByte of Word 4. The least significant 12 bits are stored in the MSByte of Word 5 and the most significant bits (4 – 7) of the LSByte of Word 5. The Northing value's most significant 4 bits are stored in the least significant bits (0 – 3) of the LSByte of Word 5. The least significant 16 bits are stored in Word 6.

The Easting and Northing values are the MGRS easting and northing coordinates with the least significant bit equal to 1 meter.

Lat/Lon Input:
Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 3-4 = ((IRU Latitude, in radians) / PI) * 2^{30}
Words 5-6 = ((IRU Longitude, in radians) / PI) * 2^{30}

UTM Input:
The Grid number is positive for all locations. Coordinates within the southern hemisphere will have a Zone Letter of one of the following: C,D,E,F,G,H,J,K,L, or M. Coordinates within the northern hemisphere will have a Zone Letter of one of the following: N,P,Q,R,S,T,U,V,W, or X.

The Zone Letter is encoded in the LSByte of Word 3. The value is the ASCII code of the letter

The Easting and Northing values are the UTM easting and northing coordinates with the least significant bit equal to 1 meter. The Easting is encoded in Word 4 and the MSByte of Word 5. The Northing value is encoded in the LSByte of Word 5 and Word 6.

Message format from the IRU: No change in output

- **008Fh**: Display Position in Specified Format – The NFM receives input data of the Position Format. Then it returns the NFM position using the message format specified by the Position Format.

Message format to the IRU:
Word 1: Header 008Fh
Word 2: Most significant 4 bits: Position Format
Word 2: Least significant 12 bits: Not Significant
Word 3-7: Not Significant
Word 8: 16-bit Checksum for this message

Message format from the IRU: (If Position format is MGRS)
Word 1: Header 008Fh
Word 2: MSByte: Position Format/NFM FOM
Word 2: LSByte: Datum Number (Integer number, Range 1-243)
Word 3: Packed Zone, Easting, and Northing Letters
Word 4: MSByte: Grid Number (Integer number, Range 1-60)
Word 4: LSByte: Most significant 8-bits of Easting Value
Word 5: Least significant 12 bits of Easting, Most significant 4 bits of Northing
Word 6: Least significant 16 bits of Northing.
Word 7: MSByte: IRU Mode/GPS Status/Moving
Word 7: LSByte: Malfunction BIT
Word 8: 16-bit Checksum for this message

Message format from the IRU: (If Position format is Lat/Lon)
Word 1: Header 008Fh
Word 2: MSByte: Position Format/NFM FOM
Word 2: LSByte: Datum Number (Integer number, Range 1-243)
Word 3-4: Latitude (32-bit Integer)
Word 5-6: Longitude (32-bit Integer)
Word 7: MSByte: IRU Mode/GPS Status/Moving

Word 7: LSByte: Malfunction BIT
Word 8: 16-bit Checksum for this message

Message format from the IRU: (If Position format is UTM)

Word 1: Header 008Fh
Word 2: MSByte: Position Format/NFM FOM
Word 2: LSByte: Datum Number (Integer number, Range 1-243)
Word 3: MSByte: Grid Number (Integer number, Range 1-60)
Word 3: LSByte: Zone Letter
Word 4: Most significant 16 bits of Easting Value (Integer, LSBit = 1 meter)
Word 5: MSByte:Least significant 8 bits of Easting value
Word 5: LSByte: Most significant 8 bits of Northing value
Word 6: Least significant 16 bits of Northing value (Integer, LSBit = 1 meter)
Word 7: MSByte: IRU Mode/GPS Status/Moving
Word 7: LSByte: Malfunction BIT
Word 8: 16-bit Checksum for this message

The Position Format for the input/output message is defined as follows:

0 – MGRS Old
1 – MGRS New
2 – UTM
3 – Lat/Lon (degrees, minutes)
4 – Lat/Lon (degrees, minutes, seconds)

For the input message, a Position format of FFFFh will cause the output message to use the current position format (current position format is synchronized with the PLGR OR DAGR display format). Using a valid value (as shown above) will cause the output to use the requested value. The output data for modes 3 and 4 is identical – there is no change to accommodate degrees/minutes vs. degrees/minutes/seconds, because the output for Latitude and Longitude is a scaled integer.

The NFM FOM for the output message is an unsigned 4-bit integer. It represents the RMS error for the vehicle position in meters as shown in Table 4 of 3.2.4 NFM/Target/GPS/Time FOM Definition.

The Position Format for the output message will be encoded in the most significant bits (4 - 7) of the MSByte of the output word 2, and the NFM FOM will be encoded in the least significant bits (0 - 3) of the MSByte of the output word 2.

MGRS Output:
The Zone Letter is encoded in the most significant 5 bits (3 – 7) of the MSByte of Word 3. The Easting Letter is encoded in the least significant 3 bits (0 – 2) of the MSByte of Word 3 and the most significant 2 bits (6 – 7) of the LSByte of Word 3. The Northing letter is encoded in bits 1 - 5 of the LSByte of Word 3. Bit 0 of the LSByte of Word 3 is zero. Each value is the ASCII code of the letter less 64, ie: A (ASCII code 65 (decimal)) would be 1 (decimal), and Z (ASCII code 90 (decimal)) would be 26 (decimal)

The Easting value's most significant 8 bits are stored in the LSByte of Word 4. The least significant 12 bits are stored in the MSByte of Word 5 and the most significant bits (4 – 7) of the LSByte of Word 5. The Northing value's most significant 4 bits are stored in the least significant bits (0 – 3) of the LSByte of Word 5. The least significant 16 bits are stored in Word 6.

The Easting and Northing values are the MGRS easting and northing coordinates with the least significant bit equal to 1 meter.

Lat/Lon Output:
Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 3-4 = ((IRU Latitude, in radians) / PI) * 2^{30}

Words 5-6 = ((IRU Longitude, in radians) / PI) * 2^{30}

UTM Output:
The Grid number is positive for all locations. Coordinates within the southern hemisphere will have a Zone Letter of one of the following: C,D,E,F,G,H,J,K,L, or M. Coordinates within the northern hemisphere will have a Zone Letter of one of the following: N,P,Q,R,S,T,U,V,W, or X.

The Zone Letter is encoded in the LSByte of Word 3. The value is the ASCII code of the letter.

The Easting and Northing values are the UTM easting and northing coordinates with the least significant bit equal to 1 meter. The Easting is encoded in Word 4 and the MSByte of Word 5. The Northing value is encoded in the LSByte of Word 5 and Word 6.

The Malfunction BIT is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

- **0092h**: Set Waypoint Position in Specified Format – The NFM receives input data of the Position Format, and the position specified by that format.

Message format to the IRU: (If Position format is MGRS)

Word 1: Header 0092h
Word 2: MSByte: Position Format
Word 2: LSByte: Waypoint Number (1 to 64)
Word 3: Packed Zone, Easting, and Northing Letters
Word 4: MSByte: Grid Number (Integer number, Range 1-60)
Word 4: LSByte: Most significant 8-bits of Easting Value
Word 5: Least significant 12 bits of Easting, Most significant 4 bits of Northing
Word 6: Least significant 16 bits of Northing.
Word 7: Not Significant
Word 8: 16-bit Checksum for this message

Message format to the IRU: (If Position format is Lat/Lon)

Word 1: Header 0092h
Word 2: MSByte: Position Format
Word 2: LSByte: Waypoint Number (1 to 64)
Word 3-4: Latitude (32-bit Integer)
Word 5-6: Longitude (32-bit Integer)

Word 7: Not Significant
Word 8: 16-bit Checksum for this message

Message format to the IRU: (If Position format is UTM)

Word 1: Header 0092h
Word 2: MSByte: Position Format
Word 2: LSByte: Waypoint Number (1 to 64)
Word 3: MSByte: Grid Number (Integer number, Range 1-60)
Word 3: LSByte: Zone Letter
Word 4: Most significant 16 bits of Easting Value (Integer, LSBit = 1 meter)
Word 5: MSByte:Least significant 8 bits of Easting value
Word 5: LSByte: Most significant 8 bits of Northing value
Word 6: Least significant 16 bits of Northing value (Integer, LSBit = 1 meter)
Word 7: Not Significant
Word 8: 16-bit Checksum for this message

The Position Format for the input/output message is defined as follows:

0 – MGRS Old
1 – MGRS New
2 – UTM
3 – Lat/Lon (degrees, minutes)
4 – Lat/Lon (degrees, minutes, seconds)

The Position Format for the input message will be encoded in the most significant bits (4 - 7) of the MSByte of the input word 2.

MGRS Input:
The Zone Letter is encoded in the most significant 5 bits (3 – 7) of the MSByte of Word 3. The Easting Letter is encoded in the least significant 3 bits (0 – 2) of the MSByte of Word 3 and the most significant 2 bits (6 – 7) of the LSByte of Word 3. The Northing letter is encoded in bits 1 - 5 of the LSByte of Word 3. Bit 0 of the LSByte of Word 3 is zero. Each value is the ASCII code of the letter less 64, ie: A (ASCII code 65 (decimal)) would be 1 (decimal), and Z (ASCII code 90 (decimal)) would be 26 (decimal)

The Easting value's most significant 8 bits are stored in the LSByte of Word 4. The least significant 12 bits are stored in the MSByte of Word 5 and the most significant bits (4 – 7) of the LSByte of Word 5. The Northing value's most significant 4 bits are stored in the least significant bits (0 – 3) of the LSByte of Word 5. The least significant 16 bits are stored in Word 6.

The Easting and Northing values are the MGRS easting and northing coordinates with the least significant bit equal to 1 meter.

Lat/Lon Input:
Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 3-4 = ((IRU Latitude, in radians) / PI) * 2^{30}
Words 5-6 = ((IRU Longitude, in radians) / PI) * 2^{30}

UTM Input:

The Grid number is positive for all locations. Coordinates within the southern hemisphere will have a Zone Letter of one of the following: C,D,E,F,G,H,J,K,L, or M. Coordinates within the northern hemisphere will have a Zone Letter of one of the following: N,P,Q,R,S,T,U,V,W, or X.

The Zone Letter is encoded in the LSByte of Word 3. The value is the ASCII code of the letter.

The Easting and Northing values are the UTM easting and northing coordinates with the least significant bit equal to 1 meter. The Easting is encoded in Word 4 and the MSByte of Word 5. The Northing value is encoded in the LSByte of Word 5 and Word 6.

Message format from the IRU: No change in output

- **0093h**: Display Waypoint Position in Specified Format – The NFM receives input data of the Position Format. Then it returns the NFM position using the message format specified by the Position Format.

  Message format to the IRU:

  Word 1: Header 0093h
  Word 2: MSByte: Position Format
  Word 2: LSByte: Waypoint Number (Integer number, Range 1-64)
  Word 3-7: Not Significant
  Word 8: 16-bit Checksum for this message

  Message format from the IRU: (If Position format is MGRS)

  Word 1: Header 0093h
  Word 2: MSByte: Position Format
  Word 2: LSByte: Waypoint Number (Integer number, Range 1-64)
  Word 3: Packed Zone, Easting, and Northing Letters
  Word 4: MSByte: Grid Number (Integer number, Range 1-60)
  Word 4: LSByte: Most significant 8-bits of Easting Value
  Word 5: Least significant 12 bits of Easting, Most significant 4 bits of Northing
  Word 6: Least significant 16 bits of Northing.
  Word 7: MSByte: IRU Mode/GPS Status/Moving
  Word 7: LSByte: Malfunction BIT
  Word 8: 16-bit Checksum for this message

  Message format from the IRU: (If Position format is Lat/Lon)

  Word 1: Header 0093h
  Word 2: MSByte: Position Format
  Word 2: LSByte: Waypoint Number (Integer number, Range 1-64)
  Word 3-4: Latitude (32-bit Integer)
  Word 5-6: Longitude (32-bit Integer)
  Word 7: MSByte: IRU Mode/GPS Status/Moving
  Word 7: LSByte: Malfunction BIT
  Word 8: 16-bit Checksum for this message

  Message format from the IRU: (If Position format is UTM)

  Word 1: Header 0093h

Word 2: MSByte: Position Format
Word 2: LSByte: Waypoint Number (Integer number, Range 1-64)
Word 3: MSByte: Grid Number (Integer number, Range 1-60)
Word 3: LSByte: Zone Letter
Word 4: Most significant 16 bits of Easting Value (Integer, LSBit = 1 meter)
Word 5: MSByte:Least significant 8 bits of Easting value
Word 5: LSByte: Most significant 8 bits of Northing value
Word 6: Least significant 16 bits of Northing value (Integer, LSBit = 1 meter)
Word 7: MSByte: IRU Mode/GPS Status/Moving
Word 7: LSByte: Malfunction BIT
Word 8: 16-bit Checksum for this message

The Position Format for the input/output message is defined as follows:

0 – MGRS Old
1 – MGRS New
2 – UTM
3 – Lat/Lon (degrees, minutes)
4 – Lat/Lon (degrees, minutes, seconds)

For the input message, a Position format of FFFFh will cause the output message to use the current Position format (current Position format is synchronized with the PLGR OR DAGR display format). Using a valid value (as shown above) will cause the output to use the requested value. The output data for modes 3 and 4 is identical – there is no change to accommodate degrees/minutes vs. degrees/minutes/seconds, because the output for Latitude and Longitude is a scaled integer.

The Position Format for the output message will be encoded in the most significant bits (4 - 7) of the MSByte of the output word 2.

MGRS Output:
The Zone Letter is encoded in the most significant 5 bits (3 – 7) of the MSByte of Word 3. The Easting Letter is encoded in the least significant 3 bits (0 – 2) of the MSByte of Word 3 and the most significant 2 bits (6 – 7) of the LSByte of Word 3. The Northing letter is encoded in bits 1 - 5 of the LSByte of Word 3. Bit 0 of the LSByte of Word 3 is zero. Each value is the ASCII code of the letter less 64, ie: A (ASCII code 65 (decimal)) would be 1 (decimal), and Z (ASCII code 90 (decimal)) would be 26 (decimal)

The Easting value's most significant 8 bits are stored in the LSByte of Word 4. The least significant 12 bits are stored in the MSByte of Word 5 and the most significant bits (4 – 7) of the LSByte of Word 5. The Northing value's most significant 4 bits are stored in the least significant bits (0 – 3) of the LSByte of Word 5. The least significant 16 bits are stored in Word 6.

The Easting and Northing values are the MGRS easting and northing coordinates with the least significant bit equal to 1 meter.

Lat/Lon Output:
Latitude and Longitude are presented as scaled integer values from the IRU. They are scaled according to the following equations:

Words 3-4 = ((IRU Latitude, in radians) / PI) * 2^{30}

Words 5-6 = ((IRU Longitude, in radians) / PI) * 2^{30}

UTM Output:
The Grid number is positive for all locations. Coordinates within the southern hemisphere will have a Zone Letter of one of the following: C,D,E,F,G,H,J,K,L, or M. Coordinates within the northern hemisphere will have a Zone Letter of one of the following: N,P,Q,R,S,T,U,V,W, or X.

The Zone Letter is encoded in the LSByte of Word 3. The value is the ASCII code of the letter.

The Easting and Northing values are the UTM easting and northing coordinates with the least significant bit equal to 1 meter. The Easting is encoded in Word 4 and the MSByte of Word 5. The Northing value is encoded in the LSByte of Word 5 and Word 6.

The Malfunction BIT is a direct copy of the Continuous BIT (CBIT) Line Replaceable Unit (LRU) word of the IRU bit message. It represents a go/no-go bit status of the IRU.

See 3.2.3 for a description of the IRU Mode word.

4. RS-422 IRU INITIALIZATION

4.1 Apply Power.

After power is applied, the IRU will attempt to read a valid saved state since the last power down. If one is found, the associated attitude and heading information will be used as the initialization data for the new run. Reinitialization of the IRU is required if the saved state information no longer represents the current position or a valid saved state was not found. To determine this, read the current IRU Datum, Position, and Heading over the RS-422. If any of this data is not valid, perform the initialization sequence described in 4.2. Note: The RS-422 interface is not functional until approximately 35 seconds after powerup.

4.2 Initialization Sequence.

If initialization is needed, enter the desired Datum for the navigation reference frame. Position and heading components must then be sent to the IRU. Latitude and longitude can be entered using message 0011h or MGRS position using 0059h. The heading component can be entered by using the Set Grid Heading message 0058h or the Set True Heading message 0013h. An alternate method of setting the heading is to have the IRU find its heading automatically by issuing a Gyrocompass Mode command, message 002Ch or 005Dh. The suggested sequence for initialization would be position first and heading last.

4.3 Gyrocompassing.

The IRU supports two different modes to perform the gyrocompass option. The first is a classical gyrocompass mode for large vehicles that are not subject to small motions while performing the gyrocompass. The second mode is a base motion compensated gyrocompass that will allow small motions created by wind buffeting or personnel movement on the vehicle while the vehicle is stationary.

A classical gyrocompass can be commanded from Navigation or Standby modes. A successful gyrocompass will take less than 3 minutes to complete and the time remaining to complete can be monitored using message 000Fh. During this time, the IRU should NOT be subjected to motion from wind gusts or personnel movements. If motion is detected, the IRU will transition into GCABORT. GCABORT will cause transition back into the initiating mode. The heading will also revert to its original value before the GC Mode.

A Base Motion Compensated (BMC) gyrocompass can be commanded from either the Navigation or the Standby modes. A successful BMC gyrocompass will take 3 to 5 minutes to complete and the time remaining to complete can be monitored using message 002Ch. During this time, the IRU can tolerate small motions but the vehicle must remain stationary. If too much motion is detected, the IRU will transition into BMCABORT. BMCABORT will cause transition back into the initiating mode. If the BMC gyrocompass process has progressed far enough the gyrocompass heading will be used, otherwise the heading will revert to its original value before the BMC GC Mode.

4.4 Health of IRU.

Periodically, the health of the IRU should be acquired by reading the BIT messages 003Dh, 003Eh, 003Fh, and 0040h. By selecting any one of the BIT messages, the IRU will send out all of the messages in rotation. This process will continue until a new output message from the IRU is requested. The first word in message 003Dh is a BIT status summary word. If any bits are set in any of the remaining bit words, a bit will also be set in word 1. Conversely, if the first word in message 003Dh is zero, then all remaining bit words will be zero.

5. BIT SPECIFICATION AND DESCRIPTION

The BIT results consist of four messages. Table 11 through Table 14 list each message with the corresponding header and BIT words. The relationships between ERRORS, FAILURES, and FAULTS are as follows: the ERROR words represent each error that has occurred in the system. Once the number of errors have exceeded the filtered value for that error, it rolls up into the FAILURE word. FAULT words are not used in this implementation of the system.

Table 11. BIT Message 1

WORD1	003Dh
WORD2	LRU CBIT
WORD3	RESERVED
WORD4	RESERVED
WORD5	RESERVED
WORD6	TEST WORD 1 (FAULT)
WORD7	TEST WORD 2 (FAULT)
WORD8	CHECKSUM

Table 12. BIT Message 2

WORD1	003Eh
WORD2	TEST WORD 3(FAULT)
WORD3	TEST WORD 1(FAILURE)
WORD4	TEST WORD 2(FAILURE)
WORD5	TEST WORD 3(FAILURE)
WORD6	TEST WORD 1 (ERROR)
WORD7	TEST WORD 2 (ERROR)
WORD8	CHECKSUM

Table 13. BIT Message 3

WORD1	003Fh
WORD2	TEST WORD 3(ERROR)
WORD3	DIAGNOSTIC WORD 1(FAULT)
WORD4	DIAGNOSTIC WORD 2(FAULT)
WORD5	DIAGNOSTIC WORD 1(FAILURE)
WORD6	DIAGNOSTIC WORD 2(FAILURE)
WORD7	DIAGNOSTIC WORD 1(ERROR)
WORD8	CHECKSUM

Table 14. BIT Message 4

WORD1	0040h
WORD2	DIAGNOSTIC WORD 2(ERROR)
WORD3	CRITICAL DATA R/W FAIL COUNT
WORD4	RESERVED
WORD5	RESERVED
WORD6	RESERVED
WORD7	RESERVED
WORD8	CHECKSUM

Figure 3 through Figure 7 show the bit pattern for each word.

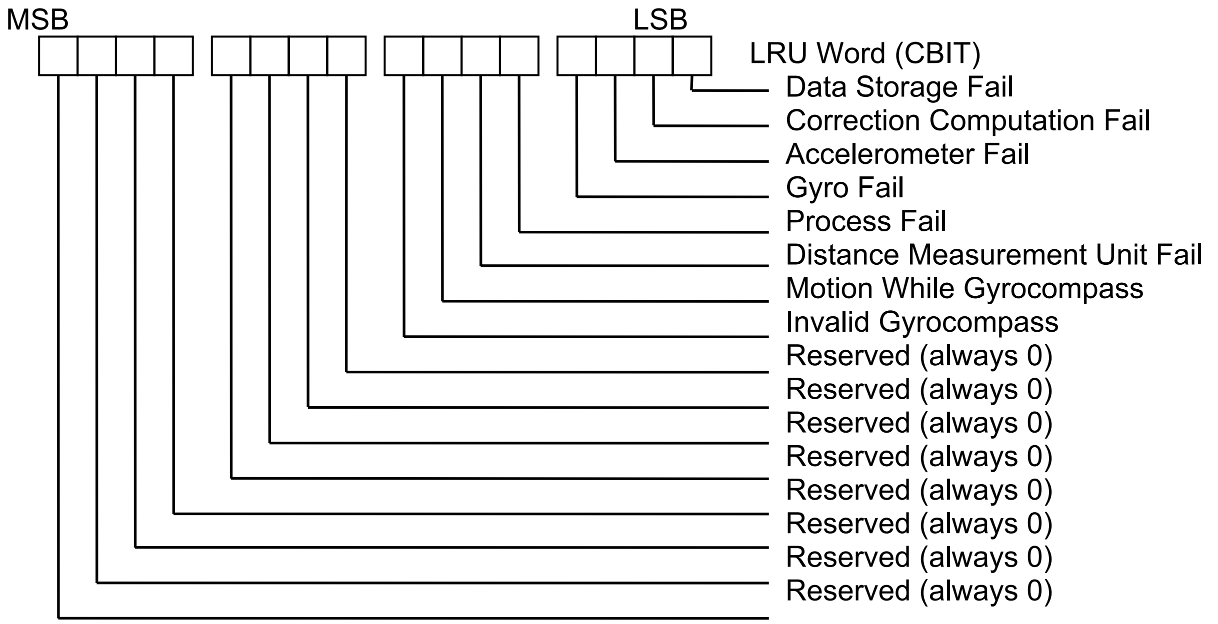

Figure 3. LRU Word (CBIT)

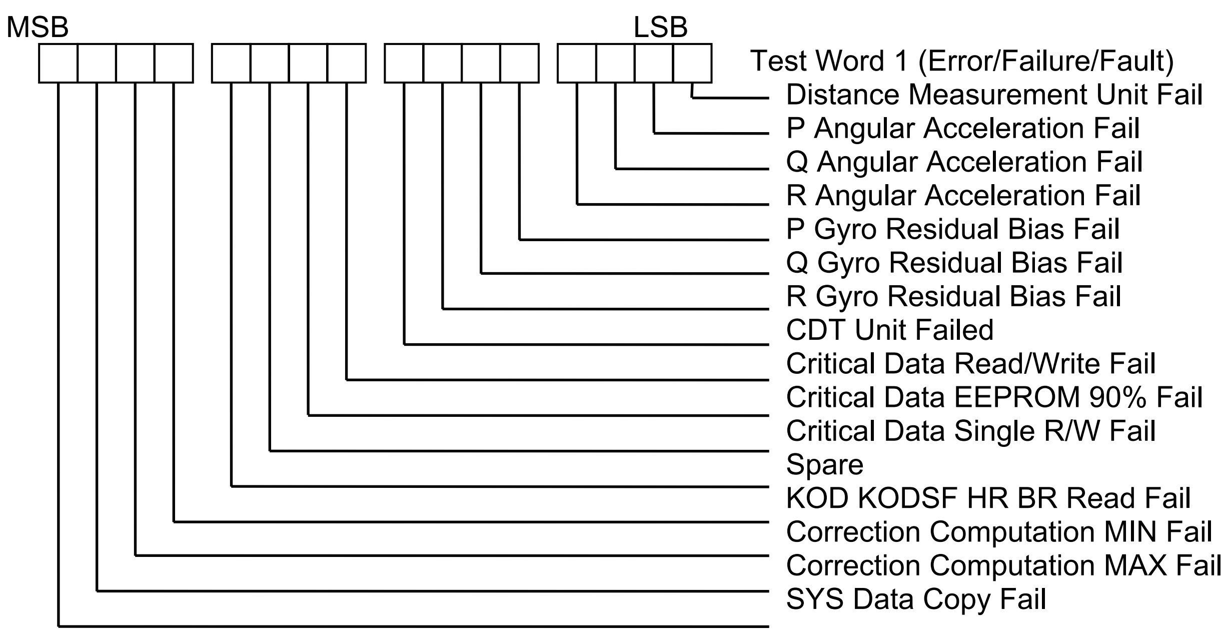

Figure 4. Test Word 1 (Error/Failure/Fault)

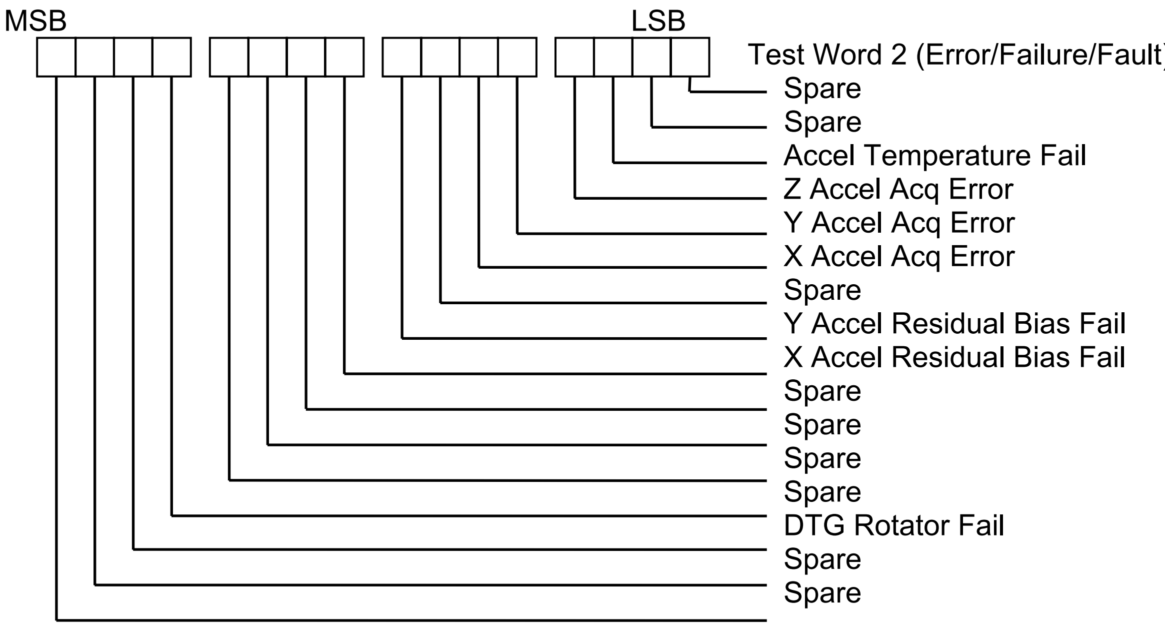

Figure 5. Test Word 2 (Error/Failure/Fault)

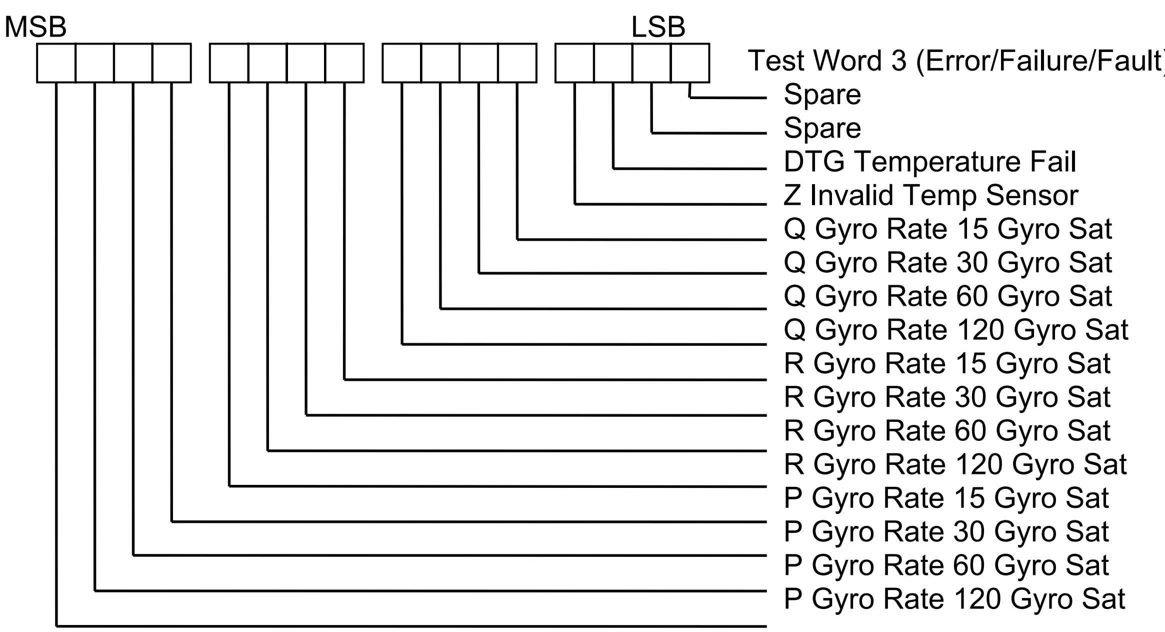

Figure 6. Test Word 3 (Error/Failure/Fault)

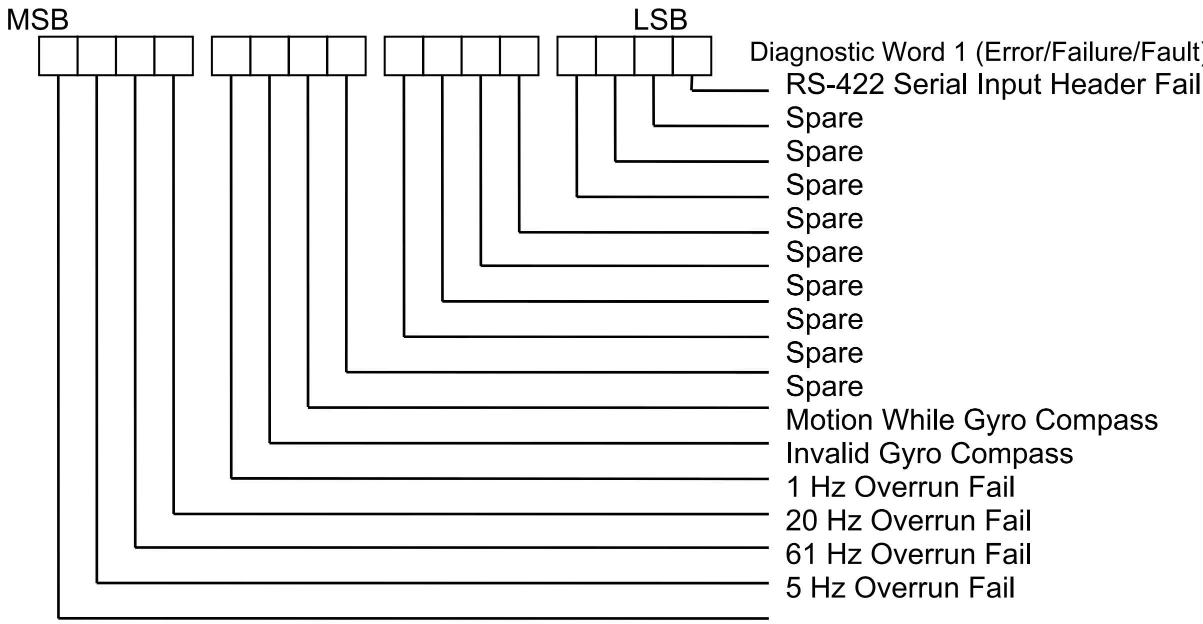

Figure 7. Diagnostic Word 1 (Error/Failure/Fault)

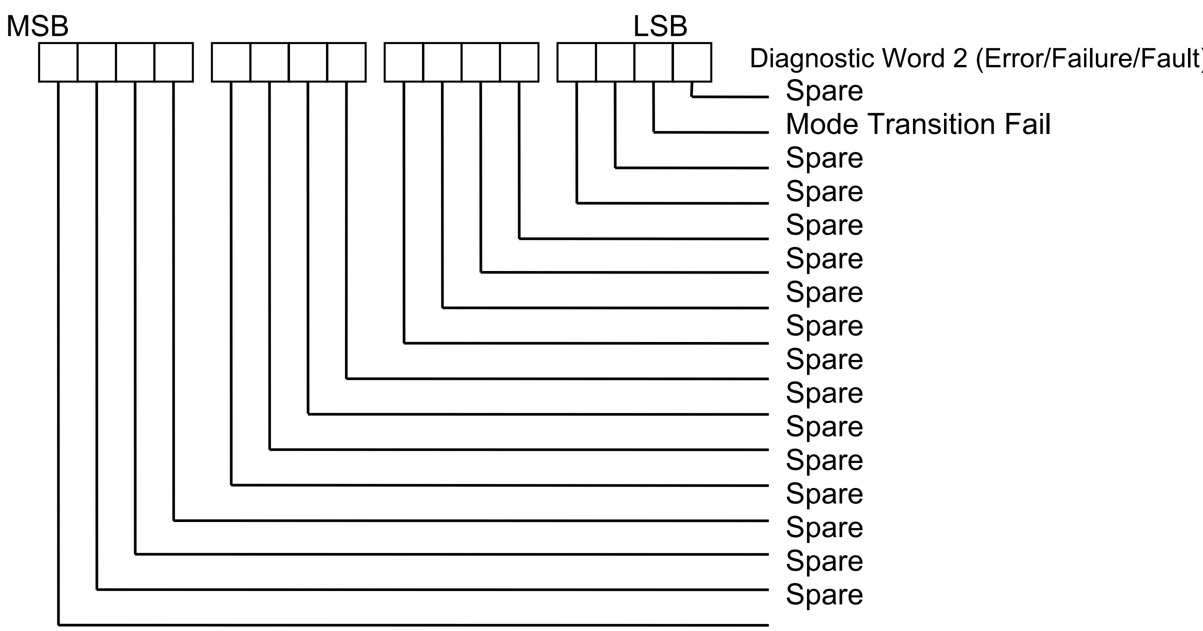

Figure 8. Diagnostic Word 2 (Error/Failure/Fault)

6. NOTES

6.1 Acronyms and Abbreviations.

The following acronyms and abbreviations are used throughout this document and are defined here for convenience.

Accel	Accelerometer
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BIT	Built-In Test
BMC	Base Motion Compensated
BMCABORT	Base Motion Compensated Coarse Abort
BMCCOARS	Base Motion Compensated Coarse Align
BMCFINE	Base Motion Compensated Fine Align
CAPS	Collins Adaptive Processing System
CBIT	Continuous BIT
CEP	Circular Error Probable
CDT	Control Display Terminal
DAGR	Defense Advanced Global Positioning System Receiver
DMU	Distance Measurement Unit
DTG	Dynamically Tuned Gyro
EEPROM	Electrically Erasable Programmable Read-Only Memory
EHE	Estimated Horizontal Error
EPE	Estimated Position Error
ETE	Estimated Time Error
ETI	Elapsed Time Indicator
FIFO	First-In-First-Out
FOM	Figure Of Merit
GC	Gyrocompass Mode
GCABORT	Gyrocompass Abort Mode
GDOP	Geometric Dilution of Precision
GPS	Global Positioning System
IBIT	Initiated BIT
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
IRU	Inertial Reference Unit
IVC	In-Vehicle Calibration Mode
I/O	Input/Output
KOD	Odometer Counts
KODSF	Odometer Scale Factor
LNS	Land Navigation System
LOS	Line of Sight
LSB	Least Significant Bit
LSByte	Least Significant Byte
LSW	Least Significant Word
LRU	Line Replaceable Unit
MGRS	Military Grid Reference System
MSB	Most Significant Bit

MSByte	Most Significant Byte
MVAR	Magnetic Variation
NAV	Navigation Mode
NFM	North Finding Module
NMEA	National Marine Electronics Association
PLGR	Precision Lightweight GPS Receiver
POS/NAV	Position/Navigation
PVT	Position, Velocity, And Time
RAM	Random Access Memory
ROM	Read-Only Memory
RMS	Root Mean Square
RSVD	Reserved
Smiths Aerospace	Smiths Aerospace LLC Electronic Systems – Grand Rapids
SPFP	Single Precision Floating Point
SWAT	Serial Wrap Around Test
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VDOP	Vertical Dilution Of Precision

6.2 IRU J1 Interface Definition.

IRU INTERFACE SIGNALS - Sorted by function

IRU J1	SIGNAL NAME	DESTINATION
18	+28 VDC INPUT	PRIME POWER
17	28VDC RETURN	POWER RETURN
16	CHASSIS GND	CHASSIS GND
7	PLUS 5 VDC	CDT P1-F, DMU P1-B
5	LOGIC COMMON	CDT P1-A, PLGR P3-3, PLGR P3-13, DAGR J2-3, DAGR J2-13Customer I/O signal ground, NDU P1-9
9	ODOMETER A	DMU P1-E
8	ODOMETER B	DMU P1-D
23	ODOMETER RETURN	DMU P1-A
15	RS422 IN A+	Customer
14	RS422 IN A-	Customer
29	RS422 OUT A+	Customer
28	RS422 OUT A-	Customer
13	RS422 IN B+	Customer
12	RS422 IN B-	Customer
27	RS422 OUT B+	Customer
26	RS422 OUT B-	Customer
11	RS422 IN C+	CDT P1-D, or NDU P1-3
10	RS422 IN C-	CDT P1-B, or NDU P1-4
25	RS422 OUT C+	CDT P1-E, or NDU P1-6
24	RS422 OUT C-	CDT P1-C, or NDU P1-7
36	RS422 IN D+	PLGR P3-5 or DAGR J2-5
35	RS422 IN D-	PLGR P3-4 or DAGR J2-4
31	RS422 OUT D+	PLGR P3-10 or DAGR J2-10
37	RS422 OUT D-	PLGR P3-9 or DAGR J2-9
4	Discrete In 1	Open for Primary OVP Grounded to IRU J1-5 for Secondary OVP

Note: Pins not listed are reserved and shall not be wired.
Note: IRU J1 mating connector is D38999/26WD35SN or equivalent.
DMU J1 mating connector is MS3106R14S-6S or equivalent.
NDU J1 mating connector is TV06RW-11-35SN or equivalent.
CDT J1 mating connector is MS27656T13B98P or equivalent.
Note: Logic Common J1-5 and Odometer Return J1-23 are the same.
Note: NDU P1-1 +28VDC
NDU P1-2 28VDC RTN