3DM[™]-CV5[™]-25

Attitude and Heading Reference System (AHRS)







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1. API Introduction

The 3DM-CV5-25 programming interface is comprised of a compact set of setup and control commands and a very flexible user-configurable data output format. The commands and data are divided into command sets and data set corresponding to the internal architecture of the device. The command sets consist of a set of "Base" commands (a set that is common across many types of devices), a set of unified "3DM" (3D Motion) commands that are specific to the LORD Sensing inertial product line, and a set of "System" commands that are specific to sensor systems comprised of more than one internal sensor block. The data sets represent the two types of data that the 3DM-CV5-25 is capable of producing: "Estimation Filter" (Attitude) data and "IMU" (Inertial Measurement Unit) data.

Base commands	Ping, Idle, Resume, Get ID Strings, etc.
3DM commands	Poll IMU Data, Estimation Filter Data, etc.
Estimation Filter commands	Reset Filter, Sensor to Vehicle Frame Transformation, etc.
System commands	Switch Communications Mode, etc.
IMU data	Acceleration Vector, Gyro Vector, etc.
Estimation Filter data	Attitude, Acceleration Estimates, etc.

The protocol is packet based. All commands, replies, and data are sent and received as fields in a message packet. Commands are all confirmed with an ack/nack (with a few exceptions). The packets have a descriptor type field based on their contents, so it is easy to identify if a packet contains IMU data, commands, or replies.





2. Basic Programming

The 3DM-CV5-25 is designed to stream and IMU data packets over a common interface as efficiently as possible. To this end, programming the device consists of a configuration stage where the data messages and data rates are configured. The configuration stage is followed by a data streaming stage where the program starts the incoming data packet stream.



In this section there is an overview of the packet, an overview of command and reply packets, an overview of how an incoming data packet is constructed, and then an example setup command sequence that can be used directly with the 3DM-CV5-25 either through a COM utility or as a template for software development.

2.1 MIP Packet Overview

This is an overview of the 3DM-CV5-25 packet structure. The packet structure used is the LORD "MIP" packet. A reference to the general packet structure is presented in the MIP Packet Reference section. An overview of the packet is presented here.

The MIP packet "wrapper" consists of a four byte header and two byte checksum footer:



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	I	Header			Checksum			
SYNC1 "u"	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Length byte Field Descriptor byte Field Data 0x0E 0x03 0x3E 7A 63 A0 0xBB 3E 3B 20			MSB	LSB
0x75	0x65	0x80	0x0E	0x0E 0x03 0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F		0x83	0xE1	
			\	Payload Lengt packet payload more fields an the lengths of	h byte. This specifi d. The packet payle d thus this byte als all the fields in the	es the length of the bad may contain one or o represents the sum of payload.		
				Descriptor Set The value 0x80 packet. Fields descriptor set.				
				Start of Packet every MIP pac packet.	Start of Packet (SOP) "sync" bytes. These are the same for every MIP packet and are used to identify the start of the packet.			
				2 byte Fletche				

The packet payload section contains one or more fields. Fields have a length byte, descriptor byte, and data. The diagram below shows a packet payload with a single field.

	1	Header		Packet Payload			Checksum		
SYNC1 "u"	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Length byte	Field Descriptor byte	Field Data	MSB	LSB	
0x75	0x65	0x80	0x0E	0x0E	0x06	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x86	0x08	
Field Len the bytes descripto of the fie data is a Field data 2. This d represen vector va	gth byte. in the fiel or byte and or byte. The Id data. T mag vector a. The len ata is 12 b ts the floa ilue from t	This represen Id including th I field data. his byte identi his descriptor r (set: 0x80, c gth of the dat ytes long (14 ting point ma he AHRS data	ts a count of al ne length byte, ifies the conter indicates that descriptor: 0x00 ta is Field Lengt - 2) and gnetometer a set.	h -					



Below is an example of a packet payload with two fields (gyro vector and mag vector). Note the payload length byte of 0x1C which is the sum of the two field length bytes 0x0E + 0x0E:

	Н	leader		Packet Payload (2 Fields)					Checksum		
SYNC1 "u"	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field 1 Length	Field 1 Descriptor	Field 1 Data	Field 2 Length	Field 2 Descriptor	Field 2 Data	MSB	LSB
0x75	0x65	0x80	0x1C	0x0E	0x05	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x0E	0x06	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0xE0	0xC6

2.2 Command Overview

The basic command sequence begins with the host sending a command to the device. A command packet contains a field with the command value and any command arguments.

The device responds by sending a reply packet. The reply contains at minimum an ACK/NACK field. If any additional data is included in a reply, it appears as a second field in the packet.

2.2.1 Example "Ping" Command Packet

Below is an example of a "Ping" command packet from the Base command set. A "Ping" command has no arguments. Its function is to determine if a device is present and responsive:

Header					Packet Payload					
SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Byte Length	Field Descriptor Byte	Field Data	MSB	LSB		
0x75	0x65	0x01	0x02	0x02	0x01	N/A	0xE0	0xC6		
Copy-Paste version of command: "7565 0102 0201 E0C6"										

The packet header has the "ue" starting sync bytes characteristic of all MIP packets. The descriptor set byte (0x01) identifies the payload as being from the Base command set. The length of the payload portion is 2 bytes. The payload portion of the packet consists of one field. The field starts with the length of the field which is followed by the descriptor byte (0x01) of the field. The field descriptor value is the command value. Here the descriptor identifies the command as the "Ping" command from the Base command descriptor set. There are no parameters associated with the ping command, so the field data is empty. The checksum is a two byte Fletcher checksum (see the MIP Packet Reference for instructions on how to compute a Fletcher two byte checksum).



2.2.2 Example "Ping" Reply Packet

The "Ping" command will generate a reply packet from the device. The reply packet will contain an ACK/NACK field. The ACK/NACK field contains an "echo" of the command byte plus an error code. An error code of 0 is an "ACK" and a non-zero error code is a "NACK":

Header					Packet F	Checksum				
SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Byte Length	ield Field Byte Descriptor Field Data ength Byte		MSB	LSB		
0x75	0x65	0x01	0x04	0x04	0xF1	Command Echo: 0x01 Error code: 0x00	0xD5	0x6A		
Copy-Paste version of reply: "7565 0104 04F1 0100 D56A"										

The packet header has the "ue" starting sync bytes characteristic of all MIP packets. The descriptor set byte (0x01) identifies the payload fields as being from the Base command set. The length of the payload portion is 4 bytes. The payload portion of the packet consists of one field. The field starts with the length of the field which is followed by the descriptor byte (0xF1) of the field. The field descriptor byte identifies the reply as the "ACK/NACK" from the Base command descriptor set. The field data consists of an "echo" of the original command (0x01) followed by the error code for the command (0x00). In this case the error is zero, so the field represents an "ACK". Some examples of non-zero error codes that might be sent are "timeout", "not implemented", and "invalid parameter in command". The checksum is a two byte Fletcher checksum (see the MIP Packet Reference for instructions on how to compute a Fletcher two byte checksum).

The ACK/NACK descriptor value (0xF1) is the same in all descriptor sets. The value belongs to a set of reserved global descriptor values.

The reply packet may have additional fields that contain information in reply to the command. For example, requesting **Device Status** will result in a reply packet that contains two fields in the packet payload: an ACK/NACK field and a device status information field.



2.3 Data Overview

Data packets are generated by the device. When the device is powered up, it may be configured to immediately stream data packets out to the host or it may be "idle" and waiting for a command to either start continuous data or to get data by "polling" (one data packet per request). Either way, the data packet is generated by the device in the same way.

2.3.1 Example Data Packet:

Below is an example of a MIP data packet which has one field that contains the scaled accelerometer vector.

		Header			Packet	Payload	Checksum				
SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Byte Length	Field Descriptor Byte	Field Data: Accel vector (12 bytes, 3 float - X, Y, Z)	MSB	LSB			
0x75	0x65	0x80	0x0E	0x0E	0x04	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x84	0xEE			
Copy-Pa	Copy-Paste version: "7565 800E 0E04 3E7A 63A0 BB8E 3B29 7FE5 BF7F 84EE"										

The packet header has the "ue" starting sync bytes characteristic of all MIP packets. The descriptor set byte (0x80) identifies the payload field as being from the IMU data set. The length of the packet payload portion is 14 bytes (0x0E). The payload portion of the packet starts with the length of the field. "E The field descriptor byte (0x04) identifies the field data as the scaled accelerometer vector from the IMU data descriptor set. The field data itself is three single precision floating point values of 4 bytes each (total of 12 bytes) representing the X, Y, and Z axis values of the vector. The checksum is a two byte Fletcher checksum (see the MIP Packet Reference for instructions on how to compute a Fletcher two byte checksum).

The format of the field data is fully and unambiguously specified by the descriptor. In this example, the field descriptor (0x04) specifies that the field data holds an array of three single precision IEEE-754 floating point numbers in big-endian byte order and that the values represent units of "g's" and the order of the values is X, Y, Z vector order. Any other specification would require a different descriptor (see the Data Reference section of this manual).

Data polling commands generate two individual reply packets: An ACK/NACK packet and a data packet. Enable/Disable continuous data commands generate an ACK/NACK packet followed by the continuous stream of data packets.

The IMU and Estimation Filter data packets can be set up so that each data quantity is sent at a different rate. For example, you can setup continuous data to send the accelerometer vector at 100



Hz and the delta theta vector at 5 Hz. This means that packets will be sent at 100 Hz and each one will have the accelerometer vector but only every 20th packet will have the delta theta vector. This helps reduce bandwidth and buffering requirements. An example of this is given in the IMU Message Format command.

2.4 Example Setup Sequence

Setup involves a series of command/reply pairs. The example below demonstrates actual setup sequences that you can send directly to the 3DM-CV5-25 either programmatically or by using a COM utility. In most cases only minor alterations will be needed to adapt these examples for your application.

2.4.1 Continuous Data Example Command Sequence

Most applications will operate with the 3DM-CV5-25 sending a continuous data stream. In the following example, the IMU data format is set, followed by the Estimation Filter data format. To reduce the amount of streaming data, if present during the configuration, the device is placed into the idle state while performing the device initialization; when configuration is complete, the required data streams are enabled to bring the device out of idle mode. Finally, the configuration is saved so that it will be loaded on subsequent power-ups, eliminating the need to perform the configuration again.

1. Put the Device in Idle Mode

Send the "Set To Idle" command to put the device in the idle state (reply is ACK/NACK), disabling the data-streams. This is not required but reduces the parsing burden during initialization and makes visual confirmation of the commands easier.

	MIP Packet Header					Command/Reply Fields					
	SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length	Field Length	Cmd. Descriptor	Field Data	MSB	LSB		
Command: Set to Idle	0x75	0x65	0x01	0x02	0x02	0x02	N/A	0xE1	0xC7		
Reply: ACK/NACK 0x75 0x65 0x01 0x04 0x04 0xF1 Cmd echo: 0x02 Error code: 0x00 0xD6 0x66											
Copy-Paste version of the command: "7565 0102 0202 E1C7"											



2. Configure the IMU Data-stream Format

Send a "Set IMU Message Format" command (reply is ACK/NACK). This example requests GPS correlation timestamp, scaled gyro, and scaled accelerometer information at Hz (Hz base rate divided by a rate decimation of 10 on the 3DM-CV5-25 = Hz.) This will result in a single IMU data packet sent at Hz containing the IMU GPS correlation timestamp followed by the scaled gyro field and the scaled accelerometer field. This is a very typical configuration for a base level of inertial data. If different rates were requested, then each packet would only contain the data quantities that fall in the same decimation frame (see the Multiple Rate Data section). If the stream was not disabled in the previous step, the IMU data would begin stream immediately.

Please note, this command will not append the requested descriptors to the current IMU datastream configuration, it will overwrite it completely.

		MIP Pac	ket Heade	r		Command	l/Reply Fields	Checksum			
	SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length	Field Length	Cmd. Descriptor	Field Data	MSB	LSB		
Command: New IMU Message Format	0x75	0x65	0x0C	0x0D	0x0D	0x08	Function: 0x01 Desc. count: 0x03 GPS TS Desc.: 0x12 Rate Dec: 0x000A Accel Desc.: 0x04 Rate Dec: 0x000A Ang Rate Desc: 0x05 Rate Dec: 0x000A	0x45	0xF2		
Reply: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Cmd echo: 0x08 Error code: 0x00	0xE7	0xBA		
Conv-Paste	Copy-Paste version of the command: "7565 0C0D 0D08 0103 1200 0A04 000A 0500 0A45 E2"										



3. Configure the Estimation Filter Data-stream Format

The following configuration command requests the GPS Timestamp followed by the Estimated , Estimated , and at Hz (Hz base rate divided by a rate decimation of 10 on the 3DM-CV5-25 = Hz.) This will result in a single IMU data packet sent at Hz containing the requested fields in the requested order. If different rates were requested, then each packet would only contain the data quantities that fall in the same data rate frame (see the Multiple Rate Data section). If the stream was not disabled in the previous step, the Estimation Filter data would begin stream immediately.

Please note, this command will not append the requested descriptors to the current Estimation Filter data stream configuration, it will overwrite it completely.

		MIP Pac	ket Heade	r		Comma	and/Reply Fields	Checksum			
	SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length	Field Length	Cmd. Desc.	Field Data	MSB	LSB		
Command: New Estimation Filter Message Format	0x75	0x65	0x0C	0x10	0x10	0x0A	Function: 0x01 Desc. count: 0x04 GPS TS Desc.: 0x11 Rate Dec: 0x000A EF Euler: 0x05 Rate Dec: 0x000A EF Accel: 0x0D Rate Dec: 0x000A EF Ang Rate: 0x0E Rate Dec: 0x000A	0x6E	0xB0		
Reply: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Cmd echo: 0x0A Error code: 0x00	0xE9	0xBE		
Copy-Paste version of the command: "7565 0C10 100A 0104 1100 0A05 000A 0D00 0A0E 000A 6EB0"											



4. Save the IMU and Estimation Filter MIP Message Format

To save the IMU and Estimation Filter MIP Message format, use the "Save" function selector (0x03) in the IMU and Estimation Filter Message Format commands. Below we've combined the two commands as two fields in the same packet. Notice that the two reply ACKs comes in one packet also. Alternatively, they could be sent as separate packets.

		MIP Pac	ket Header	ſ	С	ommar	d/Reply Fields	Checksum		
	SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length	Field Length	Cmd. Desc.	Field Data	MSB	LSB	
Command Field 1: Save Current IMU Message Format	0x75	0x65	0x0C	0x08	0x04	0x08	Function: 0x03 Desc. count: 0x00			
Command Field 2: Save Current Estimation Filter Message Format					0x04	0x0A	Function: 0x03 Desc. count: 0x00	0x0E	0x31	
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x08	0x04	0xF1 Cmd echo: 0x08 Error code: 0x00				
Reply Field 2: ACK/NACK					0x04	0xF1	Cmd echo: 0x0A Error code: 0x00	0xE9	0xBE	
Copy-Paste version of the command: "7565 0C08 0408 0300 040A 0300 0E31"										



5. Enable the IMU and Estimation Filter Data-streams

Send an Enable/Disable Continuous Stream command to enable the IMU and Estimation Filter continuous streams (reply is ACK). These streams may have already been enabled by default; this step is to confirm they are enabled. These streams will begin streaming data immediately.

		MIP Packet Header				omman	d/Reply Fields	Chec	ksum	
	SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length	Field Length	Cmd. Desc.	Field Data	MSB	LSB	
Command Field 1: Enable Continu- ous IMU Mes- sage	0x75	0x65	0x0C	0x0A	0x05	0x11	Function: 0x01 IMU: 0x01 On: 0x01			
<i>Command</i> <i>Field 2:</i> <i>Enable</i> <i>Continuous</i> <i>Estimation Filter</i> <i>Message</i>					0x05	0x11	Function: 0x01 Estimation Filter: 0x03 On: 0x01	0x24	0xCC	
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x08	0x04	0xF1	Cmd echo: 0x11 Error code: 0x00			
Reply Field 2: ACK/NACK					0x04	0xF1	Cmd echo: 0x11 Error code: 0x00	0xFA	0xB5	
Copy-Paste version of the command: "7565 0C0A 0511 0101 0105 1101 0301 24 CC"										

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6. Resume the Device: (Optional)

Sending the "Resume" command is another method of re-enabling transmission of enabled data streams (reply is ACK/NACK).

		MIP Pac	ket Header		Со	mmand	/Reply Fields	Checksum		
	SYNC1 "u	SYNC2 "e"	Descriptor Set byte	Payload Length	Field Length	Cmd. Desc.	Field Data	MSB	LSB	
Command: Resume	0x75	0x65	0x01	0x02	0x02	0x06	N/A	0xE5	0xCB	
Reply: ACK/NACK 0x75 0x65 0x01 0x04 0x04 0xF1 Cmd echo: 0x06 Error code: 0x00 0xDA 0x75										
Copy-Paste version of the command: "7565 0102 0206 E5CB"										



7. Initialize the Filter

At this point in the set-up, the 3DM-CV5-25 is streaming data, but the Kalman Filter is not yet initialized. The orientation may be initialized in different ways: Setting all of the attitude elements manually, setting only the heading and allowing the device to determine pitch and roll, using the internal IMU solution (which requires the magnetometers) to provide the initial orientation, or via auto-initialization, which uses the chosen heading update source to initialize. In this example, we will assume the magnetometers are available and use the IMU solution to initialize the Kalman Filter. Once the attitude is initialized and the GPS fix becomes valid, the Kalman Filter estimation will propagate. Note that this step is not necessary if you have the auto-initialize option enabled:

	Ν	MIP Packet Header				ommand	/Reply Fields	Checksum		
	SYNC1 "u	SYNC2 "e"	Desc. Set	Payload Length	Field Length	Cmd. Desc.	Field Data	MSB	LSB	
<i>Command:</i> Poll for CF Euler	0x75	0x65	0x0C	0x07	0x07	0x01	Function: 0x00 Field Count: 0x00 Euler Desc: 0x06 Reserved: 0x00	0x02	0xFC	
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Cmd echo: 0x01 Error code: 0x00	0xE0	0xAC	
Reply Field 2: Data Packet	0x75	0x65	0x80	0x0E	0x0E	0x0C	Roll: 0xBAE3ED9B Pitch: 0x3C7D6DDF Yaw: 0xBF855CF5	0x41	0xBB	
Copy-Paste version of the command: "7565 0C07 0701 0001 0C00 0002 FC"										

Poll for current Complementary Filter Euler Angle output:

Initialize attitude:

	Ν	MIP Packet Header				mmand	/Reply Fields	Checksum		
	SYNC1 "u	SYNC2 "e"	Desc. Set	Payload Length	Field Length	Cmd. Desc.	Field Data	MSB	LSB	
<i>Command:</i> Initialize Attitude	0x75	0x65	0x0D	0x06	0x06	0x02	Roll: 0xBAE3ED9B Pitch: 0x3C7D6DDF Yaw: 0xBF855CF5	0xC4	0x09	
Reply : ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Cmd echo: 0x02 Error code: 0x00	0xE2	0xB4	
Copy-Paste version of the command: "7565 0D0E 0E02 BAE3 ED9B 3C7D 6DDF BF85 5CF5 C409"										



2.4.2 Polling Data Example Sequence

Polling for data is less efficient than processing a continuous data stream, but may be more appropriate for certain applications. The main difference from the continuous data example is the inclusion of the Poll data commands in the data loop:

- 1. Put the Device in Idle Mode (Disabling the data-streams) Same as continuous streaming (*see Put the Device in Idle Mode on page 15*).
- 2. Configure the IMU data-stream format Same as continuous streaming (*see Configure the IMU data-stream format on page 16*).
- 3. Configure the Estimation Filter data-stream format Same as continuous streaming (*see Configure the Estimation Filter data-stream format on page 17*).
- 4. Save the IMU and Estimation Filter MIP Message format Same as continuous streaming (*see Save the IMU and Estimation Filter MIP Message Format on page 18*).
- 5. Enable the IMU and Estimation Filter data-streams Same as continuous streaming (*see Enable the IMU and Estimation Filter Data-streams on page 19*).
- 6. Resume the Device Same as continuous streaming (*see Resume the Device (Optional) on page 20*).
- **7.** Initialize the Filter Same as continuous streaming (*see Initialize the Filter on page 21*).

Send Individual Data Polling Commands

Send individual Poll IMU Data and Poll Estimation Filter Data commands in your data collection loop. After the ACK/NACK is sent by the device, a single data packet will be sent according to the settings in the previous steps. Note that the ACK/NACK has the same descriptor set value as the command, but the data packet has the descriptor set value for the type of data (IMU or Estimation Filter):



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	Ν	MIP Packet Header				ommand	/Reply Fields	Checksum		
	SYNC1 "u	SYNC2 "e"	Desc. Set	Payload Length	vload Field Cmd. ngth Length Desc. Field Data		MSB	LSB		
Command: Poll IMU Data	0x75	0x65	0x0C	0x04	0x04	0x01	Option: 0x00 Desc Count: 0x00	0xEF	0xDA	
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Cmd echo: 0x01 Error code: 0x00	0xE0	0xAC	
IMU Data Packet Field 1: Gyro Vector	0x75	0x65	0x80	0x1C	0x0E	0x04	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x41	0xBB	
IMU Data Packet Field 2: Accel Vector					0x0E	0x03	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0xAD	0xDC	
Copy-Paste version of the command: "7565 0C04 0401 0000 FEDA"										

You may specify the format of the data packet on a per-polling-command basis rather than using the pre-set data format (see the Poll IMU Data and Poll Estimation Filter Data sections)

The polling command has an option to suppress the ACK/NACK in order to keep the incoming stream clear of anything except data packets. Set the option byte to 0x01 for this feature.



2.5 Parsing Incoming Packets

Setup is usually the easy part of programming the 3DM-CV5-25. Once you start continuous data streaming, parsing and processing the incoming data packet stream will become the primary focus. The stream of data from the IMU and Kalman Filter (Estimation Filter) are usually the dominant source of data since they come in the fastest. Polling for data may seem to be a logical solution to controlling the data flow, and this may be appropriate for some applications, but if your application requires the precise delivery of inertial data, it is often necessary to have the data stream drive the process rather than having the host try to control the data stream through polling.



The "descriptor set" qualifier in the MIP packet header is a feature that greatly aids the management of the incoming packet stream by making it easy to sort the packets into logical sub-streams and route those streams to appropriate handlers. The first step is to parse the incoming character stream into packets.

It is important to take an organized approach to parsing continuous data. The basic strategy is this: parse the incoming stream of characters for the packet starting sequence "ue" and then wait for the entire packet to come in based on the packet length byte which arrives after the "ue" and descriptor set byte. Make sure you have a timeout on your wait loop in case your stream is out of sync and the starting "ue" sequence winds up being a "ghost" sequence. If you timeout, restart the parsing with the first character after the ghost "ue". Once the stream is in sync, it is rare that you will hit a timeout unless you have an unreliable communications link. After verifying the checksum, examine the "descriptor set" field in the header of the packet. This tells you immediately how to handle the packet.

Based on the value of the descriptor set field in the packet header, pass the packet to either a command handler (if it is a Base command or 3DM command descriptor set) or a data handler (if it is an IMU, or Estimation Filter data set). Since you know beforehand that the IMU and Estimation Filter data packets will be coming in fastest, you can tune your code to buffer or handle these packets at a high priority. Replies to commands generally happen sequentially after a command so the incidence of these is under program control.

For multi-threaded applications, it is often useful to use queues to buffer packets bound for different packet handler threads. The depth of the queue can be tuned so that no packets are dropped while



waiting for their associated threads to process the packets in the queue. See Advanced Programming Models section for more information on this topic.

Once you have sorted the different packets and sent them to the proper packet handler, the packet handler may parse the packet payload fields and handle each of the fields as appropriate for the application. For simple applications, it is perfectly acceptable to have a single handler for all packet types. Likewise, it is perfectly acceptable for a single parser to handle both the packet type and the fields in the packet. The ability to sort the packets by type is just an option that simplifies the implementation of more sophisticated applications.

2.6 Multiple Rate Data

The message format commands (IMU Message Format and Estimation Filter Message Format) allow you to set different data rates for different data quantities. This is a very useful feature especially for IMU data because some data, such as accelerometer and gyroscope data, usually requires higher data rates (>100 Hz) than other IMU data such as Magnetometer (20 Hz typical) data. The ability to send data at different rates reduces the parsing load on the user program and decreases the bandwidth requirements of the communications channel. Multiple rate data is scheduled on a common sampling rate clock. This means that if there is more than one data rate scheduled, the schedules coincide periodically. For example, if you request Accelerometer data at 100 Hz and Magnetometer data at 50 Hz, the magnetometer schedule coincides with the Accelerometer schedule 50% of the time. When the schedules coincide, then the two data quantities are delivered in the same packet. In other words, in this example, you will receive data packets at 100 Hz and every packet will have an accelerometer data field and EVERY OTHER packet will also include a magnetometer data field:

Packet	Packet	Packet	Packet	Packet	Packet	Packet	Packet	
1	2	3	4	5	6	7	8	
Accel	Accel Mag	Accel	Accel Mag	Accel	Accel Mag	Accel	Accel Mag	Accel

If a timestamp is included at 100 Hz, then the timestamp will also be included in every packet in this example. It is important to note that *the data in a packet with a timestamp is always synchronous with the timestamp.* This assures that multiple rate data is always synchronous.

Packet 1	Packet 2	Packet 3	Packet 4	Packet 5	Packet 6	
Accel	Accel	Accel	Accel	Accel	Accel	Accel
Timestamp	Mag	Timestamp	Mag	Timestamp	Mag	
	Timestamp		Timestamp		Timestamp	



2.7 Data Synchronicity

Because the MIP packet allows multiple data fields to be in a single packet, it may be assumed that a single timestamp field in the packet applies to all the data in the packet. In other words, it may be assumed that all the data fields in the packet were sampled at the same time.

IMU and Estimation Filter data are generated independently by two systems with different clocks. The importance of time is different in each system and the data they produce. The IMU data requires precise microsecond resolution and perfectly regular intervals in its timestamps. The Kalman Filter resides on a separate processor and must derive its timing information from the two data sources.

The time base difference is one of the factors that necessitate separation of the IMU and Estimation Filter data into separate packets. Conversely, the common time base of the different data quantities within one system is what allows grouping multiple data quantities into a single packet with a common timestamp. In other words, IMU data is always grouped with a timestamp generated from the IMU time base, and estimation filter data is always grouped with a timestamp from the Estimation Filter time base, etc.

All data streams (IMU and Estimation Filter) on the 3DM-CV5-25 output a "GPS Time"-formatted timestamp. This allows a precise common time base for all data. Due to the differences in clocks on each device, the period between two consecutive timestamp values may not be constant; this occurs because periodic corrections are applied to the IMU and Estimation Filter timestamps when the GPS Time Update Command is applied.

2.8 Communications Bandwidth Management

Because of the large amount and variety of data that is available from the 3DM-CV5-25, it is quite easy to overdrive the bandwidth of the communications channel. This can result in dropped packets. The 3DM-CV5-25 does not do analysis of the bandwidth requirements for any given output data configuration, it will simply drop a packet if its internal serial buffer is being filled faster than it is being emptied. It is up to the programmer to analyze the size of the data packets requested and the available bandwidth of the communications channel. Often the best way to determine this is empirically by trying different settings and watching for dropped packets. Below are some guidelines on how to determine maximum bandwidth for your application.



2.8.1 UART Bandwidth Calculation

Below is an equation for the maximum theoretical UART baud rate for a given message configuration. Although it is possible to calculate the approximate bandwidth required for a given setup, there is no guarantee that the system can support that setup due to internal processing delays. The best approach is to try a setting based on an initial estimate and watch for dropped packets. If there are dropped packets, increase the baud rate, reduce the data rate, or decrease the size or number of packets.

$$n(k \times f_{mr}) + n \sum (S_f \times f_{dr})$$

Where:

 S_f = size of data field in bytes f_{dr} = field of data rate in Hz f_{mr} = maximum date rate in Hz n = size of UART word = 10 bits k = size of MIP wrapper = 6 bytes

which becomes:

$$60f_{mr} + 10\sum(S_f \times f_{dr})$$

Example:

For an IMU message format of Accelerometer Vector (14 byte data field) + Internal Timestamp (six byte data field), both at 100 Hz, the theoretical minimum baud rate would be:

 $= 60 \times 100 + 10((14 \times 100) + (6 \times 100))$ = 26000 BAUD

In practice, if you set the baud rate to 115200 the packets come through without any packet drops. If you set the baud rate to the next available lower rate of 19200, which is lower than the calculated minimum, you get regular packet drops. The only way to determine a packet drop is by observing a timestamp in sequential packets. The interval should not change from packet to packet. If it does change then packets were dropped.



2.8.2 USB vs. UART

The 3DM-CV5-25 has a dual communication interface: USB or UART. There is an important difference between USB and UART communication with regards to data bandwidth. The USB "virtual COM port" that the 3DM-CV5-25 implements runs at USB "full-speed" setting of 12Mbs (megabits per second). However, USB is a polled master-slave system and so the slave (3DM-CV5-25) can only communicate when polled by the master. This results in inconsistent data streaming - that is, the data comes in spurts rather than at a constant rate and, although rare, sometimes data can be dropped if the host processor fails to poll the USB device in a timely manner.

With the UART the opposite is true. The 3DM-CV5-25 operates without UART handshaking which means it streams data out at a very consistent rate without stopping. Since the host processor has no handshake method of pausing the stream, it must instead make sure that it can process the incoming packet stream non-stop without dropping packets.

In practice, USB and UART communications behave similarly on a Windows based PC, however, UART is the preferred communications system if consistent, deterministic communications timing behavior is required. USB is preferred if you require more data than is possible over the UART and you can tolerate the possibility of variable latency in the data delivery and very occasional packet drops due to host system delays in servicing the USB port.



3. Command and Data Summary

Below is a summary of the commands and data available in the programming interface. Commands and data are denoted by two values. The first value denotes the "descriptor set" that the command or data belongs to (Base command, 3DM command, IMU data,) and the second value denotes the unique command or data "descriptor" in that set. The pair of values constitutes a "full descriptor".

3.1 Commands

3.1.1 Base Command Set (0x01)

Ping	(0x01, 0x01)
Set to Idle	(0x01, 0x02)
Get Device Information	(0x01, 0x03)
Get Device Descriptor Sets	(0x01, 0x04)
Device Built-In Test (BIT)	(0x01, 0x05)
Resume	(0x01, 0x06)
Get Extended Device Descriptor Sets	(0x01, 0x07)
GPS Time Update	(0x01, 0x72)
Device Reset	(0x01, 0x7E)

3.1.2 3DM Command Set (0x0C)

Poll IMU Data	(0x0C, 0x01)
Poll Estimation Filter Data	(0x0C, 0x03)
Get IMU Data Rate Base	(0x0C, 0x06)
Get Estimation Filter Data Rate Base	(0x0C, 0x0B)
IMU Message Format	(0x0C, 0x08)
Estimation Filter Message Format	(0x0C, 0x0A)
Enable/Disable Device Continuous Data Stream	(0x0C, 0x11)
Device Startup Settings	(0x0C, 0x30)
Accel Bias	(0x0C, 0x37)
Gyro Bias	(0x0C, 0x38)
Capture Gyro Bias	(0x0C, 0x39)
Magnetometer Hard Iron Offset	(0x0C, 0x3A)
Magnetometer Soft Iron Matrix	(0x0C, 0x3B)
Coning and Sculling Enable	(0x0C, 0x3E)
Change UART Baud rate	(0x0C, 0x40)
Advanced Low-Pass Filter Settings	(0x0C, 0x50)
Complementary Filter Settings	(0x0C, 0x51)
Device Status*	(0x0C, 0x64)



3.1.3 Estimation Filter Command Set (0x0D)

Reset Filter	(0x0D, 0x01)
Set Initial Attitude	(0x0D, 0x02)
Set Initial Heading	(0x0D, 0x03)
Set Initial Heading with Magnetometer	(0x0D, 0x04)
Sensor to Vehicle Frame Transformation	(0x0D, 0x11)
Estimation Control Flags	(0x0D, 0x14)
Heading Update Control	(0x0D, 0x18)
External Heading Update	(0x0D, 0x17)
External Heading Update with Timestamp	(0x0D, 0x1F)
Set Reference Position	(0x0D, 0x26)
Pitch-Roll Aiding Control	(0x0D, 0x4B)
Auto-Initialization Control	(0x0D, 0x19)
Magnetometer Noise Standard Deviation	(0x0D, 0x42)
Gravity Noise Standard Deviation	(0x0D, 0x28)
Accelerometer Noise Standard Deviation	(0x0D, 0x1A)
Gyroscope Noise Standard Deviation	(0x0D, 0x1B)
Gyroscope Bias Model Parameters	(0x0D, 0x1D)
Hard Iron Offset Process Noise	(0x0D, 0x2B)
Soft Iron Matrix Process Noise	(0x0D, 0x2C)
Zero Angular Rate Update Control	(0x0D, 0x20)
Tare Orientation	(0x0D, 0x21)
Commanded Zero Angular Rate Update	(0x0D, 0x23)
Declination Source	(0x0D, 0x43)
Inclination Source	(0x0D, 0x4C)
Magnetic Field Magnitude Source	(0x0D, 0x4D)
Gravity Magnitude Error Adaptive Measurement	(0x0D, 0x44)
Magnetometer Magnitude Error Adaptive Measurement	(0x0D, 0x45)
Magnetometer Dip Angle Error Adaptive Measurement	(0x0D, 0x46)
Magnetometer Capture Auto Calibration	(0x0D, 0x27)

3.1.4 System Command Set (0x7F)

Communication Mode*

(0x7F, 0x10)

*Advanced commands

3.2 Data

3.2.1 IMU Data Set (0x08)

Scaled Accelerometer Vector Scaled Gyro Vector (0x80, 0x04) (0x80, 0x05)



Scaled Magnetometer Vector	(0x80, 0x06)
Scaled Ambient Pressure	(0x80, 0x17)
Delta Theta Vector	(0x80, 0x07)
Delta Velocity Vector	(0x80, 0x08)
CF Orientation Matrix	(0x80, 0x09)
CF Quaternion	(0x80, 0x0A)
CF Euler Angles	(0x80, 0x0C)
CF Stabilized Mag Vector (North)	(0x80, 0x10)
CF Stabilized Accel Vector (Up)	(0x80, 0x11)
GPS Correlation Timestamp	(0x80, 0x12)

3.2.2 Estimation Filter Data Set (0x82)

Filter Status	(0x82, 0x10)
GPS Timestamp	(0x82, 0x11)
Orientation, Quaternion	(0x82, 0x03)
Attitude Uncertainty, Quaternion Elements	(0x82, 0x12)
Orientation, Euler Angles	(0x82, 0x05)
Attitude Uncertainty, Euler Angles	(0x82, 0x0A)
Orientation, Matrix	(0x82, 0x04)
Compensated Angular Rate	(0x82, 0x0E)
Gyro Bias	(0x82, 0x06)
Gyro Bias Uncertainty	(0x82, 0x0B)
Compensated Linear Acceleration	(0x82, 0x1C)
Linear Acceleration	(0x82, 0x0D)
Pressure Altitude	(0x82, 0x21)
Gravity Vector	(0x82, 0x13)
WGS84 Local Gravity Magnitude	(0x82, 0x0F)
Heading Update Source State	(0x82, 0x14)
Magnetic Model Solution	(0x82, 0x15)
Mag Auto Hard Iron Offset	(0x82, 0x25)
Mag Auto Hard Iron Offset Uncertainty	(0x82, 0x28)
Mag Auto Soft Iron Matrix	(0x82, 0x26)
Mag Auto Soft Iron Matrix Uncertainty	(0x82, 0x29)



4. Command Reference

4.1 Base Commands

The Base command set is common to many LORD Sensing devices. With the Base command set it is possible to identify many properties and do basic functions on a device even if you do not recognize its specialized functionality or data. The commands work the same way on all devices that implement this set.

4.1.1 Ping (0x01, 0x01)

Description	Send "Ping" command													
Description	Device													
Field Format	Field Length Field Descriptor				Field Data									
Command	0x02 0x01				N/A									
Reply: ACK/ NACK	0x04		0xF1		U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)									
		MIP Pac	ket Hea	der	Command/Reply Fields Checksum									
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB					
Command: Ping	0x75	0x65	0x01	0x02	0x02	0x01		0xE0	0xC6					
Reply: ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Command echo: 0x01 Error code: 0x00	0xD5	0x6A					
Copy-Paste version of the command: "7565 0102 0201 E0C6"														



4.1.2 Set	To Idle	€ (0x01	, 0x	02)							
Place device into idle mode											
Description	Command has no parameters. Device responds with ACK if successfully placed in idle mode. This command will suspend streaming (if enabled) or wake the device from sleep (if sleeping) to allow it to respond to status and setup commands. You may restore the device mode by issuing the Resume command.										
Field Format	Field Length			Fie De	eld scriptor	Field Data					
Command	0x02			0x0)2	N/A					
Reply : ACK/ NACK	0x04			0xF	-1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)					
	MIP Packet Header					Command/Reply Fields Checksum				ksum	
Example	Sync1	Sync2	Des Se	sc. et	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command: Set to Idle	0x75	0x65	0x0	01	0x02	0x02	0x02		0xE1	0xC7	
Reply: ACK/NACK	0x75	0x65	0x0	01	0x04	0x04	0xF1	Command echo: 0x02 Error code: 0x00	0xD6	0x6C	
Copy-Paste version of the command: "7565 0102 0202 E1C7"											



4.1.3 Get	Devic	e Info	rmation	(0x0)1, 0	x03)							
Description	Get th	Get the device ID strings and firmware version.											
Field Format	Field L	ength	Field Descrip	Field Data									
Command	0x02		0x03		N/A	۱.							
Reply Field 1: ACK/ NACK	0x04		0xF1		U8- U8-	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)							
					Binary Offset		De	Description		Data Type	Uni	ts	
Reply Field 2:	0x52				0		Fir	rmware	version	U16	N/A	N/A	
Array of Descriptors			0x81		2		Model Name		String(16)	N/A	N/A		
					18		Model Number		String(16)	N/A	N/A		
					34		Se	erial Nu	mber	String(16)	N/A	N/A	
		MIP Pa	icket Hea	der			С	omman	d/Reply Fie	lds	Cheo	ksum	
Example	Sync1	Sync2	Desc. Set	Payl Len	oad gth	Field Length	,	Field Desc.	Field Data		MSB	LSB	
Command: Get Device Info	0x75	0x65	0x01	0x	02	0x02		0x03			0xE2	0xC8	
Reply Field 1: ACK/NACK	0x75	0x65	0x01	0x58		0x04		0xF1	Command echo: 0x03 Error code: 0x00				
Reply Field 2: Device Info Field						0x54 0>		0x81	FW Version: 0x05FE " 3DM-GX5-45" " 6232-4270" " 6232-00122" " 5g, 150d/s"		0x##	0x##	
Copy-Paste version	on of the	comma	and: "756	5 0102	0203	3 E2C8"	,						



4.1.4 Get Device Descriptor Sets (0x01, 0x04)													
	Get the set of descriptors that this device supports												
Description	Reply of 16 b descri	Reply has two fields: "ACK/NACK" and "Descriptors". The "Descriptors" field is an array of 16 bit values. The MSB specifies the descriptor set and the LSB specifies the descriptor.											
Field Format	Field Lo	ength		Field Descriptor			Field Data						
Command	0x02			0x	04		N/A						
Reply Field 1: ACK/ NACK	0x04				0xF1 U8 - echo the c U8 - error code			command byte e (0: ACK, non-zero: NACK)					
									Description Data Type		pe		
Reply Field 2: Array of Descriptors	2 x <ni< td=""><td>umber of</td><td colspan="3">0x82</td><td colspan="2">0</td><td colspan="2">Firmware version U16</td><td></td></ni<>	umber of	0x82			0		Firmware version U16					
	uescrip	10152 + 2			1		Model Name U16						
									etc				
F		MIP Pac	cket I	Hea	leader			command	/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	De: Se	sc. et	Payload Length	L	Field .ength	Field Desc.	Field Data	MSB	LSB		
Command: Get Device Info	0x75	0x65	0x(01	0x02		0x02	0x04		0xE3	0xC9		
Reply Field 1: ACK/NACK	0x75	0x65	0x(01	0x04		0x04	0xF1	Command echo: 0x01 Error code: 0x00				
Reply Field 2: Array of Descriptors							<n*2></n*2>	0x82	0x0101 0x0102 0x0103 0x0C01 0x0C02 nth descriptor: 0x0C72	0x##	0x##		
Copy-Paste version of the command: "7565 0102 0204 E3C9"													



4.1.5 Device Built-In Test (0x01, 0x05)

Run the device Built-In Test (BIT). The Built-In Test command always returns a 32 bit value. A value of 0 means that all tests passed. A non-zero value indicates that not all tests passed. The failure flags are device dependent. The flags for the 3DM-CV5-25 are defined below.

3DM-CV5-25 BIT Error Flags:

	By	te	Byte 1	l (LSB)		Byte	2	Byte 4 (MS	SB)			
	Dev	vice	Proces	sor Board	b	Sens	Sensor Board			er		
	Bit	1 (LSB)	WDT F Reset comma	Reset (Lat after first anded BIT	ching, ⁻)	IMU Com	municatio	n Fault	Solution Fault			
Description	Bit 2	2	Reserv	/ed		Magr (if ap	netometer plicable)	Fault	Reserved			
	Bit 3	3	Reserv	/ed		Press (if ap	sure Sens plicable)	or Fault	Reserved			
	Bit 4	4	Reserv	/ed		Rese	erved		Reserved			
	Bit	5	Reserv	ved		Rese	erved		Reserved			
	Bite	6	Reserv	ved		Rese	erved		Reserved			
	Bit	7	Reserv	ved		Reserved			Reserved			
	Bita	8 (MSB)	Reserv	ved		Reserved			Reserved			
Field Format	Field Le	ength	Field Descrij	otor	Field L	Field Data						
Command	0x02		0x05	0x05 N/.								
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - e U8 - e	echo the command byte error code (0: ACK, non-zero: NACK)						
Reply Field 2: Array of BIT Errors	0x06		0x83	0x83 U			J32 - BIT Error Flags					
		MIP Pac	ket Head	ket Header			mmand/R	eply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	sc. Payload et Length		-ield ength	Field Desc.	Field Data	MSB	LSB		
Command Built-In Test	0x75	0x65	0x01	0x02	C)x02	0x05	N/A	0xE4	0xCA		


Reply Field 1: ACK/NACK	0x75	0x65	0x01	0x0A	0x04	0xF1	Echo cmd: 0x05 Error code: 0x00		
Reply Field 2: BIT Error Flags					0x06	0x83	BIT Error Flags: 0x00000000	0x68	0x7D
Copy-Paste version of the command: "7565 0102 0205 E4CA"									



4.1.6 Res	sume ((0x01, 0	x06)								
Description	Place	device b Set To Id	ack i le co	nto i mm	the mode it v and was not	was in bef t issued, tl	ore issui hen the d	ng the Set To Idle com levice is placed in defa	imand. iult mod-			
	e.Com enable	nmand ha ed.	as no	par	ameters. De	evice resp	onds wit	h ACK if stream succe	essfully			
Field Format	Field Le	ength		Fie De	eld escriptor	Field Da	ta					
Command	0x02	0x02 0x06					N/A					
Reply: ACK/ NACK	0x04			0x	F1	U8 - ech U8 - erro	o the cor r code (0	nmand byte : ACK, non-zero: NAC	K)			
		MIP Pac	cket l	Hea	der	С	ommand	l/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Des Se	sc. et	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: Resume	0x75	0x65	0x(01	0x02	0x02	0x06		0xE5	0xCB		
Reply: ACK/NACK	0x75	0x65	0x(01	0x04	0x04	0xF1	Command echo: 0x01 Error code: 0x00	0xDA	0x74		
Copy-Paste versi	on of the	commar	nd: "7	7565	0102 0206	E5CB"						



4.1.7 Get	Exten	ded De	vice	e Do	escriptor	Se	ets (0)	‹01, 0 x	07)		
Description	Get the set ret Reply of 16 b descri	e extend urned by has two bit values ptor.	ed se the (fields . The	et of Get s: "A e MS	descriptors Device Des CK/NACK	s tha scrip " an s the	at this c ptors co d "Des e desco	device su command criptors". riptor set	pports (descriptors in) . The "Descriptors" fiel and the LSB specifies	addition d is an a the	to the
Notes	The G MIP p for ext Get De	et Device rotocol. E ended de evice De	e De Exter escrij <mark>scrip</mark>	scrip nded ptors ptor \$	otor Sets co descriptors by search Sets comm	omn s are ing and	nand is e only s for the l.	present supporte 0x0107 d	on all devices support d on some devices. Yo descriptor in the list ret	ing the ou may o urned by	check / the
Field Format	Field Le	ength		Fie De	eld escriptor		Field	Data			
Command	0x02			0x	07		N/A				
Reply Field 1: ACK/ NACK	0x04 0xF1						U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)				
Reply Field 2: Array of	2 x <number of<="" td=""><td colspan="2">0x86</td><td></td><td>Binary Offset 0</td><td></td><td>Description Firmware version</td><td>Data Ty U16</td><td>pe</td></number>			0x86			Binary Offset 0		Description Firmware version	Data Ty U16	pe
Descriptors	descrip	1015> + 2	ź				1		Model Name etc.	U16 	
		MIP Pac	ket ł	Head	der		C	ommand	l/Reply Fields	Chec	ksum
Example	Sync1	Sync2	De: Se	sc. et	Payload Length	L L	Field ength	Field Desc.	Field Data	MSB	LSB
Command: Get Device Info	0x75	0x65	0x(01	0x02		0x02	0x04		0xE6	0xCC
Reply Field 1: ACK/NACK	0x75	0x65	0x(01	0x04	(0x04	0xF1	Command echo: 0x01 Error code: 0x00		
Reply Field 2: Array of Descriptors				~	<n*2></n*2>	0x86	0x0D27 0x0D28 0x822B 0x822C nth descriptor: 0x0C72	0x##	0x##		
Copy-Paste versi	on of the	commar	nd: "7	7565	0102 0207	E60	CC"				



4.1.8 GP	S Time	Updat	e (0x0	1, 0x72)							
	This m	nessage	updates	the interna	II GPS Time	e as repo	rted in the Filter Times	tamp.			
	This correction receive Correla clock. GPS (ommand er. Wher ation Tim It is reco Correlatio	enables combin nestamp ommende on Times	s synchroni ed with a F in the inert ed that this tamp com	zation of IM PPS input a tial data out update com mand for m	IU/AHR pplied to put is sy mmand b ore inforr	S Timestamps with an pin 7 of the I/O connec nchronized with the ex re sent once per secon nation.	externa ctor, the ternal G d. See tl	I GPS GPS PS ne		
Description	Possil	ble functi	on selec	ctor values.	ŗ						
		0x01 - Apply new settings 0x02 - Read back current settings 0x06 - Apply new settings with no ACK/NACK reply Possible field selector values:									
	Possil	Possible field selector values: 0x01 - GPS Week Number									
		Possible field selector values: 0x01 - GPS Week Number 0x02 - GPS Seconds Field Field Field Field									
Field Format	Field Le	ength	Field Desc	criptor	Field Data						
Command	0x08 0x72				U8 - Func U8 - GPS U32 - Nev	tion Sele Time Fie v Time V	ctor eld Selector alue				
Reply: ACK/NACK	0x04		0xF1		U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)						
Reply Field 2 (function = 2, selector = 1)	0x06		0x84		U32 - Cur	rent GPS	Week Value				
Reply Field 2 (function = 2, selector = 2)	0x06		0x85		U32 - Cur	rent GPS	Seconds Value				
		MIP Pac	ket Hea	nder	C	Command	d/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: GPS Time Update	0x75 0x65 0x01 0x08				0x08	0x72	Fctn (Apply): 0x01 Field (Week): 0x00 Val: 0x00000698	0xFD	0x32		
Reply : ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Cmd echo: 0x72 Error code: 0x00	0x46	0x4C		



Copy-Paste version of the command: "7565 0108 0872 0101 0000 0698 FD32"



4.1.9 Dev	lce Ke	Set (UXI	J1, UX4	(E)							
	Reset	s the devi	ce.								
Description	Device	e respond	s with A	CK if it red	cognizes the	e comma	nd and then immediate	ely reset	S.		
Field Format	Field Le	ength	Field Desci	riptor	Field Data						
Command	0x02		0x7E		N/A						
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo the command byte U8 - Error code (0: ACK, non-zero: NACK)						
		MIP Pacl	ket Hea	der	C	ommand	I/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: Ping	0x75	0x65	0x01	0x02	0x02	0x7E		0x5D	0x43		
Reply Field 1: ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Command echo: 0x7E Error code: 0x00	0x52	0x64		
Copy-Paste version	on of the	command	d: "7565	0102 027	E 5D43"						



4.2 3DM Commands

The 3DM command set is common to the LORD Sensing Inertial sensors that support the MIP packet protocol. Because of the unified set of commands, it is easy to migrate code from one inertial sensor to another.

4.2.1 Pol	I IMU C)ata (0)	(0C, 0	x01)						
	Poll th	e device	for an II	MU messa	ge with the	specified	l format			
Description	This fu will ma descrip stored and the tains a packet	Inction po aintain the ptors are format (s ere is no n ACK/N t.	olls for a e order o ignored set with stored f IACK fie	an IMU mes of descripto I. If the form the Set IMI ormat, the o eld. The pol	sage using ors sent in t nat is not pu J Message device will lled data pa	g the prov he comm rovided, t e Format respond acket is s	vided format. The resul nand and any unrecogr he device will attempt command.) If no forma with a NACK. The repl ent separately as an If	ting mes nized to use th at is prov y packe MU Data	ssage ne ided t con-	
	Possit	ole Optior	n Select	or Values:						
		0x00 - 0x01 -	Normal Suppre	ACK/NAC ss the ACK	K Reply. /NACK re	ply.				
Field Format	Field Le	ength	Field Desc	criptor	Field Data					
Command	4 + 3*N		0x01		U8 - Optic U8 - Num N*(U8 - D	on Select ber of De escriptor	or escriptors (N) r, U16 Reserved)			
Reply: ACK/ NACK	0x04		0xF1		U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)					
		MIP Pacl	ket Hea	der	C	command	I/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command: Poll IMU data (use stored format)	0x75	Set Length 75 0x65 0x0C 0x04			0x04	0x01	Option: 0x00 Desc count: 0x00	0xEF	0xDA	
Command: Poll IMU data (use specified format)	0x75	0x65	0x0C	0x0A	0x0A	0x01	Option: 0x00 Desc count: 0x02 1st Descriptor: 0x04 Reserved: 0x0000 2nd Descriptor: 0x05 Reserved: 0x0000	0x06	0x27	



Reply: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Command echo: 0x01 Error code: 0x00	0xE0	0xAC	
Copy-Paste versi Stored format: "75 Specified format:	ons of the 565 0C04 "7565 0C	e comma 0401 00 00A 0A01	ands: 00 EFD 1 0002 0	A" 1400 0005 00	000 0627"					
4.2.2 Pol	l Estim	ation F	ilter D	eata (0x00	C, 0x03)					
Description	Poll th This fu ulting r cogniz use the format reply p an Est Possit	e device unction p message e descr e stored is provic backet co imation f ble Option 0x00 - 0x01 -	for an E olls for a will ma iptors a format (ded and ontains a Filter Da n Select Normal Suppre	Estimation F an Estimation intain the o are ignored. set with the there is no an ACK/NA ata packet. tor Values: I ACK/NAC ass the ACK	Tilter mess on Filter me rder of des If the form Set Estim Stored form CK field. T K Reply.	age with essage u criptors s at is not p lation Filt nat, the d The pollec	the specified format sing the provided format ent in the command ar provided, the device wil er Message Format co evice will respond with data packet is sent se	at. The rund any un and any un mmand. a NACI eparately	es- nre- it to) If no (. The r as	
Field Format	Field Le	ength	Field Desc	l criptor	Field Dat	а				
Command	4 + 3*N	I	0x03		U8 - Option Selector U8 - Number of Descriptors (N) N*(U8 - Descriptor, U16 Reserved)					
Reply: ACK/ NACK	0x04		0xF1		U8 - echo U8 - error	the com code (0:	mand byte ACK, non-zero: NACK	()		
		MIP Pa	cket He	ader		Commar	d/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command: Poll IMU data (use stored format)	0x75	0x65	0x0C	0x04	0x04	0x03	Option: 0x00 Desc count: 0x00	0xF1	0xE0	
Command: Poll IMU data (use specified format)	0x75	0x750x650x0C0x040x040x03Option: 0x00 Desc count: 0x000xF10x750x650x0C0x0A0x0A0x0A0x03Option: 0x00 Desc count: 0x02 1st Desc riptor: 0x01 Reserved: 0x0000 2nd Descriptor: 0x02 Reserved: 0x00000xF1								



if ACK)	Reply: ACK/NACK (Data packet is 0x sent separately if ACK))x75	0x65	0x0C	0x04	0x04	0xF1	Command echo: 0x03 Error code: 0x00	0xE2	0xB0
---------	--	------	------	------	------	------	------	--	------	------

Copy-Paste versions of the commands:

Stored format: "7565 0C04 0403 0000 F1E0"

Specified format: "7565 0C0A 0A03 0002 0100 0002 0000 021E"

4.2.3 Get IMU Data Base Rate (0x0C, 0x06)

Description	Get the Return mand.	e base rat Is the valu	e for the	e IMU data for data ra	a in Hz. ate calculations. See the IMU Message Format com-						
Field Format	Field Le	ength	Field Desc	criptor	Field Dat	a					
Command	0x02		0x06		None						
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)						
Reply Field 2: IMU Base Rate	0x04 0x83				U16 - IMI	J data ba	se rate (Hz)				
	ſ	MIP Packet Header				Command	/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: Get IMU Base Rate	0x75	0x65	0x0C	0x02	0x02	0x06		0xF0	0xF7		
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x08	0x04	0xF1	Command echo: 0x06 Error code: 0x00				
Reply Field 2: IMU Base Rate					0x04	0x83	Base rate (Hz): 0x0x0064	0xD4	0x6B		
Copy-Paste versi	on of the	comman	d: "7565	5 0C02 020	06 F0F7"						



4.2.4 Get	Estim	ation Fi	ilter D	ata Base	Rate (0)	x0C, 0x	(0B)		
	Get the	e base ra	te for th	e Estimatio	on Filter dat	a in Hz.			
Description	Returr Forma	is the val t comma	ue usec nd.	l for data ra	te calculati	ons. See	the Estimation Filter N	Aessage	9
Field Format	Field Le	ength	Field Desc	criptor	Field Data	а			
Command	0x02		0x0B	5	None				
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Error	the com code (0:	mand byte ACK, non-zero: NACł	<)	
Reply Field 2: IMU Base Rate	0x04 0x8A				U16-Est	imation F	ilter data base rate (Hz	<u>z</u>)	
		MIP Pac	ket Hea	lder	С	Command	I/Reply Fields	Chec	ksum
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command: Get IMU Base Rate	0x75	0x65	0x0C	0x02	0x02	0x0B		0xF5	0xFC
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x08	0x04	0xF1	Command echo: 0x0B Error code: 0x00		
Reply Field 2: Estimation Filter Base Rate					0x04	0x8A	Base rate (Hz): 0x0x0064	0xE0	0x9E
Copy-Paste versi	on of the	comman	d: "756	5 0C02 020	B F5FC"				



4.2.5 IMU	J Mes	sage F	orma	: (0x0C, 0	x08)				
	Set, r for the tain the and a	read, or s e IMU da ne order descrip	save the ata pacl of desc tor arra	e format of th ket when in s riptors sent y as parame	ne IMU me standard n in the com ters.	essage node. Tl 1mand. ⁻	packet. This command sets he resulting data messages The command has a functic	the for will ma	mat ain- ctor
	Poss	ible Fun	ction Se	elector Value	es:				
Description	The ra You s for co	0x01 0x02 0x03 0x04 0x05 ate decir Rate should al	- Use r - Read - Save - Load - Rese mation f - Rese mation f - Rese	hew settings back current current sett saved startu t to factory of field is calcu ation = IMU etrieve the B sired rate de	nt settings ings as sta up settings default set lated as fo Base Rate cimation.	artup se tings bllows fo e / Desi from the Base ra	ettings or IMU messages: ired Data Rate e Get IMU Data Base Rate tes vary from device to dev	comma ice. The	ind e
	The d the de sage tion s Desc	levice ch escriptor format v elector i riptors =	necks the rs are in vill be u s = 1 (L : 0).	nat all descrivation valid for the nchanged. T	s 500. ptors are v IMU desc he descrip ings). For	valid prie riptor se otor arra all othe	or to executing this comman et, a NACK will be returned by only needs to be provided r functions it may be empty	nd. If ar and the l if the f (Numb	ny of e mes- unc- er of
Field Format	Field L	ength	Fie Des	ld scriptor	Field Da	ta			
Command	4 + 3*1	N	0x0	8	U8 - Fun U8 - Nun N*(U8 - [ction Se nber of I Descript	elector Descriptors (N) tor, U16 - Rate Decimation)		
Reply Field 1: ACK/ NACK	0x04		0xF	-1	U8 - ech U8 - erro	o the co r code ((mmand byte 0: ACK, non-zero: NACK)		
Reply Field 2 : Function = 2	3 + 3*1	N	0x8	0	U8 - Nun N*(U8 - [nber of [Descript	Descriptors (N) tor, U16 - Rate Decimation)		
		MIP Pa	icket H	eader		Comm	nand/Reply Fields	Chec	ksum
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command: IMU Message	0x75	0x65	0x0C	0x0A	0x0A	0x08	Function: 0x01 Desc count: 0x02	0x22	0xA0



Format (use new settings)							1st Descriptor: 0x04 Rate Dec: 0x000A 2nd Descriptor: 0x05 Rate Dec: 0x000A		
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x01 Error code: 0x00	0xE7	0xBA
Command: IMU Message Format (read back cur- rent settings)	0x75	0x65	0x0C	0x04	0x04	0x08	Function: 0x02 Desc count: 0x00	0xF8	0xF3
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x0D	0x04	0xF1	Echo cmd: 0x08 Error code: 0x00		
Reply Field 2 : Current IMU Message Format					0x09	0x80	Desc count: 0x02 1st Descriptor: 0x03 Rate Dec: 0x000A 2nd Descriptor: 0x04 Rate Dec: 0x000A	0x98	0x0F
Copy-Paste version	on of the	e comma	ands:						

Use New Settings:"7565 0C0A 0A08 0102 0400 0A05 000A 22A0" Read Current Settings: "7565 0C04 0408 0200 F8F3"



4.2.6 Est	imatio	on Filte	er M	less	sage Forr	nat	(0x0C	, 0x0/	A)				
	Set, r the fo sage tion s	read, or ormat fo will ma selector	save or the intair and a	e the Est n the a de	e format of th imation Filte order of de escriptor arra	ne E er da scrij ay as	stimatio ata packo ptors sen s parame	n Filter et wher nt in the eters.	message packet. This fund in standard mode. The re e command. The comman	nction s esulting d has a	ets mes- func-		
Description	Poss Poss The r You s comr devic The c the de return provid empt	Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings 0x05 - Reset to factory default settings The rate decimation field is calculated as follows for Estimation Filter messages: Rate Decimation = EF Base Rate / Desired Data Rate You should always retrieve the Base Rate from the Get Estimation Filter Data Base Rate command for computing the desired rate decimation. Base rates vary from device to device. The EF base rate for the 3DM-CV5 is 500. The device checks that all descriptors are valid prior to executing this command. If any of the descriptors are invalid for the Estimation Filter data descriptor set, a NACK will be returned and the message format will be unchanged. The descriptor array only needs to be provided if the function selector is = 1 (Use new settings). For all other functions it may be empty (Number of Descriptors = 0).											
Field Format	Field I	Length		Fiel Des	ld scriptor	Fie	eld Data						
Command	4 + 3*	N		0x0	A	U8 U8 N*	8 - Functi 8 - Numb (U8 - De	on Sele er of De scripto	ector escriptors (N) r, U16 - Rate Decimation))			
Reply Field 1: ACK/ NACK	0x04			0xF	1	U8 U8	3 - echo t 3 - error c	he corr ode (0:	nmand descriptor ACK, non-zero: NACK)				
Reply Field 2: Function = 2	3 + 3*	N		0x8	2	U8 - Number of Descriptors (N) N*(U8 - Descriptor, U16 - Rate Decimation)							
_		MIP	Pack	ket H	leader	Command/Reply Fields			nand/Reply Fields	Chec	ksum		
Examples	Sync1	Sync2	Deso Set	SC. et	Payload Leng	gth	Field Length	Field Desc.	Field Data	MSB	LSB		
Command:	0x75	0x65	0x0	c	0x0A		0x0A	0x0A	Function: 0x01	0x0C	0x6A		



Estimation Filter Message Format (use new settings)							Desc count: 0x02 1st Descriptor: 0x01 Data Rate: 0x0001 2nd Descriptor: 0x02 Data Rate: 0x0001		
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x0A Error code: 0x00	0xE9	0xBE
Command: Estimation Filter Message Format (read back current settings)	0x75	0x65	0x0C	0x04	0x04	0x0A	Function: 0x02 Desc count: 0x00	0xFA	0xF9
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x0D	0x04	0xF1	Echo cmd: 0x0A Error code: 0x00		
Reply Field 2 : Current Message Format					0x09	0x82	Desc count: 0x02 1st Descriptor: 0x01 Data Rate: 0x0001 2nd Descriptor: 0x02 Data Rate: 0x0001	0x84	0xED
Copy-Paste versio Use New Settings	on of the 3: "7565	э сотт 0С0А (nands: 0A09 0 ⁻	102 0300 0405 00	04 1685	11			

Read Current Settings: "7565 0C04 0409 0200 F9F6"



4.2.7 Ena	able/Dis	/Disable Continuous Data Stream (0x0C, 0x11)											
	Contro selecte be tran enable ignored	I the stre ed device Ismitted Id. For all d.	eaming c e is not c (i.e. no s functio	of IMU and continuous stale data is ns except (Estimatior ly transmit s transmitte Dx01 (use r	n Filter da ted. Upor ed.) The o new settir	ta. If disabled, the data n enabling, the most cu default for the device is ng), the new enable flag	a from th urrent da s all stre g value i	ne ta will ams s				
	Possib	ole functio	on selec	ctor values:	:								
		0x01-	Apply n	ew setting	S								
Description		0x02 - 0x03 -	Save c	ack current urrent settii	ngs as star	tup settir	ngs						
Decemption		0x04 - 0x05 -	Load sa	aved startu	p settings Ilt settings								
	The de	evice sele	ector ca	n be:									
		0x01 - IMU 0x03 - Estimation Filter											
		0x03 - Estimation Filter											
	The en	he enable flag can be either:											
		0x00 - Disable the selected stream 0x01 - Enable the selected stream <i>(default)</i>											
Field Format	Field Le	ength	Field Desc	criptor	Field Dat	а							
Command	0x05		0x11		U8 - Function Selector U8 - Device Selector U8 - New Enable Flag								
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Erroi	o the com r code (0:	mand descriptor ACK, non-zero: NAC	K)					
Reply Field 2: (function = 2)	0x04		0x85		U8 - Devi U8 - Curr	ice Selec ent Devid	tor ce Enable Flag						
	I	MIP Pac	ket Hea	der	С	command	I/Reply Fields	Chec	ksum				
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB				
Command: IMU Stream ON	0x75	0x65	0x0C	0x05	0x05	0x11	Function (Apply): 0x01 Device (IMU): 0x01 Stream (ON): 0x01	0x04	0x1A				
Command: IMU Stream	0x75	0x65	0x0C	0x05	0x05	0x11	Function (Apply): 0x01 Device (IMU): 0x01	0x03	0x19				



OFF							Stream (OFF): 0x00				
Reply: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x11 Error code: 0x00	0xF0	0xCC		
Copy-Paste version	Copy-Paste version of the 1st command: "7565 0C05 0511 0101 0104 1A"										

4.2.8 Dev	vice Sta	artup Se	ettings	s (0x0C,	0x30)								
	Read,	Save, Lo	ad, or F	Reset to De	fault the va	lues for a	Il device settings.						
	Possib	ole functio	on selec	ctor values:									
Description		0x03-	Save ci	urrent settir	ngs as starl	up settin	gs**						
		0x04 - 0x05 -	Load sa Reset t	o factory d	p settings efault settir	ngs							
Notes	**Whe all sett	n a save Fings are t	current written	settings co to non-vola	ommand is tile memory	issued a l /.	brief data disturbance	тау осс	sur as				
Field Format	Field Le	d Length Field Field Data											
Command	0x03		0x30		U8 - Func	tion selec	ctor						
Reply: ACK/ NACK	0x04		0xF1		U8 - echo U8 - error	the comr code (0: /	nand byte ACK, non-zero: NACK	()					
		MIP Pacl	ket Hea	lder	C	command	/Reply Fields	Chec	ksum				
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB				
Command: Save All	0x75	x75 0x65 0x0C 0x03 0x03 0x30 Fctn (Save): 0x03 0x1F 0x45											
Reply: ACK/NACK	0x75 0x65 0x0C 0x04 0x04 0xF1 Echo cmd: 0x30 Error code: 0x00 0x0F 0x0A												
Copy-Paste versi	on of the	comman	d: "756	5 0C03 033	0 031F 45"			•					



4.2.9 Acc	el Bias	(0x0C	, 0x37) Adı	vanced						
	Set the functic bias va	e value, c ons excep alue is su	or read t ot 0x01 Ibtracte	he current and 0x06 (a d from the	value of th apply new scaled ace	ne IMU7 settings celerome	Accelerometer Bias Vec s), the new vector value is eter value prior to output.	tor. For a s ignored	all 1. The		
	Possit	ole functio	on seleo Anniv r	ctor values	:						
Description		0x02-	Read b	ack curren	t settings						
		0x03-	Save c	urrent setti	ngs as sta	artup set	tings				
		0x04 -	Load sa	aved startu	p settings	;					
		0x05 - 0x06 -	Load ta Apply r	ctory detai	uit setting: s with no	S ACK/NA	CK reply				
Field Format	Field Le	ength	Field Desc	criptor	Field Da	ata					
Command	0x0F		0x37		U8 - Fur float - X float - Y float - Z	Accel B Accel B Accel B Accel B	lector as Value as Value as Value				
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - ech U8 - erro	no the co or code ((mmand byte): ACK, non-zero: NACK	.)			
Reply Field 2: Function = 2	0x0E		0x9A	N.	float - C float - C float - C	urrent X urrent Y urrent Z	Accel Bias Value Accel Bias Value Accel Bias Value				
	ľ	MIP Pack	ket Hea	der		Comma	nd/Reply Fields	Chec	ksum		
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: Accel Bias	0x75	0x65	0x0C	0x0F	0x0F	0x37	Fctn (Apply): 0x01 Field (Bias): 0x00000000 0x00000000 0x00000000	0x3C	0x75		
Reply Field : ACK/NACK 0x75 0x65 0x0C 0x04 0x04 0xF1 Echo cmd: 0x37 Error code: 0x00 0x16 0x18											
Copy-Paste versi	on of the	comman	d: "756	5 0C0F 0F	37 0100 0	000 0000	0000 0000 0000 003C 7	5"			



4.2.10 Gy	yro Bia	s (0x00	C, 0x3	8) Ac	lvanced							
Description	Set the except value i Possit	e value, c t 0x01 an s subtrac ole functi 0x01 - 0x02 - 0x03 - 0x04 - 0x05 - 0x06 -	or read t ad 0x06 cted from on select Apply r Read b Save c Load sa Load fa Apply r	he current (apply new m the scale ctor values new setting pack curren urrent setti aved startu actory defan	value of the settings) ed Gyro va : s t settings ngs as sta up settings ult settings s with no	artup set	Gyro Bias Vector. For all v vector value is ignored. to output. tings	functior The bias	15 5			
Field Format	Field Le	ength	Field Desc	l criptor	Field Da	ata						
Command	0x0F		0x38	3	U8 - Function selector float - X Gyro Bias Value float - Y Gyro Bias Value float - Z Gyro Bias Value							
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - ech U8 - erro	no the co or code ((mmand byte 0: ACK, non-zero: NACK	()				
Reply Field 2: Function = 2	0x0E		0x9E	3	float - C float - C float - C	urrent X urrent Y urrent Z	Gyro Bias Value Gyro Bias Value Gyro Bias Value					
	٦	MIP Pack	ket Hea	der		Commai	nd/Reply Fields	Chec	ksum			
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command: Gyro Bias	0x75 0x65 0x0C 0x0F 0x0F 0x38 Fctn (Apply): 0x01 Field (Bias): 0x00000000 0x000000000 0x3D 0x83											
Reply Field : ACK/NACK 0x75 0x65 0x0C 0x04 0x04 0xF1 Echo cmd: 0x38 Error code: 0x00 0x17 0x1A												
Copy-Paste versi	on of the	comman	nd: "756	5 0C0F 0F	38 0100 00	000 0000	0000 0000 0000 003D 8	3"				



4.2.11	Ca	aptu	re Gyr	o Bia	as	(0x0C, 0	x3	9)				
Description		Th of its Bia ve Pc	iis comm millisecc gyro bia as vector ctor, use ossible sa Tc Ra	and v onds. s erro r. The the C amplin otal sa ange o	vill The or. T bia Gyrc ng t amp of v	cause the 3 e resulting of The estimat as vector is o Bias com time values oling time ir values: 1000	3DN data ed no ma ma o to	Л-CV5- a will be gyro bia t saved nd. its of m o 3000.	25 to san e used to as error w I as a star hillisecon	nple its sensors for the spec initialize its orientation, and <i>r</i> ill be automatically written t rtup value. If you wish to sa ds.	cified nui to estim to the Gy ve this	mber nate /ro
Notes		No op	ote: The 3 eration.	3DM-(CV	′5-25 must	bes	stationa	ary during	the execution of the Captu	re Gyro I	Bias
Field Format		Fie	ld Length	ו	Fi D	ïeld Descriptor		Field	Data			
Command		0x0)4		0>	x39		U16-	Sampling	g Time (milliseconds)		
Reply Field 1: ACK/ NACK		0x0)4		0>	xF1		U8-e U8-e	cho the c rror code	command byte (0: ACK, non-zero: NACK)		
Reply Field 2: Function = 2		0x0)E		0>	x9B		float - float - float -	Current Curren	X Gyro Bias Value Y Gyro Bias Value Z Gyro Bias Value		
			MIP Pac	ket H	ead	der			Comma	and/Reply Fields	Check	ksum
Examples	Sy	nc1	Sync2	Dese Sei	c. t	Payload Length	L	Field ength	Field Desc.	Field Data	MSB	LSB
Command: Capture Gyro Bias	0>	c75	0x65	0x0	с	0x04		0x04	0x39	Sampling Time: 0x2710	0x5E	0xE0
Reply Field 1: ACK/NACK	0>	‹ 75	0x65	0x0	с	0x04		0x04	0xF1	Echo cmd: 0x39 Error code: 0x00		
Reply Field 2: Bias Vector							(0x0E	0x9B	Field (Bias): 0x00000000 0x00000000 0x00000000	0xCF	0x19
Copy-Paste v	ersi	on of	the com	mana	1: "2	7565 0C04	043	39 2710) 5EE0"			



4.2.12 M	agneto	meter H	lard I	ron Offse	set (0x0C, 0x3A)						
	This c	ommand	will rea	d or write v	alues to t	he magn	etometer Hard Iron Offse	t Vector	·.		
	For all ignore	l function d. The off	s excep set val	ot 0x01 and ue is subtra	l 0x06 (ap acted from	ply new the sca	settings), the new vector led Mag value prior to out	value is tput.			
	The va based can be atively offset	alues for t on calibra obtained , the auto is applied	his offs ation da I and se p-mag c I to the	et are dete ata taken af at by using alibration f scaled mag	ermined er fter the de the LORD eature ma gnetomete	mpirically wice is ir) "MIP In ay be use er vector	v by external software alg installed in its application. on Calibration" application ed to capture these values prior to output.	orithms These v n. Altern s in-run.	values - The		
Description	Possit	ble functio 0x01 - 0x02 - 0x03 - 0x04 - 0x05 - 0x06 -	on selec Apply r Read b Save c Load sa Load fa Apply r	ctor values new setting ack curren urrent setti aved startu ctory defan new setting	: t settings ngs as sta p settings ult setting s with no	artup set s s ACK/NA	tings ACK reply				
	Defau	efault values:									
		Hard Iron Offset: [0,0,0]									
Field Format	Field Le	ength	Field Desc	ı criptor	Field Da	ata					
Command	0x0F		0x3A	A.	U8 - Function selector float - X Hard Iron Offset float - Y Hard Iron Offset float - Z Hard Iron Offset						
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - ech U8 - erro	no the co or code (mmand byte 0: ACK, non-zero: NACK	()			
Reply Field 2: Function = 2	0x0E	Dx0E 0x9C				urrent X urrent Y urrent Z	Hard Iron Offset Hard Iron Offset Hard Iron Offset				
	1	MIP Pack	et Hea	der	Command/Reply Fields Chee				ksum		
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: Hard Iron Offset	0x75	x75 0x65 0x0C 0x0F			0x0F	0x3A	Fctn (Apply): 0x01 Offset Vector: 0x0000000 0x00000000 0x00000000	0x3F	0x9F		



Reply Field : ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x3A Error code: 0x00	0x19	0x1E
Copy-Paste version	on of the	comman	nd: "756	5 0C0F 0F3	3A 0100 0	000 000	0 0000 0000 0000 003F 9	F"	



4.2.13 Ma	agneto	etometer Soft Iron Matrix (0x0C, 0x3B)										
	This co rix.	ommand	will read	d or write v	alues to t	he magr	netometer Soft Iron Comp	ensatior	n Mat-			
	The va based can be atively matrix	lues for t on calibra obtained , the auto is applie	his mat ation da l and se o-mag c d to the	rix are dete ta taken a t by using alibration f scaled ma	ermined e fter the de the LORI eature ma agnetome	empirical evice is i D "MIP Ir ay be use ter vecto	ly by external software al nstalled in its application. on Calibration" applicatio ed to capture these value or prior to output	gorithms These v n. Altern s in-run.	; /alues - The			
Description	Possib	ole functio 0x01 -	on selec Apply n Read b	ctor values new setting	: JS							
		0x02 -	Save c	urrent setti	ings as st	artup se	ttings					
		0x04 -	Load sa	aved startu	p setting	5						
		0x05 - 0x06 -	Load fa Apply n	ctory defai	ult setting is with no	IS ACK/N	ACK reply					
	Defaul	fault values:										
	Delau	fault values: Soft Iron Compensation Matrix: (identity matrix; row order):										
		Soft Iron Compensation Matrix: (identity matrix; row order): [1,0,0][0,1,0][0,0,1]										
Field Format	Field Le	ength	Field Desc	criptor	Field D	ata						
Command	0x27		0x3B	i	U8 - Function selector float - $m_{1,1}$ float - $m_{1,2}$ float - $m_{1,3}$ float - $m_{2,1}$ float - $m_{2,2}$ float - $m_{2,3}$ float - $m_{3,1}$ float - $m_{3,2}$ float - $m_{3,3}$							
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - ecl U8 - err	ho the co or code (ommand descriptor (0: ACK, non-zero: NACk	()				
Reply Field 2: Function = 2	0x26		0x9D)	float - m float - m float - m	n _{1,1} float n _{2,1} float n _{3,1} float	- m _{1,2} float - m _{1,3} - m _{2,2} float - m _{2,3} - m _{3,2} float - m _{3,3}					
	Ν	/IP Pack	et Head	der		Comma	nd/Reply Fields	Chec	ksum			
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command: Soft Iron Matrix	0x75	0x65	0x0C	0x27	0x27	0x3B	Fctn (Apply): 0x01 Comp Matrix: 0x3F800000 0x00000000 0x00000000 0x00000000	0xAD	0x59			



							0x3F800000 0x00000000 0x00000000 0x00000000 0x3F800000		
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x12	0x04	0xF1	Echo cmd: 0x3B Error code: 0x00	0x1A	0x20



4.2.14 Coning and Sculling Enable (0x0C, 0x3E)											
	Set, re Coning ting), t	ead, or sa g and Sc he new p	ave the ulling C paramet	Coning ar ompensa er values	nd Sculling (ition Enable are ignored	Compens . For all f	sation Enable. This funct unctions except 0x01 (us	ion sets se new s	the et-		
Description	Possil	Possible function selector values: 0x01 - Apply new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Load factory default settings The enable flag can be either: 0x00 - Disable the Coning and Sculling compensation 0x01 - Enable the Coning and Sculling compensation (default)									
Field Format	Field Length Field Field Data										
Command	0x10		0x3E		U8 - Funct U8 - New (ion selec Coning a	tor nd Sculling enable settin	g			
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - echo 1 U8 - error d	the comr code (0: <i>I</i>	nand descriptor ACK, non-zero: NACK)				
Reply Field 2: Function = 2	0x03		0x9E		U8 - Curre	nt Conin	g and Sculling enable set	ting			
	I	MIP Pac	ket Hea	der		Commar	nd/Reply Fields	Chec	ksum		
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command: Enable Settings	0x75	0x65	0x0C	0x04	0x04	0x3E	Fctn (Apply): 0x01 Enable: 0x01	0x2E	0x94		
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x38 Error code: 0x00	0x1D	0x26		
Copy-Paste versi	Copy-Paste version of the command: "7565 0C04 043E 0101 2E94"										



4.2.15 UA	ART Ba	aud Ra	ite (C	x0C, 0x4(0)					
	Chang functio	ge, read, ons exce	or sa ept 0x	ve the baud)1 (use new	rate of the settings)	e main c , the nev	ommunication channel (UA w baud rate value is ignored	RT1). F	or all	
Description	Possil	Possible function selector values: 0x01 - Apply new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Supported baud rates are: 9600, 19200, 115200 (default), 230400, 460800, 921600								
Notes	A secon	The ACK/NACK packet is sent at the current baud rate and then there is a 0.25 second delay before the device will respond to commands at the new BAUD rate.								
Field Format	Field L	ength	Fi D	eld escriptor	Field L	Data				
Command	0x07		0×	40	U8 - F U8 - N	U8 - Function selector U8 - New baud rate				
Reply Field 1: ACK/ NACK	0x04		0×	F1	U8 - E U8 - E	cho the rror code	command descriptor e (0: ACK, non-zero: NACK	.)		
Reply Field 2: Function = 2	0x06		0х	87	U8 - C	urrent b	aud rate			
	Ν	/IP Pac	ket He	eader		Comm	and/Reply Fields	Chec	ksum	
Examples	Sync1	Sync2	Desc Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command: Set Baud Rate	0x75	0x65	0x0C	0x07	0x07	0x40	Fctn (USE): 0x01 Baud (115200): 0x0001C200	0xF8	0xDA	
Reply Field : ACK/NACK	Reply Field : ACK/NACK 0x75 0x65 0x0C 0x04 0x04 0xF1 Echo cmd: 0x40 Error code: 0x00 0x1F 0x2A									
Copy-Paste versi	on of the	comma	nd: "7	565 0C07 07	740 0100	01C2 00	PF8 DA"			



4.2.16 Ac	vanced Low-Pass Filter Settings (0x0C, 0x50)									
	Advanced configuration for low-pass filter settings.									
	The scaled data quantities are by default filtered through a single-pole IIR low-pass filter which is configured with a -3dB cutoff frequency of half the reporting frequency (set by decimation factor in the IMU Message Format command) to prevent aliasing on a per data quantity basis. This advanced configuration command allows for the cutoff frequency to be configured independently of the data reporting frequency as well as allowing for a complete bypass of the digital low-pass filter.									
	Possible function selector values:									
	0x01 - Apply new settings									
	0x02 - Read back current settings									
	0x04 Load saved startup settings									
	0x05 - Reset to factory default settings									
	Possible data descriptors:									
	0x04 - Scaled accel data									
D	0x05 - Scaled gyro data									
Description	0x06 - Scaled mag data (if applicable)									
	0x17 - Scaled pressure data									
	Possible filter enable values:									
	0x01 - Apply low-pass filter									
	0x00 - Do not apply low-pass filter									
	Manual filter bandwidth configuration:									
	0x01 - Use user specified -3 dB cutoff frequency 0x00 - Automatically configure -3 dB cutoff frequency to half reporting rate									
	-3 dB Cutoff Frequency:									
	Cutoff Frequency value specified must be no greater than 250 Hz.									
	**This value in a write command is ignored if Automatic Bandwidth is									
	selected.									
	Reserved Byte:									
	This byte is reserved for internal use and should be left in the $0x00$ state									
Field Format	Field Length Field Field Data									



Command	0x09		0x50		U8 U8 U8 U8 U1 U8	U8 - Function selector U8 - Data Descriptor U8 - Low-Pass Filter Enable/Disable U8 - Manual/Auto -3 dB Cutoff Frequency Configuration U163 dB Cutoff Frequency U8 - Reserved Byte						
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 U8	U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)						
Reply Field 2: Function = 2	0x08		0x8B		U8 U8 U8 U1 U8	18 - Data Descriptor 18 - Filter (0x01: Enabled, 0x00: Disabled) 18 - Cutoff Frequency (0x00: Auto, 0x01: Manual) 1163 dB Cutoff Frequency Hz 18 - Reserved						
	I	MIP Pa	cket Hea	der			Commai	nd/Reply Fields	Chec	ksum		
Examples	Sync1	Sync2	Desc. Set	Paylo Leng	ad ith	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	0x65	0x0C	0x0	9	0x09	0x50	Fctn (Apply): 0x01 Scaled Accel: 0x04 Enable Filter: 0x01 Automatic Cutoff Oconfiguration: -3dB Cutoff Frequency (ignored for 0x0000 automatic cutoff configuration) Reserved: 0x00	0x4C	0x6D		
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x0	4	0x04	0xF1	Echo cmd: 0x50 Error code: 0x00	0x2F	0x4A		
Copy-Paste versi	Copy-Paste version of the command: "7565 0C09 0950 0104 0100 0000 004E 80"											



4.2.17 Co	omplementary	Filter Settin	ngs (0x0C, 0x51)								
	Configuration for are supported in GX3.	Configuration for the AHRS complementary filter. The Complementary Filter data outputs are supported in the IMU/AHRS Data set (0x80) to provide compatibility with the 3DM-GX3.									
Description	Possible functi 0x01 - 0x02 - 0x03 - 0x04 - 0x05 -	on selector value Use new setting Read back curre Save current se Load saved sta Reset to factory	es: gs ent settings ettings as startup settings rtup settings y default settings								
	Possible up/north compensation enable values:										
	0x00 - 0x01 -	0x00 - Disable 0x01 - Enable (default)									
	Range of up/no	Range of up/north compensation time constants:									
	1-1000) seconds, defau	ult = 10 seconds								
	Values outside of the specified range for up/north compensation will be NA										
Notes	The Con and North) that culated using tu provides drop-i recommended as well as com	nplementary Filt are independen he same algorith n compatibility ti that you transitio patibility with hig	er provides attitude outputs (Matrix, Euler, Quaternion, Up, at of the Estimation Filter outputs. The CF outputs are cal- mm as the 3DM-CV5 series of Inertial Devices. This hat duplicates the performance of the 3DM-CV5. It is highly on to the EF outputs as they will provide better performance gher grade devices such as the 3DM-RQ1.								
Field Format	Field Length	Field Descriptor	Field Data								
Command	0x0D	0x51	U8 - Function selector U8 - Up compensation enable U8 - North compensation enable float - Up compensation time constant (sec) float - North compensation time constant (sec) U8 - echo the command descriptor U8 - error code (0:ACK, not 0:NACK)								
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)								
Reply Field 2: Function = 2	0x0C	0x97	U8 - Up compensation enable U8 - North compensation enable								



					float - Up o float - Nor	compens th compe	sation time constant (sec ensation time constant (s) ec)	ecksum				
	ſ	MIP Pac	ket Hea	der		Command/Reply Fields							
Examples	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB				
Command	0x75	0x65	0x0C	0x0D	0x0D	0x51	Fctn Selector 0x01 (Write): 0x01 Up Compensation 0x01 Enable: North Compensation 0x01 Enable: Up Compensation 5.0 Time Constant: (sec) North Compensation Time 5.0 Constant: (sec)	0xXX	0xXX				
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x51 Error code: 0x00	0x	0x				
Copy-Paste versi	Copy-Paste version of the command: "7565 0C09 0951 0104 0100 0000 00"												





4.2.18 De	evice Sta	ntus (0x0C,	0x64)								
	Get the	e device-speci	fic status f	for the 3DM-CV5-25.							
	Reply may be	Reply has two fields: "ACK/NACK" and "Device Status Field". The device status field may be one of two selectable formats - basic and diagnostic.									
Description	The rep parame 3DM-C which there a return selecto Possib	parameters in the command. The first parameter is the model number (which for the 3DM-CV5-25 is always = 6257 (0x 1871). That is followed by a status selector byte which determines the type of data structure returned. In the case of the 3DM-CV5-25, there are two selector values - one to return a basic status structure and a second to return an extensive diagnostics status structure. A list of available values for the selector values and specific fields in the data structure are as follows: Possible Status Selector Values: 0x01 - Basic Status Structure 0x02 - Diagnostic Status Structure									
Notes	you ch field fo except for all o but not	The reply field for this command is tightly tied to the model number. Make sure you check the model number in the reply and match it to the correct structure for the data field for the specific device model number. This reply data descriptor 0x0C,0X90 is an exception to the rule for MIP descriptors that the structure of descriptor data is the same for all devices. In this case, it is the same for all devices with the same model number but not necessarily the same for devices with different model numbers.									
Field Format	Field Length	Field Descriptor	Field Da	ta							
Command	0x02	0x64	U16-Dev U8-Stati	vice Model Number: set = 6257 (0x1 us Selector	1871))						
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - ech U8 - errc	o the command byte or code (0: ACK, non-zero: NACK)							
			Binary Offset	Description	Data Type	Units					
Reply Field 2: Basic Device		0×90	0	Echo of the Device Model Num- ber	U16	N/A					
Status Field			2	Echo of the selector byte	U8	N/A					
			3 Status Flags (Reserved) U32 N/A		N/A						
	System State	U16	N/A								



						9	System	Timer	(since start-up)	U32	mi	lliseco	ond
						Binary Offset	Descrip	otion		Data Type	Uı	nits	
						0	Echo of ber	the De	evice Model Num-	U16	N/	N/A	
						2	Echo of	the se	lector byte	U8	N/	A	
						3	Status	Flags (I	Reserved)	U32	N/	A	
						7	System State			U16	N/	A	
						9	System	Timer	(since start-up)	U32	mi	lliseco	ond
						13	IMU St	Stream Enabled			1- 0-	on off	
						14	Estimat Enabled	tion Filt d	er Stream	U8	1- 0-	on off	
Reply Field 2: Diagnostic		0.67				15	Outgoir Packet	ng IMU Count	Stream Dropped	U32	со	ount	
Device Status Field		0,35		0x90		19	Outgoing Estimation Filter Stream Dropped Packet Count			U32	со	ount	
						23	Numbe port	r of byt	es written to com	U32	со	ount	
						27	Number of bytes read from com port			U32	со	ount	
						31	Number of overruns when writing to com port			U32	со	ount	
						35	Numbe ing corr	r of ove 1 port	erruns when read-	U32	со	ount	
						39	Numbe ing erro	r of IMl rs	J message pars-	U32	со	ount	
						43	Total IN	1U mes	sages read	U32	со	ount	
						47	Last IM tem Tin	U mes ner)	sage read (Sys-	(Sys- U32 millis		lliseco	ond
			MIP	Packet	Head	er		Con	nmand/Reply Fields			Chec	ksum
Examples	Sy	nc1	Sync2	Desc. Set	Payl	oad Length	Field Length	Field Desc.	Field Data			MSB	LSB
Command: Get Device	0>	(75	0x65	0x0C		0x05	0x05	0x64	Model#(6257): 0x	1871			



Status (return Basic Status structure: selector = 1)							Status selector 0x01 (basic status):		
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x15	0x04	0xF1	Echo cmd: 0x64 Error code: 0x00		
Reply Field 2: Device Status (Basic Status struc- ture)					0x0F	0x90	Echo Model # (6257): 0x1871 Echo selector: 0x01 Additonal data: 	0x##	0x##



4.3 Estimation Filter Commands

The 3DM command set is common to the LORD Sensing Inertial sensors that support the MIP packet protocol. Because of the unified set of commands, it is easy to migrate code from one inertial sensor to another.

4.3.1 Reset Filter (0x0D, 0x01)												
Description	Reset	Reset the filter to the initialize state.										
Notes	If the a order t	If the auto-initialization feature is disabled, the initial attitude or heading must be set in order to enter the run state after a reset.										
Field Format	Field Le	ïeld Length Field Field Data										
Command	0x02			0x(0x01 N/A							
Reply Field: ACK/ NACK	0x04			0xI	F1	U8 - Ech U8 - Errc	o the cor or code (0	nmand byte : ACK, non-zero: NAC	:К)) Checksum		
		MIP Pac	cket H	lea	der	C	command	l/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Des Se	SC. Ət	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	0x65	0x0	D	0x02	0x02	0x01		0xEC	0xF6		
Reply Field: ACK/NACK	0x75)x75 0x65 0x0D 0x04 0x04 0xF1 Command echo: 0x01 Error code: 0x00 0xE1 0xB2										
Copy-Paste version of the command: "7565 0D02 0201 ECF6"												



4.3.2 Set	Initial A	Attitude	(0x0E	D, 0x02)								
	Set the	e initial att	itude.									
Description	This co estima to the le	This command can only be issued in the "INIT" state and should be used with a good estimate of the vehicle attitude. The Euler Angles are the sensor body frame with respect to the local NED frame.										
	The va	lid input ra	anges a	re as follo	ws:							
		Roll: [-п, п] Pitch: [-п/2, п/2] Yaw: [-п, п]										
Field Format	Field Le	ield Length Field Field Data										
Command	0x0E		0x02		Float - R Float - Pi Float - H	oll (radiar itch (radia eading (ra	ns) ans) adians)					
Reply Field : ACK/ NACK	0x04		0xF1		U8 - ech U8 - erro	o the con r code (0:	nmand byte ACK, non-zero: NAC	K)				
	N	/IP Pack	et Head	ler	C	command	I/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	75 0x65 0x0D 0x0E 0x0E 0x02 Roll: 0x0000000 (0.0f) 0x000 0x05 0x05 0x06										
Reply Field: ACK/NACK	0x75	0x75 0x65 0x0D 0x04 0x04 0xF1 Command echo: 0x02 Error code: 0x00 0xE2 0xB4										
Copy-Paste version of the command: "7565 0D0E0E02 0000 0000 0000 0000 0000 0000												



4.3.3 Set Initial Heading (0x0D, 0x03)										
	Set the	e initial he	eading a	angle.						
Description	This co estima accele body fi The va	This command can only be issued in the "INIT" state and should be used with a good estimation of Heading. The device will use this value in conjunction with the output of the accelerometers to determine the initial attitude estimate. The Euler Angles are the sensor body frame with respect to the local NED frame. The valid input range for heading is [-π, π].								
Field Format	Field Le	Field Length Field Field Data								
Command	0x06		0x03		Float - He	ading (ra	dians)			
Reply Field : ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Error	the com code (0:	mand byte ACK, non-zero: NACł	<)		
		MIP Pacl	ket Hea	der	C	command	I/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x06	0x06	0x03	Heading: 0x00000000 (0x0f)	0xF6	0xE4	
Reply Field: ACK/NACK	0x75 0x65 0x0D 0x04 0x04 0xF1 Command echo: 0x03 Error code: 0x00 0xE3 0xB6									
Copy-Paste versi	Copy-Paste version of the command: "7565 0D06 0603 0000 0000 F6E4"									


4.3.4 Set	Initial A	Attitud	e wit	:h №	lagnetor	neter (0)	x0D, 0>	(04)		
Description	Set the	e initial at	ttitude	e usi	ing the emb	bedded ma	ignetome	eter.		
Notes	This co magne local n Spec i headin	This command can only be issued in the "INIT" state. The device will use the on-board nagnetometer to initialize the attitude. The user may supply a declination angle for the ocal magnet field conditions Special Note : In the presence of significant magnetic interference, the magnetometer neading value can be wildly off, causing the filter to initialize improperly.								
Field Format	Field Le	eld Length Field Field Data Field Data								
Command	0x06			0x0	4	Float - D	eclination	n Angle (radians)		
Reply Field: ACK/ NACK	0x04			0xF	1	U8 - Ech U8 - Erro	o the cor r code (0	nmand byte : ACK, non-zero: NAC	:К)	
		MIP Pac	ket H	t Header		С	ommand	I/Reply Fields	Chec	ksum
Example	Sync1	Sync2	Deso Set	c. t	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command	0x75	0x65	0x0I	D	0x06	0x06	0x04	Declination: 0x00000000 (0.0f)	0xF7	0xE9
Reply Field: ACK/NACK	0x75	0x65	0x0I	D	0x04	0x04	0xF1	Command echo: 0x04 Error code: 0x00	0xE4	0xB8
Copy-Paste version	on of the	commar	nd: "75	565 (0D06 0604	0000 0000) F7E9"			



4.3.5 Ser	nsor to Vehicle	Frame Transf	formation (0x0D, 0x11)								
	Set the sensor to angles.	o vehicle frame tra	ansformation matrix using Roll, Pitch, and Yaw Euler								
	These angles de Please reference	fine the rotation fi the device Theo	rom the sensor body frame to the fixed vehicle frame. ry of Operation for more information.								
	Possible function	n selector values:									
	0x01-L	Jse new settings									
	0x02 - F	Read back current	settings.								
	0x03-S	Save current setti	ngs as startup settings								
	0x04 - L	oad saved startu	p settings								
	0x05 - F	Reset to factory d	efault settings								
	This transformat	ion affects the fol	lowing output quantities:								
Description	IMU:	IMU:									
	Scaled	Scaled Acceleration									
	Scaled	Scaled Gyro									
	Scaled	Magnetometer									
	Delta TI	heta									
	Delta Velocity										
	Estimat	Estimation Eiltor									
	Estimat	ed Orientation. Q	uaternion								
	Estimat	ed Orientation, M	latrix								
	Estimat	ed Orientation, E	uler Angles								
	Estimat	ed Linear Accele	ration								
	Estimat	ed Angular Rate									
	Estimat	ed Gravity Vecto	r								
Field Format	Field Length	Field Descriptor	Field Data								
Command	0x0F	0x11	U8 - Function Selector Float - Roll Angle (radians) Float - Pitch Angle (radians) Float - Yaw Angle (radians)								
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)								



Reply Field 2: Function = 2	0x0E	0x0E MIP Packe			Float - Roll Angle (radians) Float - Pitch Angle (radians) Float - Yaw Angle (radians)					
	ſ	MIP Pack	ket Hea	der	C	Command	/Reply Fields	Checksum		
Example	Sync1	Sync2 Desc. Payload Sync2 Set Length			Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x0F	0x0F	0x11	Fctn (Apply): Roll: 0x00000000 (0.0f) Pitch: Yaw: 0x00000000 (0x0f)	0x17	0x72	
Reply Field : ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Command echo: 0x11 Error code: 0x00	0xF1	0xD2	
Copy-Paste versi	on of the	comman	d: "7565	5 0D0F 0F 1	1 0100 00	00 0000 0	0000 0000 0000 0017 7	2"		



4.3.6 Est	imatior	Contro	ol Flaç	gs (0x0D	, 0x14)							
	Contro	ls which	parame	eters are es	timated by	the Kalm	an Filter.					
	Possib	ole functio	on selec	ctor values:								
Description		0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings										
	Availal	ble Flags	:									
	0x0001 - Enable Gyro Bias Estimation (Recommended)											
	Examp	oles :										
	0x0001 - Enable Gyro Bias Estimation											
Field Format	Field Le	Field Length Field Field Data										
Command	0x05		0x14		U8 - Func U16 - Est	tion Sele imation C	ctor Control Flags					
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)							
Reply Field 2: Function = 2	0x04		0x84		U16 - Est	imation C	Control Flags					
		MIP Pac	ket Hea	lder	C	Command	I/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command:	0x75	0x65	0x0D	0x05	0x05	0x14	Fctn (Apply): 0xFFFF Flags: (enable all states)	0x04	0x27			
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x14 Error code: 0x00	0xF4	0xD8			
Copy-Paste versi	on of the	comman	d: "756	5 0D05 051	4 01FF FF	04 27"	·					



4.3.7 Hea	ading U	pdate (Contro	ol (0x0D,	0x18)							
	Select	the sour	ce for ai	iding headii	ng updates	to the Kal	man Filter.					
	Possit	ble functio	on selec	ctor values.	;							
Description		0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings										
	Possit	ble Enabl	e Optiol	n values:								
		0x00 - No heading aids										
	0x01 - Use the Internal Magnetometer for heading updates 0x03 - Use external heading messages for heading updates											
Notes												
Field Format	Field Le	ength	Field Desc	criptor	Field Data	Э						
Command	0x04		0x18		U8 - Func U8 - Enab	tion Seleo le Flag	ctor					
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Error	the comr code (0: /	nand descriptor ACK, non-zero: NACł	<)				
Reply Field 2: Function = 2	0x03		0x87		U8 - Enab	le Flag						
		MIP Pacl	ket Hea	der	C	Command	/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	0x65	0x0D	0x04	0x04	0x18	Apply: 0x01 Enable: 0x01	0x09	0x28			
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x18 Error code: 0x00	0xF8	0xE0			
	Сору	y-Paste v	ersion d	of the comr	mand: "756	5 0D04 04	418 0101 0928"					



4.3.8 Ext	ernal H	leading	g Upda	ite (0>	٥D	, 0x17)						
	Trigge	r a filter	update s	tep usi	ng ex	xternal hea	ading info	rmation.				
	The h	eading	must be	e the se	enso	or frame w	vith respe	ect to the NED frame				
Description	The he will be	eading up ignored/	odate co 'NACK'o	ntrol m d otherv	ust b vise.	e set to ex The maxi	ternal for mum rate	this command to update for this message is 20	ate the fi 0 Hz.	lter; it		
	Angle	uncertai	nties of (0.0 will	be N	IACK'd.						
	Possit	ossible Heading Type Commands: 0x01 - True Heading* 0x02 - Magnetic Heading**										
Notes		 Or tru Or ur 	n the -25 Je head In the -45 Ddates v	model, ing up model, vill be N	, if th date , if th	e declinati s will be N e declinati K'd.	on source IACK'd. on source	e (0x0D, 0x43) is not v e is invalid, magnetic	alid, heading]		
Field Format	Field L	onath	Field		Fig	d Data						
	FIEIU LE	engun	Descrip	otor	r ie	iu Dala						
Command	0x0B		0x17		Flo Flo U8	at - Headii at - Headii - Heading	ng Angle ng Angle type (1 -	(radians, true north, +- Uncertainty (radians, ⁻ true, 2 - magnetic)	PI) 1-sigma))		
Reply Field : ACK/ NACK	0x04		0xF1		U8 U8	- Echo the - Error coo	e commai de (0: AC	nd byte K, non-zero: NACK)				
		MIP Pac	ket Hea	der		С	command	/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Paylo Leng	ad 1th	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	0x65	0x0D	0x0	в	0x0B	0x17	Angle: 0.1f ^{Angle} 0.1f Sigma: Heading 0x01 Type: (True)	0xXX	0xXX		
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x0	4	0x04	0xF1	Echo cmd: 0x17 Error code: 0x00	0xF7	0xDE		
Copy-Paste versi	on of the	commai	nd: N/A									



4.3.9 Ext	ernal H	leading	g Upda	ite wit	:h Ti	imestam	ıp (0x0l	D, 0x1F)			
	Trigge specifi	r a filter ic GPS 1	update s Fime.	tep usi	ng e>	kternal hea	iding info	rmation that is time-tag	gged wit	ha	
Description	This is in appl signific cessin ation is	more ac ications cant erro g time re s importa	ccurate t where the or in the a equired f ant. The	han the he vehi applied for the c maxim	e Ext cle h mea comn comn	ernal Head eading exp surement of nand. Accu ate for this	ding Upda beriences due to the urate time message	ate (0x0D, 0x17) and s high angular rate, whi sampling, transmissi e-stamping of the head e is 20 Hz.	hould be ch may on, and p ling infor	e used cause pro- m-	
	Angle	uncertai	nties of	0.0 will	be N	IACK'd.					
	Possit	ole Head	ling Type	e Comr	nand	s:					
		0x01-	- True Ho Magnet	eading*	, dina*	÷					
	The h	eading	must be	e the s	enso	or frame w	ith respe	ect to the NED frame.			
Notes		 On the -25 model, if the declination source (0x0D, 0x43) is not valid, true heading updates will be NACK'd. On the -45 model, if the declination source is invalid, magnetic heading updates will be NACK'd. 									
Field Format	Field Le	ength	Field Descrij	otor	Fie	ld Data					
Command	0x15		0x1F		Do U1 Flo Flo U8	uble - TOV 6 - week n at - Headir at - Headir - Heading	V (time-of umber ng Angle ng Angle type (1 -	f-week, seconds) (radians, true north, +- Uncertainty (radians, 1 true, 2 - magnetic)	PI) I-sigma)		
Reply Field : ACK/ NACK	0x04		0xF1		U8 U8	- Echo the - Error coo	e commar le (0: AC	nd descriptor K, non-zero: NACK)			
		MIP Pac	ket Hea	der	-	С	ommand	I/Reply Fields	Chec	ksum	
Example	Sync1	Sync1 Sync2 Desc. Payload Field Field Sync1 Sync2 Set Length Length Desc.								LSB	
Command	0x75	0x65	0x0D	0x1	5	0x15	0x1F	TOW: 30,000.0 Week Num- ber: 1700 Angle: (0.01f) Angle Sigma: Heading 0x01	0xXX	0xXX	



							Type: (True)		
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo Cmd: 0x01 Error Code: 0x00	0xFF	0xEE
Copy-Paste version	on of the	comman	d: N/A						



4.3.10 Se	et Refe	rence F	Posit	tior	ח (0x0D, (0x26)					
	Set the Possil	e Lat/Lor ole functi	ng/Alt ion se	ref	erence posi tor values:	tion for the	e sensor.				
Description	This p	0x01 - Use new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings his position is used by the sensor to calculate the WGS84 gravity and WMM2015 mag- etic field parameters.									
Field Format	Field Lo	ength		Fie De	eld escriptor	Field Data					
Command	0x01C	(28)		0x2	26	U8 - Fun U8 - Ena Double - Double - Double -	ction Sel ble (0 - d Latitude Longituc Altitude	ector isable, 1 - enable) (decimal degrees) le (decimal degrees) (meters)			
Reply Field: ACK/ NACK	0x04			0x	F1	U8 - Ech U8 - Erro	o the cor or code ((nmand descriptor): ACK, non-zero: NAC	CK)		
Reply Field 2: (function = 2)	0x1B (2	27)		0x	90	U8 - Ena Double - Double - Double -	ble (0 - d Latitude Longituc Altitude	isable, 1 - enable) (decimal degrees) le (decimal degrees) (meters)			
		MIP Pac	cket H	lea	der	C	ommand	l/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Des Se	c. t	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0	D	0x1C	0x1C	0x26	Fctn (Apply): 0x01 Enable: 0x01 Latitude (deg): (44.437f) Longitude (deg): (- 73.106) Altitude (m): (155.0f)	0xXX	0xXX	
Reply Field: ACK/NACK	0x75	0x65	0x0	D	0x04	0x04	0xF1	Command echo: 0x26 Error code: 0x00	0x06	0xFC	



4.3.11 Er	nable/D	isable	Mea	asu	rements	(0x0D, ()x41)					
Description	Allows	s users to	o con	itrol a	accelerome	ter and ma	gnetome	eter measurement upd	ates.			
Notes	Possit Possit	Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Possible control bitfield values: Bit 0 (0x0000001) - Accelerometer Measurements (1 - enable, 0 - disable) Field Field										
Field Format	Field Le	ïeld Length Field Field Descriptor Field Data										
Command	0x05			0x4	41	U8 - Fun U16 - Co	ction Selentrol Bitf	ector ield				
Reply Field: ACK/ NACK	0x04			0xI	=1	U8 - Ech U8 - Erro	o the con r code (0	nmand descriptor : ACK, non-zero: NAC	CK)			
Reply Field 2: (function = 2)	0x04			0xI	30	U16 - Control Bitfield						
		MIP Pac	cket l	Hea	der	c	command	I/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	De: Se	sc. et	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	x75 0x65 0x0D 0x05 0x05 0x41 Congar Door Door Door Door Door Door Door Do										
Reply Field: ACK/NACK	0x75	0x75 0x65 0x0D 0x04 0x04 0xF1 Command echo: 0x41 Error code: 0x00 0x21 0xB2										
Copy-Paste versi	on of the	comman	nd: "7	7565	0D05 0541	0100 0336	6E1"					



4.3.12 Pi	tch/Rol	ll Aiding	g Cont	rol (0x0I	D, 0x4B)							
	Select of low	pitch/roll dynamic	aiding s .	input. Aidir	ig inputs ar	e used to	improve that solution	during p	əriods			
	Possil	ble functio	on selec	ctor values.	:							
		0x01-	Use ne	w settings								
		0x02-	Read b	ack current	settings	_						
Description		0x03-	Save c	urrent settii	ngs as star	tup settin	gs					
		0x04 - 0x05 -	Reset t	o factory d	efault setti	ngs						
	Possil	Possible altitude aiding selector values:										
	Possible altitude aiding selector values:											
		0x00 - 0x01 -	NO PIIC Enable	n/roli alding dravity veo	tor aiding							
Field Format	Field Le	ength	Field Desc	criptor	Field Dat	а						
Command	0x05		0x4B		U8 - Func U8 - Aidir	ction Sele ng (0 - Dis	ctor able, 1 - Enable)					
Reply Field: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Erroi	o the com code (0:	mand descriptor ACK, non-zero: NACI	K)				
Reply Field : Function = 2	0x03		0xBE	3	U8 - Aidir	ng Selecto	or Value					
		MIP Pacl	ket Hea	der	C	Command	/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	0x65	0x0D	0x04	0x04	0x4B	Fctn (Apply): 0x01 Enable: 0x01	0x3C	0xC1			
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x47 Error code: 0x00	0xB9	0xF0			
Copy-Paste versi	on of the	comman	d: "756	5 0D04 044	B 0101 3C	C1 "						



Г

4.3.13 Au	uto-Initi	alizatio	on Cor	ntrol (0x0	D, 0x19)						
	Enable	e/Disable	automa	atic initializa	ation upon	device st	artup.				
Description	Possib	Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Possible enable values: 0x00 - Disable auto-initialization 0x01 - Enable auto-initialization (requires valid heading source)									
Field Format	Field Le	Field Length Field Field Data									
Command	0x04		0x19		U8 - Func U8 - Enab	tion Sele de Value	ctor				
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Error	the com code (0:	mand descriptor ACK, non-zero: NACk	()			
Reply Field 2: Function = 2	0x03		0x88		U8-Enab	le Value					
		MIP Pac	ket Hea	ider	C	Command	I/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command:	0x75	0x65	0x0D	0x04	0x04	0x19	Fctn 0x01 (Apply): 0x01 (Enable Enable: auto- initialization)	0x0A	0x2B		
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x19 Error code: 0x00	0xF9	0xE2		
Copy-Paste versi	on of the	comman	d: "756	5 0D04 041	9 0101 0A2	2B"	·	•			



4.3.14 Ma	agneto	meter N	loise	Standard	d Deviatio	on (0x0l	D, 0x42)			
	Set the	e expecte	d magn	etometer r	noise 1-sign	na values				
	This fu	unction ca	an be us	sed to tune	the filter pe	erformanc	e in the target applicat	ion.		
	Possit	ole functio	on selec	tor values:	:					
		0x01 - Use new settings 0x02 - Read back current settings								
Description		0x03 - Save current settings as startup settings								
		0x04 - 0x05 -	Reset to	o factory d	p settings efault settin	ıgs				
	Eacho	of the nois	e value	es must be	greater than	n 0.0				
	The no	oise value	represe	ents proce	ss noise in t	the 3DM-	CV5 NAV Estimation	Filter.	- d 4 -	
	tune th	In the performance of the filter. Default values provide good performance for most labor-								
		conditions								
Field Format	Field Le	ength	Desc	criptor	Field Data	9				
					U8 - Funct Float - X M	tion Seleo /Iag Noise	ctor e 1-siama (aauss)			
Command	0x0F		0x42		Float - Y M Float - Z M	/lag Noise /lag Noise	e 1-sigma (gauss) e 1-sigma (gauss)			
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)					
Reply Field 2: Function = 2	0x0E		0xB1		Float - X M Float - Y M Float - Z M	lag Noise lag Noise lag Noise	e 1-sigma (gauss) e 1-sigma (gauss) e 1-sigma (gauss)			
		MIP Pack	ket Hea	der	C C	Command	/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x0F	0x0F	0x42	Fctn (Apply): 0x01 X: (0.02f) Y: (0.02f) Z: (0.02f)	0x	0x	
Reply Field 1: ACK/NACK	0x75 0x65 0x0D 0x04				0x04	0xF1	Echo cmd: 0x42 Error code: 0x00	0x22	0x34	
Copy-Paste version of the command: N/A										



4.3.15 Gr	ravity N	oise St	andar	d Deviat	ion (0x0E), 0x28)				
	Set the perform	e expecte nance in	d gravit the targ	y noise 1-s et applicati	igma value: on.	s. This fur	nction can be used to t	une the	filter	
	Each c	of the nois	se value	s must be	greater thar	0.0				
Description	The no the filte Defaul	ise value er respon t values p	e represe ds to dy provide	ents proces namic inpu good perfoi	ss noise in the EKF. Changing this value modifies how ut and can be used to tune the performance of the filter. rmance for most laboratory conditions.					
Description	Possib	le functio	on selec	tor values:						
		0x01-	Use nev	w settings						
		0x02-	Read ba	ack current	settings		-			
		0x03 - Save current settings as startup settings 0x04 - Load saved startup settings								
		0x05 - Reset to factory default settings								
Field Format	Field Le	ength	Field Desc	riptor	Field Data					
Command	0x05		0x28	0x28 U8 - Function Selector Float - X Gravity Noise 1-sigma (g) Float - Y Gravity Noise 1-sigma (g) Float - Z Gravity Noise 1-sigma (g)						
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)					
Reply Field 2: Function = 2	0x04		0x93		Float - X Gravity Noise 1-sigma (g) Float - Y Gravity Noise 1-sigma (g) Float - Z Gravity Noise 1-sigma (g)					
		MIP Pac	ket Hea	der	C	Command	/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x05	0x05		Fctn (Apply): 0x01 X: (0.01f) Y: (0.01f) Z: (0.01f)	0x	0x	
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x28 Error code: 0x00	0x	0x	



4.3.16 Gy	yroscop	e Noise	e Stan	dard De	viation (0x0D, (Dx1B)				
	Set the This fu	e expecte	d gyros in be us	cope noise ed to tune	e 1-sigma v the filter pe	values. erforman	ce in the target applica	tion.			
	Possib	le functio	on selec	tor values	s:						
Description	Each c The no Chang tune th atory c	0x01 - Use new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Each of the noise values must be greater than 0.0 The noise value represents process noise in the 3DM-CV5 NAV Estimation Filter. Changing this value modifies how the filter responds to dynamic input and can be used to tune the performance of the filter. Default values provide good performance for most labor- atory conditions.									
Field Format	Field Length Field Descriptor				Field Dat	а					
Command	0x0F		0x1B	0x1B U8 - Function Selector Float - X Gyro Noise 1-sigma (rad/second) Float - Y Gyro Noise 1-sigma (rad/second) Float - Z Gyro Noise 1-sigma (rad/second)							
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Error	o the com code (0:	mand descriptor ACK, non-zero: NACI	K)			
Reply Field 2: Function = 2	0x0E		0x8A		Float - X Gyro Noise 1-sigma (rad/second) Float - Y Gyro Noise 1-sigma (rad/second) Float - Z Gyro Noise 1-sigma (rad/second)						
	I	MIP Pack	et Hea	der	C	Command	d/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	0x65	0x0D	0x0F	0x0F	0x1B	Fctn (Apply): X: (0.0000539f) Y: (0.0000539f) Z: (0.0000539f)	0xDE	0xE8		
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x1B Error code: 0x00	0xFB	0xE6		
Copy-Paste version of the command: "7565 0D0F 0F1B 013A 0D4B AD3A 0D4B AD3A 0D4B ADDE E8"											



4.3.17 Ac	celero	meter l	Noise	Stand	arc	d Deviat	ion (0x	0D, 0x1A)			
	Set the the filte	e expecto er perfori	ed accel mance ir	leromet n the tai	er n rget	oise 1-sig applicatio	ma value on.	es. This function can b	e used to	tune	
	Possib	ole functi 0x01 -	on selec	ctor valu	Jes:	:					
		0x02 - Read back current settings									
Description		0x03 - Save current settings as startup settings 0x04 - Load saved startup settings									
		0x05 - Reset to factory default settings									
	Eacho	Each of the noise values must be greater than 0.0									
	The no Chang tune th atory o	The noise value represents process noise in the 3DM-CV5 NAV Estimation Filter. Changing this value modifies how the filter responds to dynamic input and can be used to tune the performance of the filter. Default values provide good performance for most labor- atory conditions.									
Field Format	Field Le	ength	Field Descriptor								
Command	0x0F		0x1A		UX Fi Fi UX UX	8 - Functic oat - X Ac oat - Y Ac oat - Z Ac 8 - echo th 8 - error co	on Select cel Noise cel Noise cel Noise e comma ode (0:AC	or = 1-sigma (meters/seco = 1-sigma (meters/seco = 1-sigma (meters/seco = and descriptor CK, not 0:NACK)	ond^2) ond^2) ond^2)		
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)						
Reply Field 2: Function = 2	0x0E		0x89		Fl Fl Fl	Float - X Accel Noise 1-sigma (meters Float - Y Accel Noise 1-sigma (meters Float - Z Accel Noise 1-sigma (meters			ond^2) ond^2) ond^2)		
	1	MIP Pac	ket Hea	der		C	command	I/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payloa Lengt	ad th	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x0D 0x0F		0x0F	0x1A	Fctn (Apply): 0x01 X: (0.02f) Y: (0.02f) Z: (0.02f)	0x60	0xA3	
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	Ļ	0x04	0xF1	Echo cmd: 0x1A Error code: 0x00	0xFA	0xE4	



Copy-Paste version of the command: "7565 0D0F 0F01 1A013CA3D70A3CA3D70A3CA3D760A3"



4.3.18 Gy	yroscope Bias Model Parameters (0x0D, 0x1D)									
Description	Set the Possib	Set the gyroscope bias model parameters. Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings								
		Each of the noise values must be greater than 0.0								
Field Format	Field Le	ength	Field Desci	riptor	Field Data					
Command	0x1B		0x1D		U8 - Function Float - X Gy Float - Y Gy Float - Z Gy Float - X Gy Float - Y Gy Float - Z Gy	on Selecto ro Bias Be ro Bias Be ro Bias Be ro Bias No ro Bias No ro Bias No	or eta (1/second) eta (1/second) eta (1/second) oise 1-sigma (rad /seco oise 1-sigma (rad /seco oise 1-sigma (rad /seco	nd) nd) nd)		
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo t U8 - Error c	he comm ode (0: A	nand descriptor CK, non-zero: NACK)			
Reply Field 2: Function = 2	0x1A		0x8C		Float - X Gy Float - Y Gy Float - Z Gy Float - X Gy Float - Y Gy Float - Z Gy	ro Bias Be ro Bias Be ro Bias Be ro Bias Ne ro Bias Ne ro Bias Ne	eta (1/second) eta (1/second) eta (1/second) oise 1-sigma (rad /seco oise 1-sigma (rad /seco oise 1-sigma (rad /seco	nd) nd) nd)		
		MIP Pac	ket Hea	der	C	Command	I/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x0F	0x1B	0x1D	Fctn (Apply): X Beta: (0.01f) Y Beta: (0.01f) Z Beta: (0.01f) X Noise: (0.00016f) Y Noise: (0.00016f) Z Noise: (0.00016f)	0xXX	0xXX	
Reply Field 1: ACK/NACK	0x75 0x65 0x0D 0x04			0x04	0x04	0xF1	Echo cmd: 0x1D Error code: 0x00	0xFD	0xEA	
Copy-Paste version of the command: N/A										



4.3.19 Ha	ard Iron Offset Process Noise (0x0D, 0x2B)									
	Set the	e expecte	ed hard i	ron offset ı	noise 1-sig	jma value	es.			
	This fu	inction ca	an be us	ed to tune	the filter p	erforman	ce in the target applica	tion.		
	Possib	ole functio	on selec	tor values:	:					
		0x01-	Use ne	w settings						
		0x02 - 0x03 -	Read ba Save ci	ack current urrent setti	t settings. ngs as sta	rtun setti	nas			
Description		0x04 -	Load sa	wed startu	p settings		190			
		0x05 - Reset to factory default settings								
	Each c	Each of the noise values must be greater than 0.0								
	The no Chang	The noise value represents process noise in the 3DM-CV5-25 NAV Estimation Filter. Changing this value modifies how the filter responds to dynamic input and can be used to use the performance of the filter. Default values provide good performance for most								
	laborat	aboratory conditions.								
Field Format	Field Le	ength	Field Desc	criptor	Field Da	ta				
Command	0x0F		0x2B		U8 - Fun Float - X Float - Y Float - Z	ction Sel HI Offse HI Offse HI Offse	ector t Noise 1-sigma (gauss t Noise 1-sigma (gauss t Noise 1-sigma (gauss	;) ;) ;)		
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)					
Reply Field 2: Function = 2	0x0E		0x96		Float - X Float - Y Float - Z	HI Offse HI Offse HI Offse	t Noise 1-sigma (gauss t Noise 1-sigma (gauss t Noise 1-sigma (gauss	5) 5) 5)		
	ſ	MIP Pack	ket Hea	der	(Comman	d/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x0F	0x0F	0x2B	Fctn (Apply): 0x01 X: (0.001f) Y: (0.001f) Z: (0.001f)	0xEB	0xD2	
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x2B Error code: 0x00	0x0B	0x06	



Copy-Paste version of the command: "7565 0D0F 0F2B 013A 8312 6F3A 8312 6F3A 8312 6FEB D2



ft Iron I	Iron Matrix Process Noise (0x0D, 0x2C)								
Set the	expecte	d hard ii	ron offset r	noise 1-sig	jma valu	es.			
This fu	nction ca	n be us	ed to tune	the filter p	erforman	ce in the target applica	tion.		
Possib	le functio	n selec	tor values:	:					
	0x01-l	Jse nev	v settings						
	0x02 - Read back current settings. 0x03 - Save current settings as startup settings								
	0x04 - Load saved startup settings								
	0x05 - Reset to factory default settings								
Each o	Each of the noise values must be greater than 0.0 (gauss).								
The noi	The noise value represents process noise in the 3DM-CV5-25 NAV Estimation Filter.								
Changi tune the	hanging this value modifies how the filter responds to dynamic input and can be used to une the performance of the filter. Default values provide good performance for most labor-								
atory c	ory conditions.								
Field Le	ngth	Field	riptor	Field Da	ta				
				U8 - Fun	ction Sel	ector			
0x0F		0x2C		Float - m Float - m	1,1 Float 2 1 Float	- m _{1,2} Float - m _{1,3} - m _{2 2} Float - m _{2 3}			
				Float - $m_{3,1}^{2,2}$ Float - $m_{3,3}^{2,2}$ Float - $m_{3,3}^{2,3}$					
0x04		0xF1		U8 - Echo the command descriptor					
				Float - m	, eede (e	- m1 o Float - m1 o			
0x0E		0x97		Float - m	_{2,1} Float	- m _{2,2} Float - m _{2,3}			
•	ALD Dook		lor	Float - m	3,1 FIOat	- m _{3,2} Float - m _{3,3}	Choo	koum	
K	me Pack		Pavload	Field			Chec	NSUII	
Sync1	Sync2	Set	Length	Length	Desc.	Field Data	MSB	LSB	
o	0.07		o o=			Fctn (Apply): 0x01 X: (0.0001f)			
Ux 75	Ux65	Ux0D	Ux0F	UXUF	0x2C	Y: (0.0001f) Z: (0.0001f)	UxF1	UX8C	
0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x2C Error code: 0x00	0x9A	0xB2	
	t Iron Set the This fu Possib Each o The no Changi tune the atory co <i>Field Le</i> 0x0F 0x0F 0x0F 0x0F 0x0F	This function ca Possible function Possible function 0x01 - 1 0x02 - F 0x03 - S 0x04 - 1 0x05 - F Each of the noise The noise value Changing this va tune the perform atory conditions Field Length 0x0F 0x0F 0x0E MIP Pack Sync1 Sync2 0x75 0x65	Tiron Matrix ProcesSet the expected hard inThis function can be usePossible function select0x01 - Use new0x02 - Read ba0x03 - Save cu0x03 - Save cu0x04 - Load sa0x05 - Reset toEach of the noise value represeChanging this value mottune the performance ofatory conditions.Field LengthField Desc0x040x2C0x040x970x040x970x050x650x750x650x050x0D	Thon Matrix Process NoiseSet the expected hard iron offset inThis function can be used to tunePossible function selector values: $0x01 - Use new settings0x01 - Use new settings0x01 - Use new settings0x01 - Use new settings0x02 - Read back current0x02 - Read back current0x03 - Save current settin0x04 - Load saved startu0x05 - Reset to factory dEach of the noise value represents procesChanging this value modifies howtune the performance of the filter.atory conditions.Field LengthField Length0x0F$	Tron Matrix Process Noise (0x0D,Set the expected hard iron offset noise 1-sigThis function can be used to tune the filter pPossible function selector values:0x01 - Use new settings0x02 - Read back current settings.0x02 - Read back current settings as sta0x03 - Save current settings as sta0x04 - Load saved startup settings0x05 - Reset to factory default settEach of the noise values must be greater theThe noise value represents process noise in Changing this value modifies how the filter of tune the performance of the filter. Default valueOx0FOx2CField Da0x0F0x2C0x040xF1U8 - Fun Float - m Float - m Float - m0x020x97Float - m Float - m Float - m0x0E0x97Payload SetField LengthOx0FOx0F0x050x0D0x0F0x060x0D0x0F0x070x650x0D0x080x040x04	Set the expected hard iron offset noise 1-sigma value This function can be used to tune the filter performant Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings as startup setti 0x04 - Load saved startup settings 0x05 - Reset to factory default settings 0x05 - Reset to factory default settings Each of the noise values must be greater than 0.0 (gr. The noise value represents process noise in the 3DM Changing this value modifies how the filter responds tune the performance of the filter. Default values pro- atory conditions. Field Length Field Descriptor Field Length 0x2C U8 - Function Sel Float - m1,1 Float Float - m2,1 Float Float - m3,1 Float 0x0F 0xF1 U8 - Echo the cor U8 - Error code (C 0x0E 0x97 Float - m1,1 Float Float - m3,1 Float Float - m3,1 Float Float - m3,1 Float 0x0E 0x97 Float - m3,1 Float Float - m3,1 Float	Tron Matrix Process Noise (0x0D, 0x2C) Set the expected hard iron offset noise 1-sigma values. This function can be used to tune the filter performance in the target applical Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings. 0x02 - Read back current settings 0x03 - Save current settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings 0x05 - Reset to factory default settings 0x05 - Reset to factory default settings Changing this value modifies how the filter responds to dynamic input and of tune the performance of the filter. Default values provide good performance atory conditions. Field Length Field Data Qx0F 0x2C Float $- m_{1,2}$ Float $- m_{1,3}$ Float $- m_{2,2}$ Float $- m_{2,3}$ Float $- m_{3,1}$ Float $- m_{2,1}$ Float $- m_{2,1}$ Float $- m_{2,2}$ Float $- m_{3,3}$ 0x0F 0x9F1 U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NAC 0x0E 0x97 Float $- m_{1,1}$ Float $- m_{1,2}$ Float $- m_{3,3}$ Float $- m_{3,3}$ Float $- m_{3,3}$ Float $- m_{3,1}$ Float $- m_{3,1}$ Float $- m_{3,2}$ Float $- m_{3,3}$ MIP Packet Header Command/Reply Fields Sync1 Sync2 Se	Tiron Matrix Process Noise (0x0D, 0x2C) Set the expected hard iron offset noise 1-sigma values. This function can be used to tune the filter performance in the target application. Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings. 0x02 - Read back current settings. 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Each of the noise values must be greater than 0.0 (gauss). The noise value represents process noise in the 3DM-CV5-25 NAV Estimation Filte Charling filter Default values provide good performance for most atory conditions. Field Data Value modifies how the filter responds to dynamic input and can be us tune the performance of the filter. Default values provide good performance for most atory conditions. Field Data Value modifies how the filter mesponds to dynamic input and can be us tune the performance of the filter. Default values provide good performance for most atory conditions. Set Value modifies how the filter mesponds to dynamic input and can be us tary conditions. Value modifies how the filter mesponds to dynamic input and can be us tary conditions. Vale Value modifies how the	



Copy-Paste version of the command: ^{(**}7565 0D27 272C 0138 D1B7 1738 D1B7 1751 8C

4.3.21 Zero Angular Rate Update Control (0x0D, 0x20)											
	Contro	l the use	of zero	angular rat	e updates.						
Description	Possib The ze vector that an	Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings The zero angular rate update is triggered when the scalar magnitude of the angular rate vector is equal-to or less than the threshold value. The device will NACK threshold values that are less than zero (i.e. negative.)									
Field Format	Field Length Field Descriptor				Field Data						
Command	0x08		0x20	0x20 U8 - Function Selector U8 - Enable Value (0 - disable, 1 - enable) Float -Threshold (rad/s)							
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Erroi	o the com code (0:	mand descriptor ACK, non-zero: NACk	()			
Reply Field 2: Function = 2	0x07		0x8E		U8 - Enable Value Float - ZUPT threshold (rad/s)						
		MIP Pacl	ket Hea	der	C	Command	d/Reply Fields	Chec	ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	0x65	0x0D	0x08	0x08	0x20	Fctn (Apply): Enable: (Enable) Threshold: (0.0f)	0x19	0xC8		
Reply Field 1: ACK/NACK	0x75	75 0x65 0x0D 0x04 0x04 0xF1 Echo cmd: 0x20 Error code: 0x00 0x00 0xF0									
Copy-Paste version of the command: "7565 0D08 0820 0101 00000000 19C8"											



4.3.22 Ta	re Orientation (0x0D, 0x21)											
	This fu sensor	nction us to vehic	ses the le trans	current dev formation.	ice orientat	ion relativ	ve to the NED frame a	s the cu	rrent			
	This c format	ommand ion.	is prov	ided as a co	onvenient w	ay to set	the sensor to vehicle	frame tra	ans-			
	Possib	Possible function selector values:										
		0x01 - Use new settings										
		0x03-	Save c	urrent settir	ngs as start	up setting	gs					
		0x04 -	Load sa	aved startup o footony de	o settings							
	Dessib	UXUD - Reset to factory default settings										
Description	POSSIL	Possible axis bittleid values:										
		0x00 - Reset all axis										
		0x02 - Tare the pitch axis										
		0x04 - Tare the yaw axis										
	Example Combinations:											
		0v03-	Tare th	e roll and ni	tch avie							
		0x03 -	Tare all	3 axis								
		T I (1)										
	Note: valid, a	i he filter an error w	must be /ill be re	e initialized turned.	and have a	valid atti	tude output. If the attit	ude is n	ot			
	The filt	ter must l	be initia	lized and ha	ave a valid a	attitude o	utput. If the attitude is	not valio	d, an			
Notes	error w	vill be retu	ırned.									
Field Format	Field I	anath	Field		Field Data							
	T IEIU LO	Jigui	Desc	criptor								
Command	0x04		0x21		U8 - Funct U8 - Tare	tion Selec Axis Bitfi	ctor eld					
Reply Field: ACK/ NACK	0x04		0xF1		U8 - Echo U8 - Error	the comr code (0: /	nand descriptor ACK, non-zero: NACK	()				
	MIP Packet Header				С	ommand	/Reply Fields	Chec	ksum			
Example	Sync1	Sync1 Sync2 Desc. Set		Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	0x65	0x0D	0x04	0x04	0x21	Fctn (Apply): 0x01	0x18	0x49			



							X:Beta: <mark>0x07</mark> (All axis)		
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x21 Error code: 0x00	0x	0x
Conv Pasta version of the command: "7565 0D0/ 0/21 0107 18/0"									

Copy-Paste version of the command: "7565 0D04 0421 0107 1849"

4.3.23 Co	8 Commanded Zero-Angular Rate Update (0x0D, 0x23)										
Description	Perfor	Perform a commanded zero-angular rate update.									
Notes	The ma	he maximum rate for this message is 10 Hz.									
Field Format	Field Le	ength	Field Desc	criptor	Field Data						
Command	0x02		0x23		N/A						
Reply Field : ACK/ NACK	0x04		0xF1	0xF1 U8 - Echo the command byte U8 - Error code (0: ACK, non-zero: NACK)							
		MIP Pacl	ket Hea	lder	Command/Reply Fields Checksu				ksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB		
Command	0x75	0x65	0x0D	0x02	0x02	0x23		0x0E	0x18		
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x23 Error code: 0x00	0x03	0xF6		
Copy-Paste version of the command: "7565 0D02 0223 0E18"											



4.3.24 Dec	lination S	ation Source (0x0D, 0x43)									
	Set/Get t	he local declina	ation angle source.								
	This can device re ation ang	This can be used to correct for the difference in magnetic and true north. Normally, the device reports heading with-respect-to magnetic north, but when an accurate declin- ation angle is provided, the device will report heading with respect to true north.									
	Possible	Possible function selector values:									
		0x01 - Use new 0x02 - Read ba 0x03 - Save cu 0x04 - Load sav 0x05 - Reset to	v settings ck current settings. rrent settings as startup settings ved startup settings factory default settings								
Description	Possible	declination sou	irces:								
		0x01 - None 0x02 - World Magnetic Model (Default) 0x03 - Manual									
	Option de	Option description:									
		 None: orientation information will be reported with respect to magnetic north. World Magnetic Model: The declination will be sourced from the device's internal world magnetic model. Manual: The user provides the declination angle. The device does not validate this angle and it is therefore up to the user to select the correct value. 									
Field Format	Field Length	Field Descriptor	Field Data								
Command	0x08	0x43	U8 - Function Selector U8 - Declination Source Float - Manual Declination angle (radians, only required if source = Manual)								
Reply Field 1: ACK/ NACK	0x04	0x04 0xF1 U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)									
Reply Field 2: Function = 2	0x07	07 0xB2 U8 - Declination Source Float - Declination angle (radians)									



	l	MIP Pac	ket Hea	der	С	command	Checksum		
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command	0x75	0x65	0x0D	0x08	0x08	0x43	Fctn 0x01 (Apply): 0x01 Source 0x03 (Manual): 0x00000000 Angle: 0x00000000 (0.0f)	0x3E	0xC7
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x43 Error code: 0x00	0x23	0x36
Copy-Paste version	on of the	comman	ıd: N/A						



4.3.25 Incl	ination So	urce (0x0D,	0x4C)
Description	Set/Get t This can netic field performa ation ang off. Possible Possible	he local inclinate be used to correct I. Having a correct ince of the auto- le source, it is rect function selected 0x01 - Use new 0x02 - Read bac 0x03 - Save cur 0x04 - Load sav 0x05 - Reset to inclination sour 0x01 - None 0x02 - World Ma 0x03 - Manual escription: None: No inclin World Magnetic internal world me Manual: The us	tion angle source. ect for the local value of inclination (dip angle) of the earth mag- rect value for inclination (and declination) is important for best mag calibration feature. If you do not have an accurate inclin- recommended that you leave the auto-mag calibration feature or values: • settings ck current settings. rent settings as startup settings ved startup settings factory default settings rece: agnetic Model (Default) ation angle corrections are attempted. c Model: The inclination will be sourced from the device's hagnetic model. ser provides the inclination angle. The device does not gle and it is therefore up to the user to select the correct
Field Format	Field Length	Field Descriptor	Field Data
Command	0x08	0x4C	U8 - Function Selector U8 - Inclination Source Float - Manual Inclination angle (radians, only required if source = Manual)
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)
Reply Field 2: Function = 2	0x07	0xBC	U8 - Inclination Source Float - Inclination angle (radians)



Γ

Example		MIP Pac	ket Hea	ıder	C	Checksum			
	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command	0x75	0x65	0x0D	0x08	0x08	0x4C	Fctn 0x01 (Apply): Source 0x03 (Manual): Angle: 0x00000000 (0.0f)	0x47	0x06
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x4C Error code: 0x00	0x2C	0x48
Copy-Paste versi	on of the	comman	d: N/A						

4.3.26 M	agnetic Field Magnitude Source (0x0D, 0x4D)
4.3.26 M	Agnetic Field Magnitude Source (0x0D, 0x4D) Set/Get the local magnetic field magnitude source. This is used to specify the local magnitude of the earth's magnetic field. It is important for best performance of the auto-mag calibration feature and for the magnetometer adaptive magnitude. If you do not have an accurate value for the local magnetic field magnitude, it is recommended that you leave the auto-mag calibration feature off. Possible function selector values: 0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings 0x01 - None 0x02 - World Magnetic Model (Default) 0x03 - Manual 0ption description: None: A fixed value of 0.5 Gauss is used. World Magnetic Model. The magnitude will be sourced from the device's internal world magnetic model. Manual: The user provides the magnitude. The device does not constrain Device does not constrain
	this value and it is therefore up to the user to select an accurate value.



Field Format	Field	Length	Field Descript	tor	Field Data								
Command	0x08		0x4D	0x4D		U8 - Function Selector U8 - Magnetic Field Magnitude Source Float - Manual Magnitude (Gauss, only required if source = Manual)							
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - U8 -	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)							
Reply Field 2: Function = 2	0x07		0xBD		U8 - Floa	U8 - Inclination Source Float - Magnitude (Gauss)							
	MIP Packet Header					С	command	I/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Pay Ler	load ngth	Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	0x65	0x0D	0x08		0x08	0x4D	Fctn 0x01 (Apply): 0x03 (Manual): 0x3F000000 Angle: (0.0f)	0x87	0x09			
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x	04	0x04	0xF1	Echo cmd: 0x4D Error code: 0x00	0x2D	0x4A			
Copy-Paste versio	n of the	comma	and: 7565	0D08	8 084D	0103 3F0	0 0000 8	709					



4.3.27 Gi	ravity Magnit	ude Error A	daptive Measurement (0x0D, 0x44)								
	Enable or disa tion can be us	able the gravity ed to tune the	¹ magnitude error adaptive measurement feature. This func- filter performance in the target application.								
	Possible function selector values:										
	0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings										
	Possible adap	otive measurer	nent selector values:								
Description	0x00 - No adaptive measurement (disable) 0x01 - Enable fixed adaptive measurement (use specified limits) 0x02 - Enable auto adaptive measurement ²										
	Filter and limit parameters (only used for enable option 1):										
	Pick values that give you the least occurrence of invalid EF attitude output. The default values are good for standard low vibration applications. Increase values for higher vibration conditions, lower values for lower vibration. Too low a value will result in excessive heading errors. Higher values increase pitch and roll errors when undergoing linear accelerations.										
	Adaptive measurements can be enabled/disabled without the need for providing the addi- tional parameters. In this case, only the function selector and enable value are required; all other parameters will remain at their previous values. When "auto-adaptive" is selected, the filter and limit parameters are ignored. Instead, aiding measurements which rely on the gravity vector will be automatically reweighted by the Kalman filter according to the per- ceived measurement quality.										
Notes	1. This comm urement."	and is also refe	erred to as "Accelerometer Magnitude Error Adaptive Meas-								
	2. Enable opti	on 2 (auto-ada	ptive) is only available on 3DM-CV5 and later.								
Field Format	Field Length	Field Descriptor	Field Data								
Command	0x1C	0x44	U8 - Function Selector U8 - Disable/Fixed/Auto Float - Low-pass filter cutoff frequency (Hz) Float - Low Limit (meters/second ²) Float - High Limit (meters/second ²) Float - Low Limit Uncertainty, 1-Sigma (meters/second ²)								



					Float - High Limit Uncertainty, 1-Sigma (meters/second ²) Float - Minimum Uncertainty, 1-Sigma (meters/second ²)								
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - I U8 - I	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)							
Reply Field 2: Function = 2	0x1B		0xB3		U8 - I Float Float Float Float Float	U8 - Enable (0 - Disable, 1 - Enable) Float - Low-pass filter cutoff frequency (Hz) Float - Low Limit (meters/second ²) Float - High Limit (meters/second ²) Float - Low Limit Uncertainty, 1-Sigma (meters/second ²) Float - High Limit Uncertainty, 1-Sigma (meters/second ²) Float - Minimum Uncertainty, 1-Sigma (meters/second ²)							
		MIP Pa	cket Hea	der		C	Command	/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Payload Length		Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	0x65	0x0D	0x1C		0x1C	0x44	Fctn (Apply): 0x01 Enable: 0x01 Freq (Hz): (1.0f) Low Limit: (-0.2f) High Limit: (0.2f) Low Limit 1-sigma: (0.2f) High Limit 1-sigma: (0.004f)	-	-			
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0)	‹04	0x04	0xF1	Echo cmd: 0x44 Error code: 0x00	0xB2	0xE2			



4.3.28 M	lagnetometer	[.] Magnitude	Error Adaptive Measurement (0x0D, 0x45)							
	Enable or disa will reject may adaptive) or c	able the magne gnetometer rea alculated interr	tometer magnitude error adaptive measurement. This feature dings that are out of range of the thresholds specified (fixed nally (auto-adaptive).							
	Possible func	tion selector va	alues:							
	0x01 0x02 0x03 0x04 0x04	0x01 - Use new settings 0x02 - Read back current settings. 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings								
	Possible adap	Possible adaptive measurement selector values:								
Description	0x00 - No adaptive measurement (disable) 0x01 - Enable fixed adaptive measurement (use specified limits) 0x02 - Enable auto adaptive measurement ¹									
	Filter and limit parameters (only used for enable option 1):									
	Pick values that give you the least occurrence of invalid EF attitude output. The default values are good for standard low dynamics applications. Increase values for higher dynamic conditions, lower values for lower dynamic. Too low a value will result in excess- ive heading errors. Higher values increase heading errors when undergoing magnetic field anomalies caused by DC currents, magnets, steel structures, etc.									
	Auto-adaptive parameters. I parameters w and limit para netometers w ceived measu	Auto-adaptive measurements can be enabled without the need for providing the additional parameters. In this case, only the function selector and enable value are required; all other parameters will remain at their previous values. When "auto-adaptive" is selected, the filter and limit parameters are ignored. Instead, aiding measurements which rely on the magnetometers will be automatically re-weighted by the Kalman filter according to the perceived measurement quality.								
Notes	1. Enable valu	ue 2 (auto-adap	tive) is only available on 3DM -CV5 and later devices.							
Field Format	Field Length	Field Descriptor	Field Data							
Command	0x1C	0x45	U8 - Function Selector U8 - Disable/Fixed/Auto Float - Low-pass filter cutoff frequency (Hz) Float - Low Limit (meters/second ²) Float - High Limit (meters/second ²) Float - Low Limit Uncertainty, 1-Sigma (meters/second ²)							



			Float - High Limit Uncertainty, 1-Sigma (meters/second ²) Float - Minimum Uncertainty, 1-Sigma (meters/second ²)						ld ²) 1 ²)				
Reply Field 1: ACK/ NACK	0x04		0xF1		U8 - U8 -	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)							
Reply Field 2: Function = 2	0x1B		0xB4		U8 - Floa Floa Floa Floa Floa	U8 - Enable (0 - Disable, 1 - Enable) Float - Low-pass filter cutoff frequency (Hz) Float - Low Limit (Gauss) Float - High Limit (Gauss) Float - Low Limit Uncertainty, 1-Sigma (Gauss) Float - High Limit Uncertainty, 1-Sigma (Gauss) Float - Minimum Uncertainty, 1-Sigma (Gauss)							
	MIP Packet Header					c	command	/Reply Fields	Chec	ksum			
Example	Sync1	Sync2	Desc. Set	Payload Length		Field Length	Field Desc.	Field Data	MSB	LSB			
Command	0x75	0x65	0x0D	0x1C		0x1C	0x45	Fctn (Apply): 0x01 Enable: 0x01 Freq (Hz): (1.0f) Low Limit: (-0.2f) High Limit: (0.2f) Low Limit 1-sigma: (0.2f) High Limit 1-sigma: (0.004f)	-	-			
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x	04	0x04	0xF1	Echo cmd: 0x45 Error code: 0x00	0xB3	0xE4			



4.3.29 M	agnetometer l	Dip Angle Er	ror Adaptive Measurement (0x0D, 0x46)					
	Enable or disat will reject magr	ble the magnetor netometer readir	meter magnitude error adaptive measurement. This feature ngs that are out of range of the thresholds specified ¹ .					
	Possible functi	on selector valu	es:					
Description	0x01 - 0x02 - 0x03 - 0x04 - 0x05 - Possible adapt 0x00 - 0x01 - Filter and limit p	Use new setting Read back curr Save current se Load saved sta Reset to factor ive enable option No adaptive me Enable fixed ad	gs ent settings. ettings as startup settings rtup settings y default settings ns: easurement (disable) laptive measurement (use specified limits)					
	Pick values that give you the least occurrence of invalid EF attitude output. The default values are good for standard low dynamics applications. Increase values for higher dynamic conditions, lower values for lower dynamic. Too low a value will result in excess-ive heading errors. Higher values increase heading errors when undergoing magnetic field anomalies caused by DC currents, magnets, steel structures, etc.							
Notes	1. The magneton netometer mag	ometer dip angle nitude or auto-a	adaptive measurement is ignored if the auto-adaptive mag- daptive accel magnitude options are selected.					
Field Format	Field Length	Field Descriptor	Field Data					
Command	0x14	0x46	U8 - Function Selector U8 - Enable (0 - Disable, 1 - Enable) Float - Low-pass filter cutoff frequency (Hz) Float - High Limit (Radians) Float - High Limit Uncertainty, 1-Sigma (Gauss) Float - Minimum Uncertainty, 1-Sigma (Gauss)					
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)					
Reply Field 2: Function = 2	0x13	0xB5	U8 - Enable (0 - Disable, 1 - Enable) Float - Low-pass filter cutoff frequency (Hz) Float - High Limit (Radians) Float - High Limit Uncertainty, 1-Sigma (Gauss) Float - Minimum Uncertainty, 1-Sigma (Gauss)					



Example	l	MIP Pac	ket Hea	der	С	Checksum			
	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command	0x75	0x65	0x0D	0x14	0x14	0x46	Fctn (Apply): 0x01 Enable: 0x01 Freq (Hz) (10.0f) High Limit (rad): (0.3f) High Limit 1-sigma: Min 1-sigma: (0.01f)	-	-
Reply Field 1: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x46 Error code: 0x00	0xB4	0xE6



4.3.30 Ma	agneto	meter (Captur	e Auto C	alibratio	n (0x0E), 0x27)			
Description	This co fixed h soft iro This m such a Functio	This command captures the current value of the auto-calibration, applies it to the current fixed hard and soft iron calibration coefficients, and replaces the current fixed hard and soft iron calibration coefficients with the new values. This may be used in place of (or in addition to) a manual hard and soft iron calibration utility such as <i>MIP Iron Calibration</i> . This command also resets the auto-calibration coefficients. Function selector values: 0x01 - Capture and use new settings 0x03 - Save current settings as startup settings ¹								
Notes	1. This is the same as issuing the 0x0C, 0x3A and 0x0C, 0x3B commands with the "0x03 - Save current settings as startup settings" function selector.									
Field Format	Field Length Field Descriptor			Field Data						
Command	0x27		0x27		U8 - Function Selector					
Reply Field: ACK/ NACK	0x04		0xF1		U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)					
		MIP Pac	ket Hea	der	C	command	/Reply Fields	Chec	ksum	
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB	
Command	0x75	0x65	0x0D	0x02	0x02	0x27	Selector: 01	0x15	0x36	
Reply Field: ACK/NACK	0x75	0x65	0x0D	0x04	0x04	0xF1	Echo cmd: 0x27 Error code: 0x00	0x95	0xA8	
Copy-Paste versi	on of the	comman	d: "756	5 0D03 032	7 0115 36"					


4.4 System Commands

The System Command set provides a set of advanced commands that are specific to devices such as the 3DM-CV5-25 that have multiple intelligent internal sensor blocks. These commands allow special modes such as talking directly to the native protocols of the embedded sensor blocks. For example, with the 3DM-CV5-25, you may switch into a mode that talks directly to another LORD Sensing Inertial Sensor with an internal IMU.

4.4.1 Cor	າຫເ	unication N	/lode (0x7F, 0	x10) Advanced			
	Ad	vanced spec	ialized communio	cation modes.			
	Th "Se jus ting	is will change ensor Direct" en when swit t prior to swit gs), the new	e the communicat (MIP IMU protoc sched to the direct tching to the new communications	tions protocol to and from "Estimation Filter"mode to ol for the 3DM-CV5-25). This command is always active, t modes. This command responds with an ACK/NACK protocol. For all functions except 0x01 (use new set- mode value is ignored.			
	Po	ssible functio	on selector values	5:			
Deceription		UxU1 - Apply new settings					
Description		0x03 - Save current settings as startup settings					
	0x04 - Load saved startup settings						
	0x05 - Reset to factory default settings						
	Possible Communications Modes:						
	Value Mode		Mode	Protocol(s)			
		0x01	Standard	3DM-CV5-25 MIP Packet (default)			
		0x02	Sensor Direct	MIP IMU			
		0x03	GNSS Direct	NMEA, UBX (GNSS Models only)			
Field Format	Fiel	ld Length	Field Descriptor	Field Data			
Command	0x04 0x10		0x10	U8 - Function selector U8 - New Communications Mode			
Reply Field 1: ACK/ NACK	0x0	4	0xF1	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)			





Reply Field 2:

Function = 2

Freemale	MIP Packet Header				(Checksum			
Example	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Field Desc.	Field Data	MSB	LSB
Command	0x75	0x65	0x7F	0x04	0x04	0x10	Fctn (USE): 0x01 New mode (IMU direct):	0x74	0xBD
Reply Field 1: ACK/NACK	0x75	0x65	0x7F	0x04	0x04	0xF1	Echo cmd: 0x10 Error code: 0x00	0x62	0x7C
Copy-Paste version	Copy-Paste version of the command: "7565 7F04 0410 0102 74BD"								

4.5 Error Codes

Error Name	Error Value	Description
MIP Unknown Command	0x01	The command descriptor is not supported by this device
MIP Invalid Checksum	0x02	An otherwise complete packet has a bad checksum
MIP Invalid Parameter	0x03	One or more parameters in the packet are invalid. This can refer to a value that is outside the allowed range for a command or a value that is not the expected size or type
MIP Command Failed	0x04	Device could not complete the command
MIP Command Timeout	0x05	Device could not complete the command within the expected time



5. Data Reference

5.1 IMU Data

5.1.1 Scaled Accelerometer Vector (0x80, 0x04)									
Description	Scaled Acce	Scaled Accelerometer Vector							
Notes	This is a vect 3DM-CV5-2 scaled into p the 3DM-CV	This is a vector quantifying the direction and magnitude of the acceleration that the 3DM-CV5-25 is exposed to. This quantity is fully temperature compensated and scaled into physical units of g (1 g = 9.80665 m/sec^2). It is expressed in terms of he 3DM-CV5-25's local coordinate system.							
	Field Length	Data Descriptor	Message Dat	а					
Field Format			Binary Off- set	Description	Data Type	Units			
	14 (0x0E)	0x04	0	X Accel	float	g			
			4	Y Accel	float	g			
			8	Z Accel	float	g			

5.1.2 Sc	aled Gyro \	/ector (0x80	, 0x05)				
Description	Scaled Gyr	caled Gyro Vector					
Notes	This is a ve This quanti ans/second	This is a vector quantifying the rate of rotation (angular rate) of the 3DM-CV5-25. This quantity is fully temperature compensated and scaled into units of radi- ans/second. It is expressed in terms of the 3DM-CV5-25's local coordinate system.					
	Field Length	Data Descriptor	Message Data				
Field Format			Binary Offset	Description	Data Type	Units	
	14 (0x0E)	0x05	0	X Gyro	float	Radians/second	
			4	Y Gyro	float	Radians/second	
			8	Z Gyro	float	Radians/second	



5.1.3 Scaled Magnetometer Vector (0x80, 0x06)								
Description	Scaled Magr	Scaled Magnetometer Vector						
Notes	This is a vect nitude. This o Gauss. It is e	his is a vector which gives the instantaneous magnetometer direction and mag- itude. This quantity is fully temperature compensated and scaled into units of Gauss. It is expressed in terms of the 3DM-CV5-25's local coordinate system.						
	Field Length	Data Descriptor	Message Data					
Field Format			Binary Offset	Description	Data Type	Units		
	14 (0x0E)	0x06	0	X Mag	float	Gauss		
			4	Y Mag	float	Gauss		
			8	Z Mag	float	Gauss		

5.1.4 Scaled Ambient Pressure (0x80, 0x17)							
Description	Scaled Ambi	Scaled Ambient Vector					
Notes	This is a scal ity is fully terr	This is a scalar which gives the instantaneous ambient pressure reading. This quant- ity is fully temperature compensated and scaled into units of milliBar.					
	Field Length	Data Descriptor	Message Data				
Field Format	22 (2, 22)	0x17	Binary Offset	Description	Data Type	Units	
	00 (0x00)		0	Ambient Pressure	float	milliBar	



5.1.5 Delta Theta Vector (0x80, 0x07)								
Description	Time integra	ime integral of angular rate.						
Notes	This is a vect the IMU mes local coordin	his is a vector which gives the time integral of angular rate over the interval set by the IMU message format command. It is expressed in terms of the 3DM-CV5-25's succeal coordinate system in units of radians.						
	Field Length	Data Descriptor	Message Data					
Field Format			Binary Offset	Description	Data Type	Units		
	14 (0x0E)	0x07	0	X Delta Theta	float	radians		
			4	Y Delta Theta	float	radians		
			8	Z Delta Theta	float	radians		

5.1.6 Delta Velocity Vector (0x80, 0x07)							
Description	Time integra	ime integral of acceleration.					
Notes	This is a vect set by the IM CV5-25's loc itational cons m/sec, simply	This is a vector which gives the time integral of specific acceleration over the interval tet by the IMU message format command. It is expressed in terms of the 3DM- 2V5-25's local coordinate system in units of g*second where g is the standard grav- cational constant. To convert Delta Velocity into the more conventional units of n/sec, simply multiply by the standard gravitational constant, 9.80665 m/sec ² .					
	Field Length	Data Descriptor	Message	e Data			
Field Format			Binary Offset	Description	Data Type	Units	
	14 (0x0E)	0x08	0	X Delta Velocity	float	g*seconds	
			4	Y Delta Velocity	float	g*seconds	
			8	Z Delta Velocity	float	g*seconds	



5.1.7 CF	Orientatio	n Matrix (0x80,	0x09)					
D	3 x 3 Orienta	ation Matrix <i>M</i> .						
Description	This value is produced by the Complementary Filter fusion algorithm.							
	This is a nine entation of t	e component coc he 3DM-CV5 wit	ordinate trans h respect to t	formation matrix he fixed earth coc	which descril ordinate syste	pes the ori- em.		
		$M = \begin{bmatrix} M_{1,1} & M_{1,2} & M_{1,3} \\ M_{2,1} & M_{2,2} & M_{2,3} \\ M_{3,1} & M_{3,2} & M_{3,3} \end{bmatrix}$						
Notes	<i>M</i> satisfies t	he following equa	ation:					
			V_IL _i = I	M _{ij} · V_E _j				
	Where:							
	 V_IL is a vector expressed in the 3DM-CV5's local coordinate system. V_E is the same vector expressed in the stationary, earth-fixed coordinate system 							
	Field Length	Data Descriptor	Message Da	ata				
			Binary Off- set	Description	Data Type	Units		
			0	M _{1,1}	Float	N/A		
			4	M _{1,2}	Float	N/A		
Field Format			8	M _{1,3}	Float	N/A		
	38 (0x26)	0x09	12	M _{2,1}	Float	N/A		
			16	M _{2,2}	Float	N/A		
			20	M _{2,3}	Float	N/A		
			24	M _{3,1}	Float	N/A		
			28	M _{3,2}	Float	N/A		



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5.1.7 CF	Orientatior	n Matrix (0x80,	0x09)			
			32	M _{3,3}	Float	N/A



5.1.8 CF	Quaternion	(0x80, 0x0A)						
Description	4 x 1 quaternion Q.							
Description	This value is produced by the Complementary Filter fusion algorithm.							
Notes	This is a four CV5 with res	component qua spect to the fixed	ternion which earth coordin	describes the orienter ate system.	entation of th	e 3DM-		
			$Q = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$	q0 q1 q2 q3				
	Q satisfies the following equation:							
	$V_IL_i = Q^{-1} \cdot V_E \cdot Q$							
	Where:							
	V_IL is a vector expressed in the 3DM-CV5's local coordinate system.							
	V c	'_E is the same oordinate system	e vector expro	essed in the stati	onary, earth	n-fixed		
	Field Length	Data Descriptor	Message Da	ta				
			Binary Off- set	Description	Data Type	Units		
Field Format			0	q ₀	Float	N/A		
	18 (0x12)	0x0A	4	q ₁	Float	N/A		
			8	q ₂	Float	N/A		
			12	q ₃	Float	N/A		



5.1.9 CF Euler Angles (0x80, 0x0C)						
Description	Pitch, Roll, a	and Yaw (aircraft) values.			
Description	This value is	s produced by the	Compleme	ntary Filter fusion	algorithm.	
Notes	This is a three component vector containing the Roll, Pitch and Yaw angles in radians. It is computed by the IMU/AHRS from the orientation matrix <i>M</i> . $Euler = \begin{bmatrix} Roll \\ Pitch \\ Yaw \end{bmatrix}$					
	Field Length	Data Descriptor	Message Da	ata		
Field Format			Binary Offset	Description	Data Type	Units
	14 (0x0E)	0x0C	0	Roll	Float	Radians
			4	Pitch	Float	Radians
			8	Yaw	Float	Radians



5.1.10 CF Stabilized North Vector (0x80, 0x10)						
Description	Gyro stabiliz	ed estimated ve	ector for geom	agnetic vector.		
·	This value is	This value is produced by the Complementary Filter fusion algorithm.				
Notes	This is a vector which represents the complementary filter's best estimate of the geo- magnetic field direction (magnetic north). In the absence of magnetic interference, it should be equal to <i>Magnetometer</i> . When transient magnetic interference is present, <i>Magnetometer</i> will be subject to transient (possibly large) errors. The IMU/AHRS complementary filter computes <i>Stabilized North</i> which is its estimate of the geo- magnetic field vector only, even thought the system may be exposed to transient magnetic interference. Note that sustained magnetic interference cannot be adequately compensated for by the complementary filter.					
	Field Length	Data Descriptor	Message Dat	а		
Field Format			Binary Offset	Description	Data Type	Units
	14 (0x0E)	0x10	0	X Stab Mag	Float	Gauss
			4	Y Stab Mag	Float	Gauss
			8	Z Stab Mag	Float	Gauss



5.1.11 CF Stabilized Up Vector (0x80, 0x11)						
Description	Gyro stabiliz	ed estimated ve	ector for the gr	avity vector.		
Decemption	This value is	produced by th	e Complemer	ntary Filter fusior	n algorithm.	
Notes	This is a vect ate of the ver In dynamic c well as linear its estimate c exposed to s	This is a vector which represents the IMU/AHRS complementary filter's best estim- ate of the vertical direction. Under stationary conditions, it should be equal to Accel. In dynamic conditions, Accel will be sensitive to both gravitational acceleration as well as linear acceleration. The Complementary filter computes Stab Accel which is its estimate of the gravitation acceleration only, even thought the system may be exposed to significant linear acceleration.				
	Field Length	Data Descriptor	Message Dat	а		
Field Format		Binary Offset	Description	Data Type	Units	
	14 (0x0E)	0x11	0	X Stab Accel	Float	G
			4	Y Stab Accel	Float	G
			8	Z Stab Accel	Float	G



5.1.12 G	PS Correlat	tion Timestar	np (0x80, 0>	(12)			
Description	GPS correla	GPS correlation timestamp.					
	This timestamp has three fields:						
	Dou U16 U16	ble GPS TOW GPS Week nu Timestamp flag	mber gs				
	Timestamp	Status Flags:					
Notes	Bit0 Bit1 Bit2 GPS This timestan the GPS Time for a correlated. T each time the (regains sign remain set. The "PPS Bo beacon com IMU internal TOW repress If the GPS los slowly drift a there will be ing the amou	 I imestamp Status Flags: Bit0 - PPS Beacon Good If set, PPS signal is present Bit1 - GPS Time Refresh (toggles with each refresh) Bit2 - GPS Time Initialized (set with the first GPS Time Refresh) (<i>See GPS Time Update (0x01, 0x72) on page 40</i>) This timestamp correlates the IMU packets with the GPS packets. It is identical to the GPS Time record except the flags are defined specifically for the IMU. When the GPS Time Initialized flag is asserted, the GPS Time and IMU GPS Timestamp are correlated. This flag is only set once upon the first valid GPS Time record. After that, each time the GPS Time becomes invalid (from a lack of signal) and then valid again (regains signal) the GPS Time Refresh flag will toggle. The GPS Time Initialized will remain set. The "PPS Beacon Good" flag in the Timestamp flags byte indicates if the PPS beacon coming from the GPS is present. If this flag is not asserted, it means that the IMU internal clock is being used for the PPS. The fractional portion of the GPS TOW represents the amount of time that has elapsed from the last PPS. If the GPS loses signal, the GPS and IMU timestamps become free running and will slowly drift away from each other. If the timestamp clocks have drifted apart, then there will be a jump in the timestamp when the PPS Beacon Good reasserts, reflect- 					
	timestamps.						
	Field Length	Data Descriptor	Message Dat	a			
Field Format			Binary Offset	Description	Data Type	Units	
	14 (0x0E)	0x12	0	GPS Time of Week	Double	Seconds	
			8	GPS Week	U16	N/A	



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5.1.12 GPS Correlation Timestamp (0x80, 0x12)						
				Number		
			10	Timestamp Flags	U16	See Notes



5.2 Estimation Filter Data

5.2.1 Filt	ter Status (0x82, 0x10)					
Description	Estimation Filter Status					
	Possible Filter States:					
	0x00 - Startup 0x01 - Initialization (see status flags) 0x02 - Running, Solution Valid 0x03 - Running, Solution Error (see status flags)					
	Possible Dynamics Modes:					
	0x01 - Portable 0x02 - Automotive 0x03 - Airborne					
	Possible Status Flags:					
	Filter State = Initialization:					
	0x1000 - Attitude not initialized 0x2000 - Position & Velocity not initialized					
Notes	Filter State = Running:					
	0x0001 - IMU unavailable 0x0002 - GNSS (GNSS versions only) 0x0008 - Matrix singularity in calculation 0x0010 - Position covariance high warning* 0x0020 - Velocity covariance high warning* 0x0040 - Attitude covariance high warning* 0x0080 - NAN in solution 0x0100 - Gyro bias estimate high warning 0x0200 - Accel bias estimate high warning 0x0400 - Gyro scale factor estimate high warning 0x0800 - Accel scale factor estimate high warning 0x1000 - Mag bias estimate high warning 0x4000 - Hard Iron offset estimate high warning 0x8000 - Soft iron correction estimate high warning					
	*Note: The covariance high warnings are triggered when any axis of the covariance vector exceeds normal operating limits. If more information is required, please					



5.2.1 Filter Status (0x82, 0x10)								
	inspect the r	nspect the relevant uncertainty packet to determine which axis is in error.						
	Field Length	Data Descriptor	Message Data					
	08 (0x08) 0x		Binary Offset	Description Data Type	Units			
Field Format		0x10	0 Filter State U16	U16	See Notes			
			2	Dynamics Mode U16	U16	See Notes		
			4	Status Flags	U16	See Notes		

5.2.2 GPS Timestamp (0x82, 0x11)						
Description	Estimation F	Filter Calculated	/alue Time	stamp Data		
Notes	Valid Flag M 0x0 0x0	′alid Flag Mapping: 0x0000 - Time Invalid 0x0001 - Time Valid				
	Field Length	Data Descriptor	Message L	Data		
Field Format			Binary Offset	Description	Data Type	Units
	14 (0x0E)	0x11	0	Time of Week	Double	Seconds
			8	Week Number	U16	N/A
		10	Valid Flags	U16	See Notes	



5.2.3 Or	Orientation, Quaternion (0x82, 0x03)					
Description	Estimated O	rientation in qua	aternion form.			
	This is a four CV5 with res	component qua spect to the fixed	aternion whic d earth coordi	h describes the on a the system.	prientation of	the 3DM-
		$Q = \begin{bmatrix} q 0\\ q 1\\ q 2\\ q 3 \end{bmatrix}$				
Q satisfies the following equation:						
Notes	$V_IL_i = Q \cdot V_E \cdot Q^{-1}$					
	Where:					
	V sj V c	 V_IL is a vector expressed in the 3DM-CV5's local coordinate system. V_E is the same vector expressed in the stationary, earth-fixed coordinate system 				
	Valid Flag M	Valid Flag Mapping:				
	0x00 0x00	000 - Quaternion 101 - Quaternion	n is Invalid n Valid			
	Field Length	Data Descriptor	Message Dat	a		
			Binary Offset	Description	Data Type	Units
Field Format			0	q ₀	Float	N/A
	20 (0x14)	0x03	4	q ₁ *i	Float	N/A
			8	q ₂ *j	Float	N/A
			12	q ₃ *k	Float	N/A
			16	Valid Flags	U16	See Notes



5.2.4 Att	itude Unce	rtainty, Quat	ernion Ele	ments (0x82, 0x12)			
Description	Estimated a	attitude 1-sigma	a uncertainty	expressed in quatern	ion compon	ents.	
	This is a thr quaternion	ee component elements.	vector conta	aining the attitude unce	ertainty expre	essed in	
Notes	Valid Flag Mapping:						
	0x0000 - Attitude uncertainties are Invalid 0x0001 - Attitude uncertainties are Valid Field Data Length Descriptor Message Data						
	Field Length	Data Descriptor	Message Data				
	20 (0x14) 0		Binary Offset	Description	Data Type	Units	
			0 1-Sigma Attitude Uncertainty (q ₀) Flo	Float			
Field Format		0x12	4	1-Sigma Attitude Uncertainty (q ₁)	Float		
			8	1-Sigma Attitude Uncertainty (q ₂)	Float		
			12	1-Sigma Attitude Uncertainty (q ₃)	Float		
			16	Valid Flags	U16	See Notes	



5.2.5 Orientation, Euler Angles (0x82, 0x05)						
Description	Estimated F	Pitch, Roll, and Ya	aw (aircraft) v	alues.		
	This is a thre ans. It is cor	ee component ve nputed by the INS	ctor containin S from the or	ng the Roll, Pitch a ientation quaterni	and Yaw ar on <i>Q</i> .	ngles in radi-
Notes	$Euler = \begin{bmatrix} Roll \\ Pitch \\ Yaw \end{bmatrix}$ Valid Flag Mapping: 0x0000 - Euler Angles are Invalid 0x0001 - Euler Angles Valid					
	Field Length	Data Descriptor	Message Da	ota		
			Binary Offset	Description	Data Type	Units
Field Format			0	Roll	Float	Radians
	16 (0x10)	0x05	4	Pitch	Float	Radians
			8	Yaw	Float	Radians
		12	Valid Flags	U16	See Notes	



5.2.6 Attitude Uncertainty, Euler Angles (0x82, 0x0A)							
Description	Estimated attitude 1-sigma uncertainty expressed in Pitch, Roll, and Yaw (aircraft) elements.						
This is a three component vector containing the Roll, Pitch and Yaw angle unce tainties in radians. IMPORTANT: These values are derived from the quaternion elements and become increasingly inaccurate as the pitch angle approaches +-90 degrees. T						gle uncer- and	
Notes	compensate for this limitation, these values will be marked as invalid when the pi angle exceeds +-70 degrees.						
	Valid Flag Mapping:						
0x0000 - Attitude Uncertainties are Invalid 0x0001 - Attitude Uncertainties Valid							
	Field Length	Data Descriptor	Message Data				
			Binary Offset	Description	Data Type	Units	
Field Format			0	1-Sigma Attitude Uncertainty (Roll)	Float	Radians	
	16 (0x10)	0x0A	4	1-Sigma Attitude Uncertainty (Pitch)	Float	Radians	
			8	1-Sigma Attitude Uncertainty (Yaw)	Float	Radians	
			12	Valid Flags	U16	See Notes	



5.2.7 Or	ientation, Ma	atrix (0x82, 0	x04)			
Description	Estimated or	ientation in ma	trix form.			
	This is a nine component coordinate transformation matrix which describes the entation of the 3DM-CV5 with respect to the fixed earth coordinate system.					
			$M = \begin{bmatrix} M_{1,1} \\ M_{2,1} \\ M_{3,1} \end{bmatrix}$	$\begin{bmatrix} M_{1,2} & M_{1,3} \\ M_{2,2} & M_{2,3} \\ M_{3,2} & M_{3,3} \end{bmatrix}$		
	M satisfies the following equation:					
			V_IL _i =	M _{ij} · V_E _j		
Notes	Where:					
	 V_IL is a vector expressed in the 3DM-CV5's local coordinate system. V_E is the same vector expressed in the stationary, earth-fixed coordinate system 					
	Valid Flag Mapping:					
	0x0000 - Orientation Matrix is Invalid 0x0001 - Orientation Matrix Valid					
	Field Length	Data Descriptor	Message Dat	a		
			Binary Offset	Description	Data Type	Units
			0	M _{1,1}	Float	N/A
Field Format			4	M _{1,2}	Float	N/A
	40 (0x28)	0x04	8	M _{1,3}	Float	N/A
			12	M _{2,1}	Float	N/A
			16	M _{2,2}	Float	N/A
			20	M _{2,3}	Float	N/A
			24	M _{3,1}	Float	N/A



5.2.7 Orientation, Matrix (0x82, 0x04)								
			28	M _{3,2}	Float	N/A		
			32	M _{3,3}	Float	N/A		
			36	Valid Flags	U16	See Notes		

5.2.8 Compensated Angular Rate (0x82, 0x0E)							
	Filter-Comp	Filter-Compensated Angular Rate Data expressed in:					
Description		 The Se defined The Ve defined 	nsor Frame, hicle Frame,	if no sensor to b if a sensor to bo	ody rotation	has been has been	
Notes	The estimate Valid Flag M 0x00 0x00	The estimated gyro bias has been removed from these angular rate values. Valid Flag Mapping: 0x0000 - Angular Rates are not Valid 0x0001 - Angular Rates are Valid					
	Field Length	Data Descriptor	Message Da	nta			
			Binary Offset	Description	Data Type	Units	
Field Format			0	Х	Float	Radians/Sec	
	16 (0x10)	0x0E	4	Y	Float	Radians/Sec	
			8	Z	Float	Radians/Sec	
		12	Valid Flags	U16	See Notes		



5.2.9 Gyro Bias (0x82, 0x06)							
Description	Estimated (Estimated Gyro Biases expressed in the Sensor Body Frame.					
Notes	Valid Flag M 0x0 0x0	/alid Flag Mapping: 0x0000 - Gyro Bias are Invalid 0x0001 - Gyro Bias Valid					
	Field Length	Data Descriptor	Message Data				
			Binary Offset	Description	Data Type	Units	
Field Format			0	X Gyro Bias	Float	Radians/Sec	
	16 (0x10)	0x06	4	Y Gyro Bias	Float	Radians/Sec	
			8	Z Gyro Bias	Float	Radians/Sec	
			12	Valid Flags	U16	See Notes	

5.2.10 Gyro Bias Uncertainty (0x82, 0x0B)							
Description	Estimated Gyro Bias 1-sigma Uncertainty expressed in the Sensor Body Frame.						
Notes	Valid Flag 0: 0:	Valid Flag Mapping: 0x0000 - Gyro Bias Uncertainties are Invalid 0x0001 - Gyro Bias Uncertainties Valid					
	Field Length	Data Descriptor	Message Data				
			Binary Offset	Description	Data Type	Units	
Field Format			0	1-Sigma Gyro Bias Uncertainty (X)	Float	Radians/Sec	
	16 (0x10)	0x0B	4	1-Sigma Gyro Bias Uncertainty (Y)	Float	Radians/Sec	
			8	1-Sigma Gyro Bias Uncertainty (Z)		Radians/Sec	
			12	Valid Flags	U16	See Notes	



5.2.11 C	5.2.11 Compensated Acceleration (0x82, 0x1C)							
	Filter-Compe	nsated Accele	ration Data e	xpressed in:				
Description		 The Sensor Frame, if no sensor to body rotation has been defined. The Vehicle Frame, if a sensor to body rotation has been defined. 						
Notes	Valid Flag Ma 0x000 0x000	Valid Flag Mapping: 0x0000 - Compensated Accelerations are Invalid 0x0001 - Compensated Accelerations are Valid						
	Field Length	Data Descriptor	Message Data					
			Binary Offset	Description	Data Type	Units		
Field Format			0	Х	Float	Meters / Sec ²		
	16 (0x10)	0x1C	4	Y	Float	Meters / Sec ²		
			8	Z	Float	Meters / Sec ²		
			12	Valid Flags	U16	See Notes		



5.2.12 Linear Acceleration (0x82, 0x0D)						
	Filter-Comp in:	pensated Linear	Acceleration	n Data (gravity ve	ector remove	ed) expressed
Description	 The Sensor Frame, if no sensor to body rotation has been defined. The Vehicle Frame, if a sensor to body rotation has been defined. 					
Notes	Valid Flag Mapping: 0x0000 - Linear Accelerations are Invalid 0x0001 - Linear Accelerations are Valid					
	Field Length	Data Descriptor	Message Da	əta		
			Binary Offset	Description	Data Type	Units
Field Format			0	Х	Float	Meters / Sec ²
	16 (0x10)	0x0D	4	Y	Float	Meters / Sec ²
			8	Z	Float	Meters / Sec ²
			12	Valid Flags	U16	See Notes



5.2.13 Pressure Altitude (0x82, 0x21)							
Description	Estimated F	Estimated Pressure Altitude.					
Notes	The US 1976 Standard Atmosphere Model is used to calculate the pressure altitude in meters. A valid pressure sensor reading is required for the pressure altitude to be valid. The minimum pressure reading supported by the model is 0.0037 mBar, cor- responding to an altitude of 84,852 meters. Valid Flag Mapping: 0x0000 - Pressure Altitude is Invalid 0x0001 - Pressure Altitude is Valid						
	Field Length	Data Descriptor	Message Da	nta			
Field Format			Binary Offset	Description	Data Type	Units	
	8 (0x08) 0x21	0x21	0	Pressure Altitude	Float	Meters	
		4	Valid Flags	U16	See Notes		



5.2.14 Gravity Vector (0x82, 0x13)							
	Estimated Gr	Estimated Gravity Vector expressed in:					
Description		 The Sensor Frame, if no sensor to body rotation has been defined. The Vehicle Frame, if a sensor to body rotation has been defined. 					
	Valid Flag Mapping:						
Notes	0x0000 - Gravity vector is Invalid 0x0001 - Gravity vector is Valid						
	Field Length	Data Descriptor	Message Data				
			Binary Offset	Description	Data Type	Units	
Field Format			0	Х	Float	Meters / Sec ²	
	16 (0x10) 0x1	0x13	4	Y	Float	Meters / Sec ²	
			8	z	Float	Meters / Sec ²	
			12	Valid Flags	U16	See Notes	



5.2.15 WGS84 Local Gravity Magnitude (0x82, 0x0F)							
Description	Local Mag	Local Magnitude of Earth's gravity using the WGS84 gravity model.					
Notes	The -CV5 less. Valid Flac	The -CV5-25 implements the WGS84 gravity model, valid for altitudes of 20 km or less. Valid Flag Mapping:					
	0x0000 - Gravity value is Invalid 0x0001 - Gravity value is Valid						
	Field Length	Data Descriptor	Message Data				
Field Format			Binary Offset	Description	Data Type	Units	
	08 (0x08)	08 (0x08) 0x0F	0	Gravity Mag- nitude	Float	Meters/Sec ²	
			4	Valid Flags	U16	See Notes	



5.2.16 Heading Update Source State (0x82, 0x14)							
Description	Heading U	pdate Source ir	nformation e	expressed in the sensor	frame.		
	Heading u Heading U	pdates can be a pdate Control.)	applied from	a number of sources (li	ces (listed below. Also see		
	The headir	ng value is alwa	ys relative to	o true north.			
	Possible Source Flags (may be combined):						
Notes	0x0000 - No source, heading updates disabled 0x0001 - Magnetometer 0x0004 - External Heading Update or External Heading Update with Timestamp Message Valid Flag Mapping: 0x0000 - No heading update received in 2 seconds. 0x0001 - The heading update source has provided data within 2 seconds.						
	Field Length	Data Descriptor	Message D	Data			
			Binary Offset	Description	Data Type	Units	
Field Format			0	Heading (True)	Float	Radians	
	14 (0x0E)	0x14	4	Heading 1-sigma Uncertainty	Float	Radians	
			8	Source	U16	See Notes	
			10	Valid Flags	U16	See Notes	



5.2.17 Magnetic Model Solution (0x82, 0x15)							
Description	Magnetic m	odel solution ex	pressed in th	ne NED frame.			
	The World model to be	Magnetic Model valid.	2010 is used	d. A valid GNSS loca	ation is requ	uired for the	
	Valid Flag Mapping:						
Notes	0x0000 - Magnetic model solution is invalid (note: this will be the state when the magnetic model is recalculating for the current time and location as well as when GNSS is unavailable) 0x0001 - Magnetic model solution is valid						
	Field Length	Data Descriptor	Message Data				
			Binary Offset	Description	Data Type	Units	
			0	Intensity (North)	Float	Gauss	
Field Format			4	Intensity (East)	Float	Gauss	
	24 (0x18)	0x15	8	Intensity (Down)	Float	Gauss	
			12	Inclination	Float	Radians	
			16	Declination	Float	Radians	
			20	Valid Flags	U16	See Notes	



5.2.18 Mag Auto Hard Iron Offset (0x82, 0x25)								
Description	This is an offset vector applied to the hard iron offset vector to compensate for mag- netometer in-run bias errors.							
Notes	Valid Flag Mapping: 0x0000 - Vector is Invalid 0x0001 - Vector is Valid							
Field Format	Field Length	Data Descriptor	Message Data					
	16 (0x10)	0x25	Binary Offset	Description	Data Type	Units		
			0	Х	Float	Gauss		
			4	Y	Float	Gauss		
			8	Z	Float	Gauss		
			12	Valid Flags	Valid Flags U16			

5.2.19 Mag Auto Hard Iron Offset Uncertainty (0x82, 0x28)								
Description	This is the und	This is the uncertainty of the Magnetometer Compensation Offset.						
Notes	Valid Flag Mapping: 0x0000 - Vector is Invalid 0x0001 - Vector is Valid							
Field Format	Field Length	Data Descriptor	Message Data					
	16 (0x10)	0x28	Binary Offset	Description	Data Type	Units		
			0	Х	Float	Gauss		
			4	Y	Float	Gauss		
			8	Z	Float	Gauss		
			12	Valid Flags	U16	See Notes		



5.2.20 Mag Auto Soft Iron Matrix (0x82, 0x26)								
Description	Magnetometer Soft Iron compensation matrix.							
	This is a 9 component matrix which is applied to the magnetometer soft iron cal- ibration matrix to compensate for magnetometer in-run errors.							
Notes	$M = egin{bmatrix} M_{1,1} & M_{1,2} & M_{1,3} \ M_{2,1} & M_{2,2} & M_{2,3} \ M_{3,1} & M_{3,2} & M_{3,3} \end{bmatrix}$							
	Valid Flag Mapping: 0x0000 - Orientation Matrix is Invalid 0x0001 - Orientation Matrix is Valid							
	Field Length	Data Descriptor	Message Data					
	40 (0x28)	0x26	Binary Offset	Description	Data Type	Units		
			0	M ₁₁	Float	n/a		
			4	M ₁₂	Float	n/a		
			8	M ₁₃	Float	n/a		
Field Format			12	M ₂₁	Float	n/a		
			16	M ₂₂	Float	n/a		
			20	M ₂₃	Float	n/a		
			24	M ₃₁	Float	n/a		
			28	M ₃₂	Float	n/a		
			32	M ₃₃	Float	n/a		
			36	Valid Flags	U16	See Notes		



5.2.21 Mag Auto Soft Iron Matrix Uncertainty (0x82, 0x29)									
Description	Magnetometer Soft Iron compensation matrix.								
	This is the und	certainty of the	Magnetomet	er Compensatio	on matrix.				
Notes	$M = egin{bmatrix} M_{1,1} & M_{1,2} & M_{1,3} \ M_{2,1} & M_{2,2} & M_{2,3} \ M_{3,1} & M_{3,2} & M_{3,3} \end{bmatrix}$								
	Valid Flag Mapping:								
	0x0000 - Orientation Matrix is Invalid 0x0001 - Orientation Matrix is Valid								
	Field Length	Data Descriptor	Message Data						
	40 (0x28)	0x29	Binary Offset	Description	Data Type	Units			
			0	M ₁₁	Float	n/a			
			4	M ₁₂	Float	n/a			
			8	M ₁₃	Float	n/a			
Field Format			12	M ₂₁	Float	n/a			
			16	M ₂₂	Float	n/a			
			20	M ₂₃	Float	n/a			
			24	M ₃₁	Float	n/a			
			28	M ₃₂	Float	n/a			
			32	M ₃₃	Float	n/a			
			36	Valid Flags	U16	See Notes			



6. MIP Packet Reference

6.1 Structure

Commands and Data are sent and received as fields in the LORD "MIP" packet format. Below is the general definition of the structure:

The packet always begins with the start-of-packet sequence "ue" (0x75, 0x65). The "Descriptor Set" byte in the header specifies which command or data set is contained in fields of the packet. The payload length byte specifies the sum of all the field length bytes in the payload section.

6.2 Payload Length Range

The payload section can be empty or can contain one or more fields. Each field has a length byte and a descriptor byte. The field length byte specifies the length of the entire field including the field length byte and field descriptor byte. The descriptor byte specifies the command or data that is contained in the field data. The descriptor can only be from the set of descriptors specified by the descriptor set byte in the header. The field data can be anything but is always rigidly defined. The definition of a descriptor is fundamentally described in a ".h" file that corresponds to the descriptor set that the descriptor belongs to.

LORD Sensing provides a "Packet Builder" functionality in the "MIP Monitor" software utility to simplify the construction of a MIP packet. Most commands will have a single field in the packet, but multiple field packets are possible. Extensive examples complete with checksums are given in the command reference section.

6.3 MIP Checksum Range

The checksum is a 2 byte Fletcher checksum and encompasses all the bytes in the packet:

6.4 16-bit Fletcher Checksum Algorithm (C Language)

```
for(i=0; i<checksum_range; i++)
{
    checksum_byte1 += mip_packet[i];
    checksum_byte2 += checksum_byte1;
    }
checksum = ((u16) checksum byte1 << 8) + (u16) checksum byte2;</pre>
```



7. Advanced Programming

7.1 Multiple Commands in a Single Packet

MIP packets may contain one or more individual commands. In the case that multiple commands are transmitted in a single MIP packet, the 3DM-CV5-25 will respond with a single packet containing multiple replies. As with any packet, all commands must be from the same descriptor set (you cannot mix Base commands with 3DM commands in the same packet).

Below is an example that shows how you can combine the commands from step 2 and 3 of the Example Setup Sequence into a single packet. The commands are from the 3DM set. The command packet has two fields as does the reply packet (the fields are put on separate rows for clarity):

Examples	MIP Packet Header			Command/Reply Fields			Checksum		
	Sync1	Sync2	Desc. Set	Payload Length	Field Length	Cmd Desc.	Field Data	MSB	LSB
Command Field 1: Set IMU Message Format	0x75	0x65	0x0C	0x20	0x0D	0x08	Function: 0x01 Desc. count: 0x03 GPS TS Descriptor: Rate Dec: 0x000A Accel 0x04 Descriptor: Rate Dec: 0x000A Ang Rate Descriptor: Rate Dec: 0x000A		
Command Field 2: Set EF Mes- sage Format					0x13	0x0A	Function: 0x01 Desc. count: 0x05 GPS TS Desc.: 0x11 Rate Dec: 0x000A Filter Status Desc: 0x10 Rate Dec: 0x000A Est. Pos. Desc.: 0x01 Rate Dec: 0x000A Est. Vel. Desc.: 0x02 Rate Dec: 0x000A Est. Quat. Desc: 0x03 Rate Dec: 0x000A	0xD4	0x3D
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x08	0x04	0xF1	Echo cmd: 0x08 Error code: 0x00		
Reply Field 2: ACK/NACK					0x04	0xF1	Echo cmd: 0x0A Error code: 0x00	0xEA	0x71
Copy-paste version of the command: "7565 0C20 0D08 0103 1200 0A04 000A 0500 0A13 0A01 0511 000A 1000 0A01 000A 0200 0A03 000A D43D"									



Note that the only difference in the packet headers of the single command packets compared to the multiple command packets is the payload length. Parsing multiple fields in a single packet involves subtracting the field length of the next field from the payload length until the payload length is less than or equal to zero.

7.2 Direct Modes

The 3DM-CV5-25 has special "direct" modes that switch the device into a Sensor direct device. The Device Communications Mode command is used to switch between modes. When in these modes, the 3DM-CV5-25 acts like an "IMU only" sensor. Any code or tools developed for these devices may be used in these modes.

These modes can be used to access advanced (native) data of the individual sensors, data that isn't represented in the 3DM command sets of the 3DM-CV5-25. These modes are primarily advanced modes for programmers to allow the 3DM-CV5-25 to be used in unusual situations where the normal functions of the 3DM-CV5-25 are bypassed.

IMPORTANT: When you switch modes, you are switching to a new device protocol EXCEPT for two commands: the Device Communications Mode and commands. Those commands are always available regardless of which mode you are in. For example, if you switch to direct mode, then the protocol recognized by the device is protocol, however the 3DM-CV5-25 is still "listening" for mode switch or device status commands and will respond to them. It will not respond to any other 3DM-CV5-25 Base or 3DM commands until switched back to the "Standard Mode".

7.3 Internal Diagnostic Functions

The 3DM-CV5-25 supports two device specific internal functions used for diagnostics and system status. These are Device Built In Test and Device Status. These commands are defined generically but the implementation is very specific to the hardware implemented on this device. Other LORD Sensing devices will have their own implementations of these functions depending on the internal hardware of the devices.

7.3.1 3DM-CV5-25 Internal Diagnostic Commands

- Device Built In Test (0x01, 0x05)
- Device Status (0x0C, 0x64)



7.4 Handling High Rate Data

The size of the data fields from an inertial device is substantially greater than on most other types of sensors. On top of that, in many applications it is desirable to receive that data with the lowest latency possible and thus the highest baud rate is selected. The result is that the port servicing requirements in terms of both speed and buffer size can be surprisingly large for inertial data. This can lead to a couple of common problems: runaway latency and dropped packets.

7.4.1 Runaway Latency

Most operating systems provide drivers that have ample buffers and take care of port servicing at the hardware level. Dropping packets or losing data is not usually an issue on these systems. What can be an issue is latency, that is, when the buffer is not emptied by the application in a timely manner. In the worst case, the buffer is being filled faster than it is emptied and the application operates with increasingly "old" data - which causes runaway latency. It is important to monitor the incoming data buffer to make sure you do not reach this condition.

7.4.2 Dropped Packets

Many applications do not use an operating system but are written from scratch or on top of proprietary application frameworks. These are most often embedded MCUs or small single board microcontrollers. On these systems, port handling is usually done in code at the hardware level. Collecting data from a port requires the use one of three techniques: register polling, hardware interrupts, or direct memory access (DMA). Register polling is very easy to do and is adequate for simple communications where data comes in very small chunks and at reasonable data rates. The problem with register polling is that you either waste time looping while waiting for a byte to come in at the port or you get too busy doing other tasks so that by the time you poll the port, the byte is lost because the next one overwrites it. This causes dropped packets. On these systems, it is imperative to utilize either a hardware interrupt or hardware DMA on the UART receiving data from the 3DM-CV5-25. The DMA or UART interrupt service routine only takes processor time when a byte is ready and as long as the interrupts are preemptive, the processor will fetch every byte received. Using the interrupt routine to fill a ring buffer makes the most efficient use of an MCU and makes it easier to write your application main line code. This is essentially what drivers in operating systems do.

7.5 Creating Fixed Data Packet Format

The MIP packet structure and protocol provides a great deal of flexibility to the user for creating a custom data stream. It does this by allowing selectable data fields and individual data rates for each field. The side effect of this feature is that packets vary in size depending on what data is being delivered in any particular time frame. For example, if acceleration data is configured for 100 Hz and magnetometer data is configured for 25 Hz, every fourth packet is larger than the previous three


because of the additional magnetometer data. In some applications, this is undesirable and there may be a requirement for a fixed packet structure so that each data packet is exactly the same. A fixed packet structure allows you to find data fields by fixed offsets rather than parsing the packet for each field.

A fixed packet structure is easily achieved with MIP packet protocol by simply making sure the data rate for each data quantity is the same. The order of the data fields in the packet reflect the order of the fields in the Message Format command and thus are completely under the control of the user. Once an acceptable data packet structure is determined, and all the rates are set to the same decimation, use the "Save current settings as startup settings" function selector in the message format command, and that format will be saved and used automatically on subsequent device startups. The message formats for each of the data classes (IMU, EF, etc) work the same way, however the available data rates for each class is different, so you will need to create a fixed message format for each one.



7.6 Advanced Programming Models

Many applications will only require a single threaded programming model which is simple to implement using a single program loop that services incoming packets. In other applications, advanced techniques such as multithreading or event based processes are required. The MIP packet design simplifies implementation of these models. It does this by limiting the packet size to a maximum of 261 bytes and it provides the "descriptor set" byte in the header. The limited packet size makes scalable packet buffers possible even with limited memory space. The descriptor set byte aids in sorting an incoming packet stream into one or more command-reply packet queues and/or data packet queues. A typical multithreaded environment will have a command/control thread and one or more data processing threads. Each of these threads can be fed with individual incoming packet queues, each containing packets that only pertain to that thread - sorted by descriptor set. Packet queues can easily be created dynamically as threads are created and destroyed. All packet queues can be fed by a single incoming packet parser that runs continuously independent of the queues. The packet queues are individually scaled as appropriate to the process; smaller queues for lower latency and larger queues for more efficient batch processing of packets.



Multithreaded application with multiple incoming packet queues



8. Glossary

Α

A/D Value

The digital representation of analog voltages in an analog-to-digital (A/D) conversion. The accuracy of the conversion is dependent on the resolution of the system electronics. Higher resolution produces a more accurate conversion.

Acceleration

In physics, acceleration is the change in the rate of speed (velocity) of an object over time.

Accelerometer

A sensor used to detect and measure magnitute and direction of an acceleration force (g-force) in reference to its sensing frame. For example, at rest perpendicular to the Earth's surface an accelerometer will measure 9.8 meters/second squared as a result of gravity. If the device is tilted the acceleration force will change slightly, indicating tilt of the device. When the accelerometer is moving it will measure the dynamic force (including gravity).

Adaptive Kalman Filter (AKF)

A type of Extended Kalman Filter (EKF) that contains an optimization algorithm that adapts to dynamic conditions with a high dependency on adaptive technology. Adaptive technology refers to the ability of a filter to selectively trust a given measurement more or less based on a trust threshold when compared to another measurement that is used as a reference. Sensors that have estimation filters that rely on adaptive control elements to improve their estimations are referred to as an AKF.

AHRS (Attitude and Heading Reference System)

A navigation device consisting of sensors on the three primary axes used to measure vehicle direction and orientation in space. The sensor measurements are typically processed by an onboard algorithm, such as an Estimation Filter, to produce a standardized output of attitude and heading.

Algorithm

In math and science, an algorithm is a step-by-step process used for calculations.

Altitude

the distance an object is above the sea level

Angular rate

The rate of speed of which an object is rotating. Also know as angular frequency, angular speed, or radial frequency. It is typically measured in radians/second.

API (Applications Programming Interface)

A library and/or template for a computer program that specifies how components will work together to form a user application: for example, how hardware will be accessed and what data structures and variables will be used.



ASTM (Association of Standards and Testing)

a nationally accepted organization for the testing and calibration of technological devices

Attitude

the orientaion of an object in space with reference to a defined frame, such as the North-East-Down (NED) frame

Azimuth

A horizontal arc measured between a fixed point (such as true north) and the vertical circle passing through the center of an object

В

Bias

A non-zero output signal of a sensor when no load is applied to it, typically due to sensor imperfections. It is also called offset.

С

Calibration

to standardize a measurement by determining the deviation standard and applying a correction, or calibration, factor

Complementary Filter (CF)

A term commonly used for an algorithm that combines the readings from multiple sensors to produce a solution. These filters typically contain simple filtering elements to smooth out the effects of sensor over-ranging or anomalies in the magnetic field.

Configuration

A general term applied to the sensor indicating how it is set up for data acquisition. It includes settings such as sampling rate, active measurements, measurement settings, offsets, biases, and calibration values

Convergance

when mathematical computations approach a limit or a solution that is stable and optimal.

D

Data Acquisition

the process of collecting data from sensors and other devices

Data Logging

the process of saving acquired data to the system memory, either locally on the device, or remotely on the host computer

Data rate

the rate at which sampled data is transmitted to the host



Delta-Theta

the time integral of angular rate expressed with refernce to the device local coordinate system, in units of radians

Delta-velocity

the time integral of velocity expressed with refernce to the device local coordinate system, in units of g*second where g is the standard gravitational constant

Ε

ECEF (Earth Centered Earth Fixed)

a reference frame that is fixed to the earth at the center of the earth and turning about earth's axis in the same way as the earth

Estimation Filter

A mathematical algorithm that produces a statistically optimum solution using measurements and references from multiple sources. Best known estimation filters are the Kalman Filter, Adaptive Kalman Filter, and Extended Kalman Filter.

Euler angles

Euler angles are three angles use to describe the orientation of an object in space such as the x, y and z or pitch; roll; and yaw. Euler angles can also represent a sequence of three elemental rotations around the axes of a coordinate system.

Extended Kalman Filter (EKF)

Used generically to describe any estimation filter based on the Kalman Filter model that can handle non-linear elements. Almost all inertial estimation filters are fundamentally EKFs.

G

GNSS (Global Navigation Statellite System)

a global network of space based statellites (GPS, GLONASS, BeiDou, Galileo, and others) used to triangulate position co-ordinates and provide time information for navigational purposes

GPS (Global Positioning System)

a U.S. based network of space based statellites used to triangulate position co-ordinates and provide time information for navigational purposes

Gyroscope

a device used to sense angular movements such as rotation

н

Heading

an object's direction of travel with reference to a co-ordinate frame, such as lattitude and longitude



Host (computer)

The host computer is the computer that orchestrates command and control of attached devices or networks.

<u>|</u>

IMU

Inertial Measurement System

Inclinometer

device used to measure tilt, or tilt and roll

Inertial

pertaining to systems that have inertia or are used to measure changes in inertia as in angular or linear accelerations

INS (Inertial Navigation System)

systems that use inertial measurements exclusively to determine position, velocity, and attitude, given an initial reference

Κ

Kalman Filter

a linear quadratic estimation algorithm that processes sensor data or other input data over time, factoring in underlying noise profiles by linearizing the current mean and covariance to produces an estimate of a system's current state that is statistically more precise than what a single measurement could produce

L

LOS (Line of Sight)

Describes the ideal condition between transmitting and receiving devices in a wireless network. As stated, it means they are in view of each other with no obstructions.

Μ

Magnetometer

A type of sensor that measures the strength and direction of the local magnetic field with refernce to the sensor frame. The magnetic field measured will be a combination of the earth's magnetic field and any magnetic field created by nearby objects.

MEMS (Micro-Electro-Mechanical System)

The technology of miniaturized devices typically made using micro fabrication techniques such as nanotechnology. The devices range in size from one micron to several millimeters and may include very complex electromechanical parts.



Ν

NED (North-East-Down)

A geographic reference system

0

OEM

acronym for Original Equipment Manufacturer

Offset

A non-zero output signal of a sensor when no load is applied to it, typically due to sensor imperfections. Also called bias.

Orientation

The orientaion of an object in space with reference to a defined frame. Also called attitude.

Ρ

Pitch

In navigation pitch is what occurs when vertical force is applied at a distance forward or aft from the center of gravity of the platform, causing it to move up or down with respect to the sensor or platform frame origin.

Position

The spatial location of an object

PVA

acronym for Position, Velocity, Attitude

Q

Quaternion

Mathematical notation for representing orientation and rotation of objects in three dimensions with respect to the fixed earth coordinate quaternion. Quaternions convert the axis-angle representation of the object into four numbers and to apply the corresponding rotation to a position vector representing a point relative to the origin.

R

Resolution

In digital systems, the resolution is the number of bits or values available to represent analog voltages or information. For example, a 12-bit system has 4096 bits of resolution and a 16-bit system has 65536 bits.



RMS

acronym for Root Mean Squared

Roll

In navigation roll is what occurs when a horizontal force is applied at a distance right or left from the center of gravity of the platform, causing it to move side to side with respect to the sensor or platform frame origin.

RPY

acronym for Roll, Pitch, Yaw

RS232

a serial data communications protocol

RS422

a serial data communications protocol

S

Sampling the process of taking measurements from a sensor or device

Sampling rate

rate at which the sensors are sampled

Sampling Rate

the frequency of sampling

Sensor

a device that physically or chemically reacts to environmental forces and conditions and produces a predictable electrical signal as a result

Sigma

In statistics, sigma is the standard deviation from the mean of a data set.

Space Vehicle Information

refers to GPS satellites

Streaming

typically when a device is sending data at a specified data rate continuously without requiring a prompt from the host

U

USB (Universal Serial Bus) A serial data communications protocol



UTC (Coordinated Universal Time)

The primary time standard for world clocks and time. It is similar to Greenwich Mean Time (GMT).

V

Vector

a measurement with direction and magnitude with refernce from one point in space to another

.

Velocity

The rate of change of position with respect to time. Also called speed.

W

WAAS (Wide Area Augmentation System)

An air navigation aid developed to allow aircraft to rely on GPS for all phases of flight, including precision approaches to any airport.

WGS (World Geodetic System)

a protocol for geo-referencing such as WGS-84

Υ_____

Yaw

In navigation yaw is what occurs when rotational force is applied at a distance forward or aft from the center of gravity of the platform, causing it to move around the center axis of a sensor or platform frame origin.

