Navigation, Guidance and Sensors

GNAV540 User Manual

Installation Configuration Reference

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Preface

This document provides information about GNAV540, including operational functions and configuration options.

Intended Audience

This document is intended for those who install, configure, extract data and use inertial systems. It is assumed the reader is familiar with the technology of navigation. For advanced use of the GNAV540, knowledge of C programming is required.

NOTE: Uploading firmware (DMU upgrade) to the unit is outside the scope of this document. For information, contact Customer Service (refer to page 128).

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Related Documents

NOTE: Moog, Inc. is ISO9001:2008 certified.

Table 2 Reference Documents

Title	Description
MIL-STD-810G	Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
MIL-STD-461E	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-HDBK-217F	Military Handbook, Reliability Prediction of Electronics Equipment
ICD-GPS-153C IRN001 21 February 2006	GPS User Equipment Interface Control Document for the GPS Standard Serial Interface Protocol (GSSIP) of DoD Standard GPS UE Radio Receivers
QL-11-0382	Certification of Conformance (vibration, shock, temperature, altitude, humidity), Quanta Laboratories
MET Laboratories #3277	Certification of Compliance (MILSTD 461E: control of electromagnetic interference), Met Laboratories

Text Conventions

Table 3 Text Conventions

Convention	Definition
Italics	Emphasizes important information, or indicates the title of a document.
Bold	Stronger emphasis of important information.
`System items`	Indicates a sample of screen output, a command in the body of the document or an example of a command to enter.
Command	A software command that must be entered as shown.
NOTE:	Additional information.
CAUTION:	The information provided should be followed to prevent damage to the equipment.
WARNING:	The information provided must be followed to prevent physical injury.

Glossary

Table 4 Glossary

Term	Definition
6DOF	Six Degree of Freedom
ACL	Accelerometer
AHRS	Attitude Heading Reference
BIT	Built In Test
DSP	Digital Signal Processor
ECEF	Earth-Centered Earth-Fixed
ESS	Environmental Stress Screening
EKF	Extended Kalman Filter
FIR	Finite Impulse Response
GB-GRAM	Ground-Based GPS Receiver Application Module
GPS	Global Positioning System
Hard failure	Fatal condition, non-operational
Hard iron	Magnetism is retained (*permanent*)
IMU	Inertial Measurement Unit
LLA	Latitude Longitude and Altitude
LSB	Least Significant Byte
MEMS	Micro-Electro-Mechanical Systems
MSB	Most Significant Byte
MTBF	Mean Time Between Failure
PPS	Precise Positioning Service
QTP	Qualification Test Plan
SAASM	Selective Availability / Anti-Spoofing Module
SDGPS	Satellite Differential GPS
Soft error	Persistent error, repeated many times within a period of time
Soft iron	Magnetism is not retained; magnetism only occurs while the material exposed to a magnetic field
VDC	Voltage Direct Current
VG	Vertical Gyroscope
WAAS	Wide Area Augmentation System: enhanced accuracy of GPS positioning

Chapter 1. Overview

This chapter provides a high level summary of the GNAV540:

- Features, page 17
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Features

- Pitch and roll accuracy of <0.4°, heading error < 0.75°
- Ethernet user interface
- MIL-C-38999 connector
- GPS aiding from GPS-ICD-153C Compliant Receivers
- Altitude (operating): 10,000M
- Velocity Range (NAV message limit): +/- 256 m/s
- TTFF < 100 sec (cold)
- Less than 4W power
- Optimized for ground vehicle
- Rugged sealed enclosure meeting MIL-STD-810G and MIL-STD-46IE EMI immunity
- Internal C/A code GPS module, interchangeable with GB-GRAM SAASM receiver
- Switch between embedded GPS and external GPS
- Switch between embedded magnetometer and external magnetometer
- Tested to military standards for environmental conditions including temperature, vibration and shock
- Three independent RS422 serial interfaces and precise time pulse outputs
- 12-channel continuous satellite tracking for true All-In-View operation
- Field reprogrammable or easy updates of application software
- WGS84 datum
- High reliability with MTBF >75,000 hours (calculated)

System Performance

Table 5 GNAV540 Measurements

Measurement	Accuracy
Position/Velocity	Position Accuracy <2 m CEP, SDGPS Velocity Accuracy < 0.05 m/s steady state
Heading	Accuracy <1.0° rms (magnetic) <0.75° rms (with GPS aiding)

Measurement	Accuracy
Attitude	Range: Roll, Pitch ±180°, ±90° Accuracy <0.4°
Angular Rate	Range: Roll, Pitch, Yaw ±200° Bias Stability in run <10°/hr Bias Stability over temp <0.02°/sec
Acceleration	Input Range ±4 g Bias Stability in run <1 mg Bias Stability over temp <4 mg

Signal Interface

The J1 port of the GNAV540 provides the connections listed in Table 6 below. Details of the signal interface, including I/O pin out, is provided in *Chapter 3. Hardware Interface* on page 35.

Table 6 J1 Interface Connector

Connection	Description
RS422	There are three serial interfaces (RS422): • **Mag**: connect to external Magnetometer • **GPS**: Connect to external GPS • **User**: Connect to computer or host CPU
Ethernet	Connect to user interface: The default IP address of the unit: 192.168.1.2.
Power Input	Labeled **12-30 VDC** and **Ground**; connect to DC power source

Software Compatibility

Crossbow's GNAV540 Inertial Systems are generally software compatible with the 440 series of Crossbow products. The GNAV540 utilizes the 440 series extensible communication protocol, which is described in *Chapter 9. Communicating with the GNAV540 Unit.*

GNAV540 Unit

The GNAV540 is Crossbow's fourth generation of MEMS-based Inertial Systems, building on over a decade of field experience, and encompassing thousands of deployed units and millions of operational hours in a wide range of land, marine, airborne, and instrumentation applications.

Summary of GNAV540 features: 6-DOF IMU; 3-Axis Internal Magnetometer; Dynamic Velocity; Dynamic Roll, Pitch and Heading; GPS Receiver for Position.

- At the core of the GNAV540 unit is a rugged 6-DOF (Degrees of Freedom) MEMS inertial sensor cluster.

  The 6-DOF MEMS inertial sensor cluster includes three axes of MEMS angular rate sensing and three axes of MEMS linear acceleration sensing. These sensors are based on rugged, field proven silicon bulk micromachining technology. Each sensor within the cluster is individually factory calibrated for temperature and non-linearity effects during Crossbow's manufacturing and test process using automated thermal chambers and rate tables.

- Coupled to the 6-DOF MEMS inertial sensor cluster is a high performance Digital Signal Processor (DSP) that utilizes the inertial sensor measurements to accurately compute navigation information including attitude, heading, and linear velocity thru dynamic maneuvers (actual measurements are a function of the GNAV540 as shown in Table 2).

  The DSP processor makes use of internal and external magnetic sensor and/or GPS data to aid the performance of the inertial algorithms and help correct long term drift and estimate errors from the inertial sensors and computations. The navigation algorithm utilizes a multi-state configurable Extended Kalman Filter (EKF) to correct for drift errors and estimate sensor bias values. This algorithm runs on a 150MHz 32-bit DSP that has approximately four times the computational power of Crossbow's earlier generation Inertial Systems.

- A significant feature of the GNAV540 is the extensive field configurability.

  This field configurability allows the GNAV540 Inertial Systems to satisfy a wide range of applications and performance requirements with a single mass produced hardware platform. The basic configurability includes parameters such as baud rate, packet type, and update rate, and the advanced configurability includes the defining of custom axes and how the sensor feedback is utilized in the Kalman filter during the navigation process.

The GNAV540 unit is packaged in a fully sealed, lightweight housing that provides EMI, vibration and moisture resistance to levels consistent with most land, marine, and airborne environments. The GNAV540 utilizes an RS-422 serial link or Ethernet interface for data communication, and each data transmission includes a BIT (Built-In-Test) message providing system health status. The GNAV540 is supported by Crossbow's NAV-VIEW 2.2, a powerful PC-based operating tool that provides complete field configuration, diagnostics, charting sensor performance, and data logging with playback.

Chapter 2. GNfAV540 Functions

This chapter provides an overview of the hardware and software systems of the GNAV540 unit, and the functions provided.

GNAV540 System

GNAV540 is a compact MEMS based GPS/inertial navigation system. It delivers continuous GPS position, true heading and vehicle attitude tracking information for ground tactical vehicles and other platform navigation applications. The system integrates advanced MEMS inertial gyros and accelerometers, embedded or optional remote 3-axis magnetometer, a SAASM or C/A code GPS receiver, and 10/100 Ethernet interface in a fully sealed enclosure for tactical vehicles operating in combat or homeland security environments.

Figure 1 on page 22 shows the GNAV540 system configuration block diagram. To maximize system performance and reduce cost, the GNAV540 provides RS422 interfaces for an external magnetometer and a SAASM GPS receiver: interface to pre-existing equipment. The internal GPS receiver is the Rockwell Collins Polaris Link card.

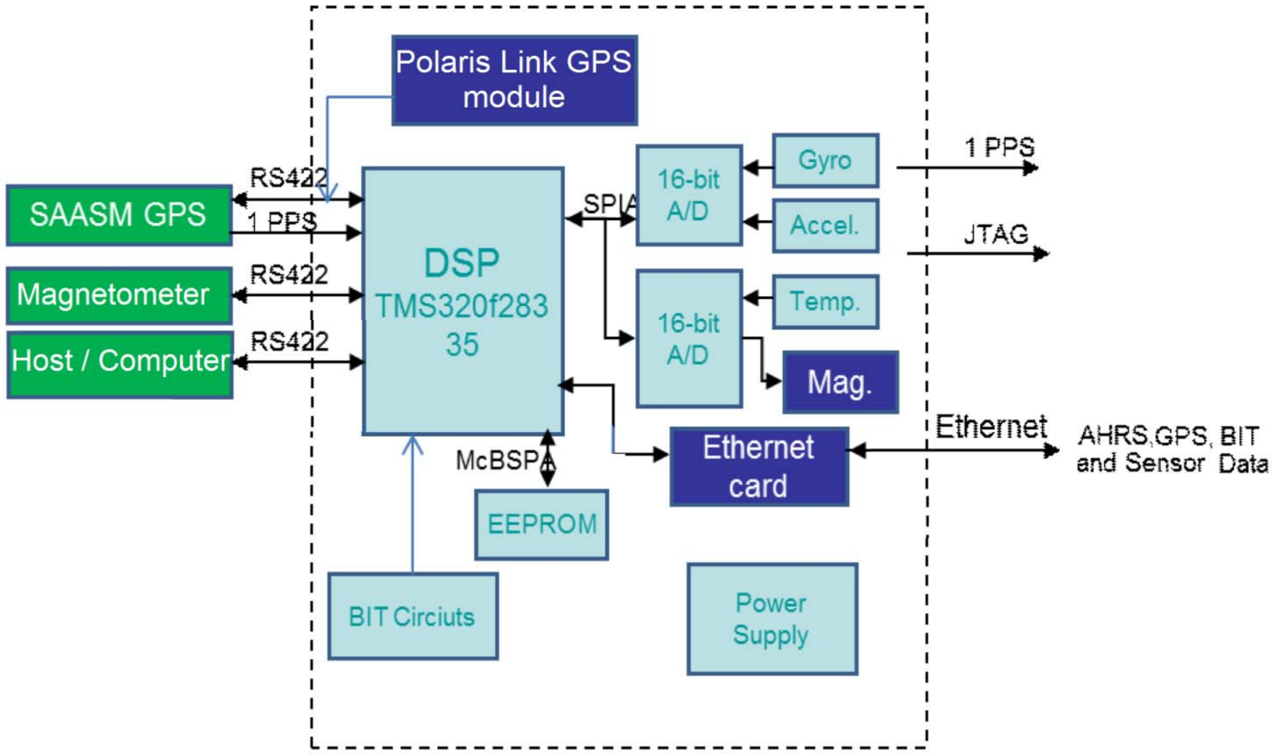
Configuring GNAV540 Functions

Based on the User Behavior settings, the GNAV540 can be configured to fulfill various functions.

1. Using only the calibrated sensor data, the GNAV540 functions as an Inertial Measurement Unit (IMU) to output angular rates and accelerations.
2. Incorporating the gyroscope and accelerometer data with the EKF, the GNAV540 can output roll and pitch attitude information, functioning as a Vertical Gyroscope (VG) unit.
3. Building on the VG function and combining magnetic field measurement, the GNAV540 can function as an Attitude Heading Reference System (AHRS): provide a heading angle estimate in addition to the (VG) roll and pitch. The GNAV540 is provided with an internal magnetometer; an external magnetometer can be integrated with the unit and configured to override the internal magnetometer.
4. Combining GPS sensor data into the EKF, the GNAV540 can provide a complete attitude system, as well as outputting 3D velocity and position measurements, thereby functioning as a Navigation unit (NAV). An internal C/A code GPS receiver is provided; an external SAASM GPS receiver can be integrated with the unit and configured to override the internal receiver.

The following sections provide details about the system level and functional operations of the GNAV540.

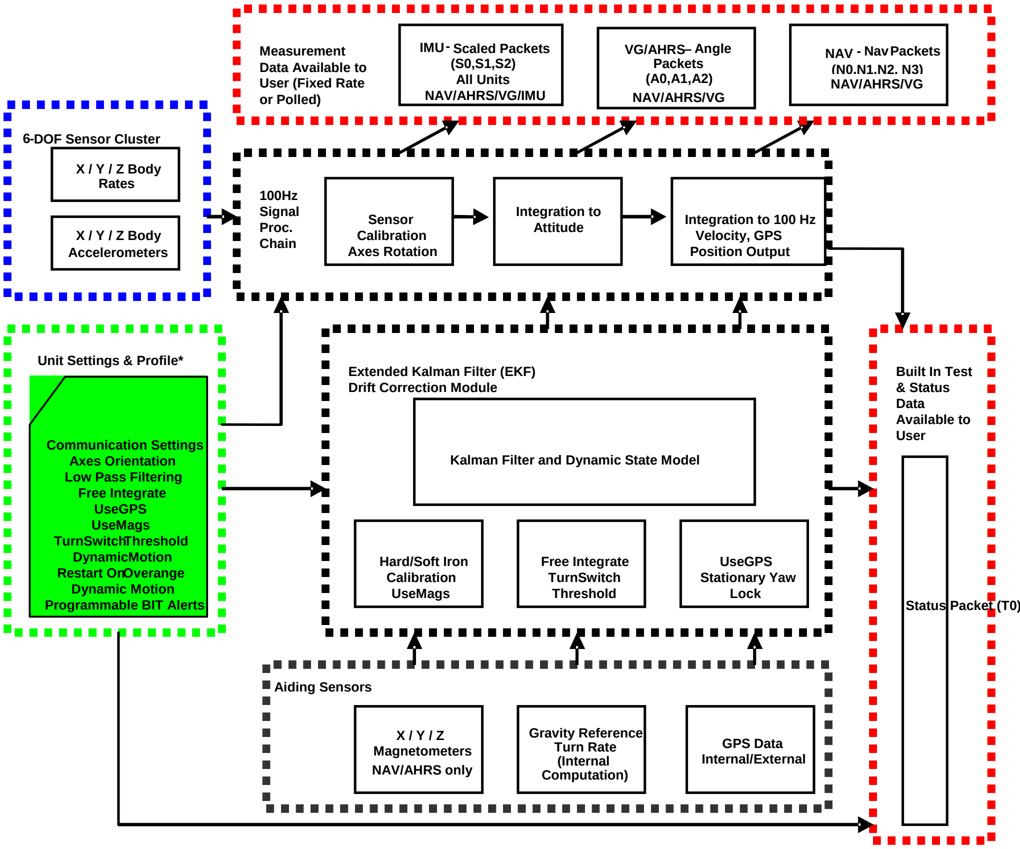
Figure 1 GNAV540 System



Software Structure

Figure 2 below shows the software block diagram. The 6-DOF inertial sensor cluster data is fed into a high speed 100Hz signal processing chain. These 6-DOF signals pass through one or more of the processing blocks and these signals are converted into output measurement data as shown. Measurement data packets are available at fixed continuous output rates or on a polled basis. The type of measurement data packets available depends on the unit type according to the software block diagram and system configuration. Aiding sensor data is used by an Extended Kalman Filter (EKF) for drift correction. Built-In-Test and Status data are available in the measurement packet or via the special Status Packet T2.

Figure 2 GNAV540 Software Block Diagram

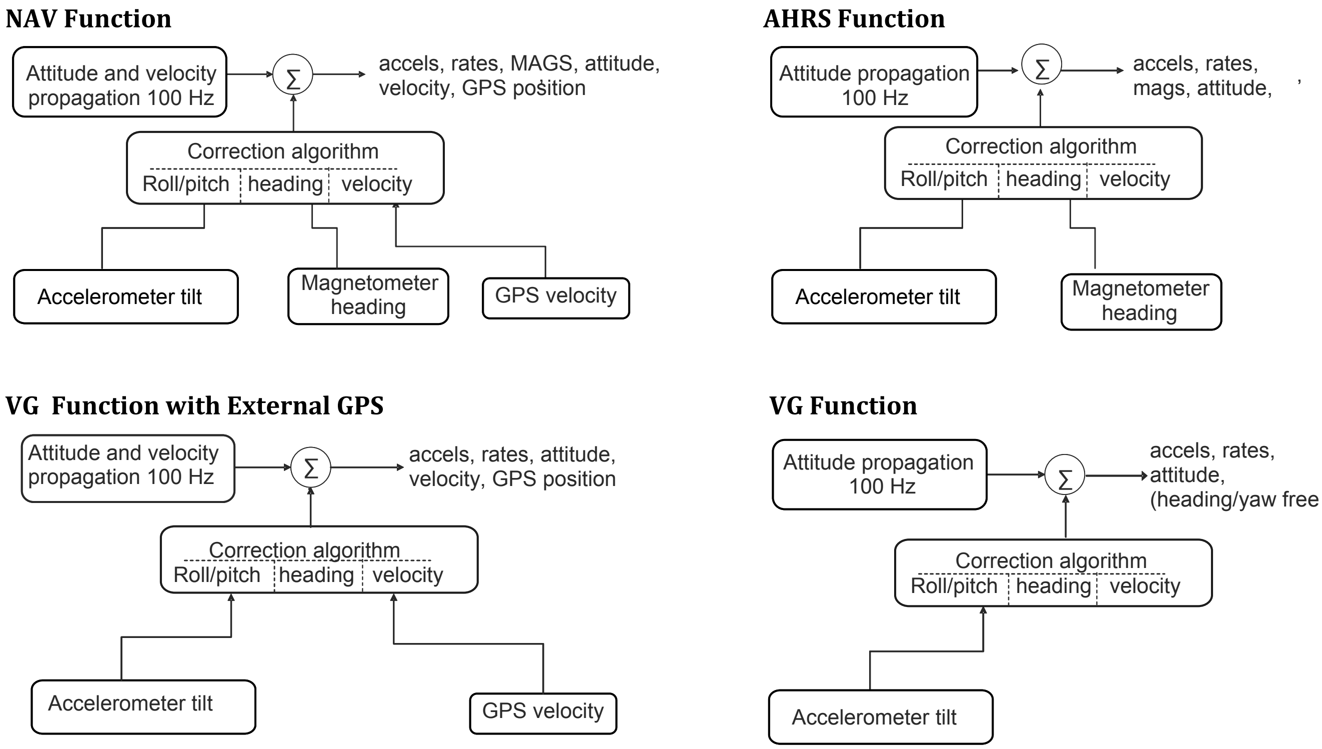


The GNAV540 features include sensors used in the EKF for the drift correction of the 6-DOF inertial sensor cluster.

A 3-axis magnetometer and a GPS receiver are used for correcting the drift on yaw/heading angle, increasing the accuracy of the attitude estimation by incorporating these sensor signals into the EKF and providing a navigation solution. The common aiding sensor for the drift correction for the attitude (i.e., roll and pitch only) is a 3-axis accelerometer.

Figure 3 below illustrates the unit setting and profile block, which configures the algorithm to user and application specific needs. This feature is one of the more powerful features in the GNAV540 architecture, as it allows the GNAV540 to work in a wide range of commercial applications by setting different modes of operation.

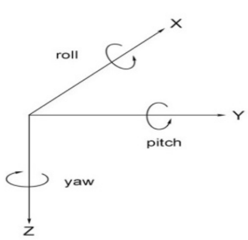
Figure 3 GNAV540 Functions



GNAV540 Default Coordinate System

The GNAV540 Inertial System default coordinate system is shown in *Figure* 4 below. The coordinate system is configurable with either NAV-VIEW 2.2 or by sending the appropriate serial commands. This section of the manual describes the default coordinate system settings of the unit when it leaves the factory. For information about configuring GNAV540, refer to *Chapter 7. Configuring GNAV540 with NAV-VIEW 2.2 Chapter 6. Viewing and Logging Data with NAV-VIEW* 2.2 and *Chapter 10. Programming Guidelines.* With the GNAV540 connector facing you and the mounting plate down, the axes are defined as shown below:

Figure 4 GNAV540 Default Coordinate System



X-axis: from face with connector through the unit

Y-axis: along the face with connector from left to right

Z-axis: along the face with the connector from top to bottom

The axes form an orthogonal SAE right-handed coordinate system. Acceleration is positive when it is oriented towards the positive side of the coordinate axis. For example, with a GNAV540 sitting on a level table, it will measure zero g along the x and y-axes and -1 g along the z-axis. Normal Force acceleration is directed upward, which would be defined as negative for the GNAV540 z-axis.

The angular rate sensors are aligned with the same axes. The rate sensors measure angular rotation rate around a given axis. The rate measurements are labeled by the appropriate axis. The direction of a positive rotation is defined by the right-hand rule. With the thumb of your right hand pointing along the axis in a positive direction, your fingers curl around in the positive rotation direction. For example, if the GNAV540 product is sitting on a level surface and you rotate it clockwise on that surface, this will be a positive rotation around the z-axis. The x and y-axis rate sensors would measure zero angular rates, and the z-axis sensor would measure a positive angular rate.

The magnetic sensors are aligned with the same axes definitions and sign as the linear accelerometers. For example, when oriented towards magnetic North, you will read approximately +0.25 Gauss along X, 0.0 Gauss along Y, and +0.35 Gauss along Z direction (North America). Magnetic values at other geographic locations are available at http://www.ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml.

Pitch is defined positive for a positive rotation around the y-axis (pitch up). Roll is defined as positive for a positive rotation around the x-axis (roll right). Yaw is defined as positive for a positive rotation around the z-axis (turn right).The angles are defined as standard Euler angles using a 3-2-1 system. To rotate from the body frame to an earth-level frame, roll first, then pitch, and then yaw.

The position output from GPS is represented in Latitude, Longitude, and Altitude (LLA) convention on the WGS84 Ellipsoid. This is the most commonly used spherical coordinate system. The GPS velocity is defined in North, East and Down reference frame, which can be converted to the Cartesian coordinate system: Earth-Centered, Earth-Fixed (ECEF). ECEF uses three-dimensional XYZ coordinates (in meters) to describe the location of a GPS user or satellite. Several online resources are available to help users with this transformation. Application notes are available on the Crossbow website: http://www.moog-crossbow.com.

Advanced Settings

The GNAV540 Inertial Systems have a number of advanced settings that can be changed. The specific settings available vary from unit to unit, and a detailed description of each unit is found in the subsequent sections of this manual. All units support baud rate, power-up output packet type, output rate, and custom axes configuration. The units can be configured via two methods:

- NAV-VIEW 2.2, a GUI application: *Chapter 7. Configuring GNAV540 with NAV-VIEW 2.2*
- C Language Programming: *Chapter 10. Programming Guidelines.*

IMU Function

Inertial Measurement Unit (IMU) Function provides inertial rate and acceleration data in the forms of changes in velocity and rotation angle (Δv and $\Delta \phi$). The IMU Function signal processing chain consists of the 6-DOF sensor cluster, analog to digital conversion, and the DSP signal processor for sensor error compensation. The rate and acceleration analog sensor signals are sampled and converted to digital data at 1 kHz.

The sensor data is filtered and down-sampled to 100Hz by the DSP using FIR (finite impulse response) filters. The factory calibration data, stored in EEPROM, is used by the DSP to remove temperature bias, misalignment, scale factor errors, and non-linearities from the sensor data. Additionally any advanced user settings such as axes rotation are applied to the IMU data. The 100Hz IMU data is continuously being maintained inside the unit. Digital IMU data is output over the RS-422 or Ethernet link at a selectable fixed rate (100, 50, 25, 20, 10, 5 or 2 Hz) or an on request basis using the GP (Get Packet) command.

The digital IMU data is available in one of several measurement packet formats including Scaled Sensor Data (S1 Packet) and Delta-Theta, Delta-V (S2 Packet). In the Scaled Sensor Data (S1 Packet) data is output in scaled engineering units. In the Delta-Theta, Delta-V format (S2 Packet) scaled sensor data is integrated with respect to the time of the last output packet and the data is reported in units of accumulated (i.e., delta) degrees and meters/second. For information about full packets, refer to *Chapter 9. Communicating with the GNA540 Unit* and *Chapter 10. Programming Guidelines.*

NOTE: The Delta-Theta, Delta-V packet is only recommended for use in continuous output mode at 5Hz or greater. Polled requests for this packet will produce values accumulated since the last poll request; they are subject to overflow (data type wrap around).

IMU Advanced Settings

The IMU advanced settings are described in *Table 7* below. All of the advanced settings are accessible thru NAV-VIEW 2.2 under the Configuration Menu→Unit Configuration settings. For information about using NAV-VIEW 2.2, refer to *Chapter 7. Configuring GNAV540 with NAV-VIEW 2.2.*

Table 7 IMU Function Advanced Settings

Setting	Default Value	Comments
Baud Rate	38,400	9600, 19200, 57600 also available
Packet Type	S1	S2 also available
Packet Rate	100Hz	This sets the rate at which the selected *Packet Type* packets are output. If polled mode is desired, then select Quiet. If Quiet is selected, the unit will only send measurement packets in response to GP commands.
Orientation	See *Figure 4* on page 24.	To configure the axis orientation, select the desired measurement for each axis: NAV-VIEW 2.2 will show the corresponding image of the unit, so it easy to visualize the mode of operation. Refer to *Orientation Field* on page 86 for the twenty four possible orientation settings. The default setting points the connector AFT.

Vertical Gyroscope (VG) Function

The Vertical Gyroscope (VG) Function provides dynamic roll and pitch measurements in addition to the IMU Function data. The dynamic roll and pitch measurements are stabilized by using the accelerometers as a long-term gravity reference. The VG Function can also output a free integrating yaw angle measurement that is not stabilized by a magnetometer or compass heading.

At a fixed 100Hz rate, the VG Function continuously maintains both the digital IMU data as well as the dynamic roll and pitch data. As shown in the software block diagram (*Figure 2* on page 23), after the *Sensor Calibration* block, the IMU data is passed into an *Integration to Orientation* block. (If using external GPS, refer to Figure 4 on page 24.) The *Integration to Orientation* block integrates body frame sensed angular rate to orientation at a fixed 100 times per second. For improved accuracy and to avoid singularities when dealing with the cosine rotation matrix, a quaternion formulation is used in the algorithm to provide attitude propagation.

Also shown in the software block diagram (*Figure 2*, page 23) the *Integration to Orientation* block receives drift corrections from the *Extended Kalman Filter* or *Drift Correction Module*. In general, rate sensors and accelerometers suffer from bias drift, misalignment errors, acceleration errors (g-sensitivity), nonlinearity (square terms), and scale factor errors.

The largest error in the orientation propagation is associated with the rate sensor bias terms. The Extended Kalman Filter (EKF) module provides an on-the-fly calibration for drift errors, including the rate sensor bias, by providing corrections to the Integration to Orientation block and a characterization of the gyroscope bias state. In the VG Function, the internally computed gravity reference vector provides a reference measurement for the EKF when the unit is in quasi-static motion to correct roll and pitch angle drift and to estimate the X and Y gyroscope rate bias. Because the gravity vector has no horizontal component, the EKF has no ability to estimate either the yaw angle error or the Z gyroscope rate bias.

VG Function adaptively tunes the EKF feedback in order to best balance the bias estimation and attitude correction with distortion free performance during dynamics when the object is accelerating either linearly (speed changes) or centripetally (false gravity forces from turns). Because centripetal and other dynamic accelerations are often associated with yaw rate, the unit maintains a low-pass filtered yaw rate signal and compares it to the turnSwitch threshold field (user adjustable).

When the platform the unit is attached to exceeds the *turnSwitch* threshold yaw rate, the unit lowers the feedback gains from the accelerometers to allow the attitude estimate to coast through the dynamic situation with primary reliance on angular rate sensors. This situation is indicated by the softwareStatus→turnSwitch status flag. Using the turn switch maintains better attitude accuracy during short-term dynamic situations, but care must be taken to ensure that the duty cycle of the turn switch generally stays below 10% during the vehicle mission. A high turn switch duty cycle does not allow the system to apply enough rate sensor bias correction and could allow the attitude estimate to become unstable.

The VG Function algorithm has two major phases of operation. The first phase of operation is the initialization phase. During the initialization phase, the unit is expected to be stationary or quasi-static so the EKF weights the accelerometer gravity reference heavily in order to rapidly estimate the roll and pitch angles, and X, Y rate sensor bias. The initialization phase lasts approximately 60 seconds, and the initialization phase can be monitored in the softwareStatus BIT transmitted by default in each measurement packet. After the initialization phase, the unit operates with lower levels of feedback (also referred to as EKF gain) from the accelerometers to continuously estimate and correct for roll and pitch errors, as well as to estimate X and Y rate sensor bias. To reset the algorithm or re-enter the initialization phase, sending the algorithm reset command, AR, will force the algorithm into the reset phase.

In addition to the scaled sensor packets described in the IMU Function section, the VG Function has additional measurement output packets including the default A2 Angle Packet which outputs the roll angle, pitch angle, and digital IMU data. N0 and N1 packets are also available for use with an external GPS receiver. For more information, refer to *Chapter 9. Communicating with the GNAV540 Unit* and *Chapter 10. Programming Guidelines* for packet descriptions.

VG Function Advanced Settings

In addition to the configurable baud rate, packet rate, axis orientation, and sensor low-pass filter settings, VG Function provides additional advanced settings that are selectable for tailoring the unit to a specific application requirements. The settings are listed in *Table* 8 below.

Table 8 VG Function Advanced Settings

Setting	Default Value	Comments
Baud Rate	38,400 baud	9600, 19200, 57600 also available
Packet Type	A2	S1, S2, N0, N1 also available
Packet Rate	25Hz	This setting sets the rate at which selected Packet Type, packets are output. If polled mode is desired, then select *Quiet*. If Quiet is selected, the unit will only send measurement packets in response to GP commands.
Orientation	See *Figure 4* on page 24.	To configure the axis orientation, select the desired measurement for each axis: NAV-VIEW 2.2 will show the corresponding image of the unit, so it easy to visualize the mode of operation. Refer to *Orientation Field* on page *86* for the twenty four possible orientation settings. The default setting points the connector AFT.

Setting	Default Value	Comments
Freely Integrate	OFF	The *Freely Integrate* setting allows configuring the unit into a *free gyroscope*. In free gyroscope mode, the roll, pitch and yaw are computed exclusively from angular rate with no Kalman filter based corrections of roll, pitch, or yaw. When turned on, there is no coupling of acceleration based signals into the roll and pitch. As a result, the roll, pitch, and yaw outputs will drift roughly linearly with time due to sensor bias. For best performance, the Freely Integrate mode should be used after the algorithm has initialized. This allows the Kalman Filter to estimate the roll and pitch rate sensor bias prior to entering the free gyroscope mode. Exiting the free *gyroscope* mode (OFF), causes one of the following behaviors to occur: • If the unit has been in freely integrate mode for less than sixty seconds, the algorithm will resume operation at normal gain settings. • If the unit has been in freely integrate mode for greater than sixty seconds, the algorithm will force a reset and reinitialize with high gains automatically.
Restart On Over Range	OFF	This setting forces an algorithm reset when a sensor over range occurs, i.e., a rotational rate on any of the three axes exceeds the maximum range. The default setting is OFF. Algorithm reset returns the unit to a high gain state, where the unit rapidly estimates the gyroscope bias and uses the accelerometer feedback heavily. This setting is recommended when the source of over-range is likely to be sustained and potentially much greater than the rate sensor operating limit. Large and sustained angular rate over-ranges result in unrecoverable errors in roll and pitch outputs. An unrecoverable error indicates the EKF cannot stabilize the resulting roll and pitch reading. If the over-ranges are expected to be of short duration (<1 sec) and a modest percentage over the maximum operating range, it is recommended that the restart on over range setting be turned off. Handling an inertial rate sensor over-range is controlled with the *restartOnOverRange* switch. • If *restartOnOverRange* is off, the system will flag the overRange status flag and continue to operate through it. • If *restartOnOverRange* is on, the system will flag a masterFail error during an over-range condition and continue to operate with this flag until a quasi-static condition is met to allow for an algorithm restart. The quasi-static condition required is that the absolute value of each low-pass filtered rate sensor falls below 3 deg/sec to begin initialization. The system will then attempt a normal algorithm start.
Dynamic Motion	ON	The default setting is ON. Turning off the dynamic motion setting results in a higher gain state that uses the accelerometer feedback heavily. During periods of time when there is known low dynamic acceleration, this switch can be turned off to allow the attitude estimate to quickly stabilize.
Turn Switch threshold	10.0 deg/sec	With respect to centripetal or false gravity forces from turning dynamics (or coordinated turn), the unit monitors the yaw-rate. If the yaw rate exceeds a given turn switch threshold, the feedback gains from the accelerometer signals for attitude correction are reduced because they are likely corrupted.

AHRS Function

The Attitude Heading Reference System (AHRS) Function utilizes a 3-axis magnetometer (internal or external) in addition to the accelerometers and gyroscopes, as well as the associated software running on the DSP processor. This enables the computation of dynamic heading, as well as dynamic roll and pitch. AHRS Function provides dynamic heading, roll, and pitch measurements in addition to the VG Function and IMU Function data. The dynamic heading measurement is stabilized using the 3-axis magnetometer as a magnetic north reference. The dynamic roll and pitch measurements are stabilized using the accelerometers as a long-term gravity reference. The unit can be configured to turn on and off the magnetic reference for user defined periods of time.

This function utilizes data from calibrated sensors, the gyroscopes, the accelerometers and a magnetometer (internal or external). For details of the IMU functions, refer to IMU Function on page 25. For details of the VG functions, refer to *Vertical Gyroscope (VG) Function* on page 26.

In addition to the features described in the previous sections (*IMU Function* and *Vertical Gyroscope (VG) Function*), the AHRS algorithm has two major phases of operation. The first phase of operation is the high-gain initialization phase. During the initialization phase, the unit is expected to be stationary or quasi-static so the EKF weights the accelerometer gravity reference and Earth's magnetic field reference heavily in order to rapidly estimate the X, Y, and Z rate sensor bias, and the initial attitude and heading of the unit. The initialization phase lasts approximately 60 seconds, and the initialization phase can be monitored in the softwareStatus BIT transmitted by default in each measurement packet. After the initialization phase, the unit operates with lower levels of feedback (also referred to as EKF gain) from the accelerometers and magnetometers to continuously estimate and correct for roll, pitch, and heading (yaw) errors, as well as to estimate X, Y, and Z rate sensor bias.

The AHRS Function provides the same scaled sensor and angle mode packets of the VG Function. The AHRS Function defaults to the *A1* Angle Packet which outputs the roll angle, pitch angle, yaw angle, and digital IMU data. In the AHRS Function , the `A0` and `A1` packets contain accurate magnetometer readings. For more information, refer to *Chapter 9. Communicating with the GNAV540 Unit* and *Chapter 10. Programming Guidelines* for packet descriptions.

NOTE: For proper operation, the unit relies on magnetic field readings from a 3-axis magnetometer. The unit must be installed correctly and calibrated for hard-iron and soft iron effects to avoid any system performance degradation. Refer to *Chapter 4. Magnetometer Calibration and Alignment Guidelines* for information about magnetic calibration; review that section before using the AHRS Function.

NOTE: The GNAV540 unit and the external magnetometer (if used) must be mounted at least 24" away from large ferrous objects and fluctuating magnetic fields. Failure to locate the unit in a clean magnetic environment will affect the attitude solution.

AHRS Advanced Settings

In addition to the configurable baud rate, packet rate, axis orientation, and sensor low-pass filter settings, the unit provides additional advanced settings which are selectable for tailoring the unit to a specific application requirements. The AHRS advanced settings are listed in *Table 9* below:

Table 9 AHRS Series Advanced Settings

Setting	Default Value	Comments
Baud Rate	38400	9600, 19200, 57600 also available
Packet Type	A1	S0, S1, S2, A0, A2, N0, N1 also available
Packet Rate	25 Hz	This setting sets the rate at which selected Packet Type, packets are output. If polled mode is desired, then select Quiet.

Setting	Default Value	Comments
Orientation	See *Figure 4* on page 24.	To configure the axis orientation, select the desired measurement for each axis: NAV-VIEW 2.2 then shows the corresponding image of the unit, making it easy to visualize the mode of operation. Refer to *Orientation Field* on page *86* for the twenty four possible orientation settings. The default setting points the connector AFT.
Freely Integrate	OFF	The Freely Integrate setting allows a user to turn the unit into a *free gyroscope*. In free gyroscope mode, the roll, pitch and yaw are computed exclusively from angular rate with no Kalman filter based corrections of roll, pitch, or yaw. When turned on, there is no coupling of acceleration based signals into the roll and pitch or magnetometer based signals to the yaw. Due to sensor bias., the roll, pitch, and yaw outputs will drift roughly linearly with time. For best performance, the Freely Integrate mode should be used after the algorithm has initialized. This allows the Kalman Filter to estimate the roll and pitch rate sensor bias prior to entering the free gyroscope mode. Upon exiting the free gyroscope mode (OFF), one of two behaviors will occur: • If the unit has been in freely integrate mode for less than sixty seconds, the algorithm will resume operation at normal gain settings • If the unit has been in freely integrate mode for greater than sixty seconds, the algorithm will force a reset and reinitialize with high gains automatically.
Use Mags	ON	The Use Mags setting enables turning on and off the magnetometer feedback for yaw/heading stabilization. • The default setting is ON. When Use Mags is turned ON, the GNAV540 unit uses the magnetic field sensor readings to stabilize the drift in yaw, and it slaves the yaw to the compass reading provided from the magnetic field sensor readings. • When Use Mags is turned OFF, the heading (yaw) angle measurement of the unit will drift and freely integrate. In effect, this setting converts the functionality to VG. However, unlike a unit in the VG Function, this can be done on a selectable basis and changed in real time during a mission. This setting enables turning off the magnetometer stabilization when severe magnetic distortion may be occurring. This setting is desirable when the system temporarily moves in close proximity to a large ferrous object. When the Use Mags switch is turned from OFF to ON, the unit will reinitialize the yaw/heading angle with the compass reading provided from the magnetic field sensor readings.

Setting	Default Value	Comments
Restart On Over Range	OFF	This setting forces an algorithm reset when a sensor over range occurs, i.e., a rotational rate on any of the three axes exceeds the maximum range. The default setting is OFF. Algorithm reset returns the unit to a high gain state, where the unit rapidly estimates the gyroscope bias and uses the accelerometer feedback heavily. This setting is recommended when the source of over-range is likely to be sustained and potentially much greater than the rate sensor operating limit. Large and sustained angular rate over-ranges result in unrecoverable errors in roll and pitch outputs. An unrecoverable error is one where the EKF cannot stabilize the resulting roll and pitch reading. If the over-ranges are expected to be of short duration (<1 sec) and a modest percentage over the maximum operating range, it is recommended that the restart on over range setting be turned off. Handling of an inertial rate sensor over-range is controlled using the restartOnOverRange switch. If this switch is off, the system will flag the overRange status flag and continue to operate through it. If this switch is on, the system will flag a masterFail error during an over-range condition and continue to operate with this flag until a quasi-static condition is met to allow for an algorithm restart. The quasi-static condition required is that the absolute value of each low-pass rate sensor falls below 3 deg/sec to begin initialization. The system will then attempt a normal algorithm start.
Dynamic Motion	ON	The default setting is ON. Turning off the dynamic motion setting results in a higher gain state that uses the accelerometer feedback heavily. During periods of time when there is known low dynamic acceleration, this switch can be turned off to allow the attitude estimate to quickly stabilize.
Turn Switch threshold	0.5 deg/sec	With respect to centripetal or false gravity forces from turning dynamics (or coordinated turn), the unit monitors the yaw-rate. If the yaw rate exceeds a given TurnSwitch threshold, the feedback gains from the accelerometer signals for attitude correction are reduced because they are likely corrupted.

NAV Function

The NAV Function supports all the features of the IMU, VG and AHRS functions. In addition, the NAV function integrates the sensor information from an internal or external GPS receiver, and runs internal software on the DSP processor for computing navigation and orientation information. In this function, the unit outputs GPS information (Latitude, Longitude, and Altitude), inertial-aided 3-axis velocity information, as well as heading, roll, and pitch measurements in addition to digital IMU data.

At a fixed 100Hz rate, the unit continuously maintains the following: digital IMU data the dynamic roll, pitch, and heading data, as well as the navigation data. As shown in *Figure 2* on page 23, after the Sensor Calibration block, the IMU data is passed into an Integration to Orientation block. The Integration to Orientation block integrates body frame sensed angular rate to orientation at a fixed 100 times per second. For improved accuracy and to avoid singularities when dealing with the cosine rotation matrix, a quaternion formulation is used in the algorithm to provide attitude propagation. Following the integration to orientation block, the body frame accelerometer signals are rotated into the NED level frame and are integrated to velocity. At this point, the data is blended with GPS position data, and output as a complete navigation solution.

As shown in *Figure 2* on page 23, the Integration to Orientation and the Integration to Velocity signal processing blocks receive drift corrections from the Extended Kalman Filter (EKF) drift correction module. The drift correction module uses data from the aiding sensors, when they are available, to correct the errors in the velocity, attitude, and heading outputs. Additionally, when aiding sensors are available corrections to the rate gyroscopes and accelerometers are performed.

The NAV Function blends GPS derived heading and accelerometer measurements into the EKF update depending on the health and status of the associated sensors. If the GPS link is lost or poor, the Kalman Filter solution stops tracking accelerometer bias, but the algorithm continues to apply gyroscope bias correction and provides stabilized angle outputs. The EKF tracking states are reduced to angles and gyroscope bias only. The accelerometers will continue to integrate velocity. However, accelerometer noise, bias, and attitude error will cause the velocity estimates to start drifting within a few seconds. The attitude tracking performance will degrade, the heading will freely drift, and the filter will revert to the VG Function; if the magnetometer is running, then the filter will revert to the AHRS function. In either function, the EKF formulation will continue without GPS velocity. The UTC packet synchronization will drift due to internal clock drift.

The status of GPS signal acquisition can be monitored from the hardwareStatus BIT (refer to *Chapter 11. Built In Test (BIT)*). From a cold start, it typically takes 40–90 seconds for GPS to lock. The actual lock time depends on the antenna's view of the sky and the number of satellites in view. The DSP performs time-triggered trajectory propagation at 100Hz and synchronizes the sensor sampling with the GPS UTC (Universal Coordinated Time) second boundary when available.

As with the AHRS and VG Functions, the algorithm has two major phases of operation. Immediately after power-up, the unit uses the accelerometers and magnetometers to compute the initial roll, pitch and yaw angles. The roll and pitch attitude will be initialized using the accelerometer's reference of gravity, and yaw will be initialized using the leveled magnetometers X and Y axis reference of the earth's magnetic field. During the first 60 seconds of startup, the unit should remain approximately motionless in order to properly initialize the rate sensor bias. The initialization phase lasts approximately 60 seconds, and the initialization phase can be monitored in the softwareStatus BIT transmitted by default in each measurement packet. After the initialization phase, the unit operates with lower levels of feedback (also referred to as EKF gain) from the GPS, accelerometers, and magnetometers.

The NAV Function provides additional output measurement packets including the default *N*1 Navigation Packet, which *outputs* the Latitude, Longitude, Altitude, X,Y,Z velocities, accelerations, and roll angle, pitch angle, yaw angle, and digital IMU data. For more information about packets, refer to *Chapter 9. Communicating with the GNAV540 Unit* and *Chapter 10. Programming Guidelines.*

NAV Advanced Settings

In addition to the configurable baud rate, packet rate, axis orientation, and sensor low-pass filter settings, the NAV Function provides additional advanced settings which are selectable for tailoring the unit to a specific application requirements. The advanced settings are listed in *Table 10 GNAV540 Advanced Settings* below:

Table 10 GNAV540 Advanced Settings

Setting	Default Value	Comments
Baud Rate	38400	9600, 19200, 57600 also available
Packet Type	N3	S0, S1, S2, A0, A1, A2, N0, N3, N4 also available
Packet Rate	25 Hz	This setting sets the rate at which selected Packet Type, packets are output. If polled mode is desired, then select Quiet.

Setting	Default Value	Comments
Orientation	See *Figure 4* on page 24.	To configure the axis orientation, select the desired measurement for each axis: NAV-VIEW 2.2 will show the corresponding image of the unit, so it easy to visualize the mode of operation. Refer to *Orientation Field* on page *86* for the twenty four possible orientation settings. The default setting points the connector AFT.
Freely Integrate	OFF	The Freely Integrate setting allows a user to turn the unit into a *free gyroscope*. In free gyroscope mode, the roll, pitch and yaw are computed exclusively from angular rate with no Kalman filter based corrections of roll, pitch, and yaw. When turned on, there is no coupling of acceleration based signals into the roll and pitch or magnetometer based signal to the yaw. As a result, the roll, pitch, and yaw outputs will drift roughly linearly with time due to sensor bias. For best performance, the Freely Integrate mode should be used after the algorithm has initialized. This allows the Kalman Filter to estimate the roll and pitch rate sensor bias prior to entering the free gyroscope mode. Upon exiting the *free gyroscope* mode (OFF), one of two behaviors will occur ▪ If the unit has been in freely integrate mode for less than sixty seconds, the algorithm will resume operation at normal gain settings ▪ If the unit has been in freely integrate mode for greater than sixty seconds, the algorithm will force a reset and reinitialize with high gains automatically.
Use GPS	ON	The Use GPS setting enables turning on and off the GPS feedback. The default setting is ON. When *Use GPS* is turned OFF, the unit's behavior will revert to that of AHRS Function.
Stationary Yaw Lock	OFF	This setting defaults to OFF; it is recommended to be OFF for NAV Function. The stationary yaw lock is only recommended for consideration when the unit is operating with GPS (Use GPS = ON) and WITHOUT magnetometer feedback (Use Mags = OFF). Stationary yaw lock may be appropriate if the user platform is a ground vehicle.
Use Mags	ON	The Use Mags setting enables turning on and off the magnetometer feedback for yaw/heading stabilization. The default setting is ON.. When Use Mags is turned ON, the unit uses the magnetic field sensor readings to stabilize the drift in yaw, and it slaves the yaw to the compass reading provided from the magnetic field sensor readings. When *Use Mags* is turned OFF, the heading (yaw) angle measurement of the unit will be slaved to the GPS heading if GPS is available, otherwise the heading will drift feely. The reason for this setting is to give the user an ability to turn off the magnetometer stabilization when severe magnetic distortion may be occurring. This setting is desirable when the user vehicle temporarily moves in close proximity to a large ferrous object. When the *Use Mags* switch is turned from OFF to ON, the unit will reinitialize the yaw/heading angle with the compass reading provided from the magnetic field sensor readings.

Setting	Default Value	Comments
Restart On Over Range	ON	This setting forces an algorithm reset when a sensor over range occurs, i.e., a rotational rate on any of the three axes exceeds the maximum range. The default setting is OFF.. Algorithm reset returns the unit to a high gain state, where the unit rapidly estimates the gyroscope bias and uses the accelerometer feedback heavily. This setting is recommended when the source of over-range is likely to be sustained and potentially much greater than the rate sensor operating limit. Large and sustained angular rate over-ranges result in unrecoverable errors in roll and pitch outputs. An unrecoverable error is one where the EKF cannot stabilize the resulting roll and pitch reading. If the over-ranges are expected to be of short duration (<1 sec) and a modest percentage over the maximum operating range, it is recommended that the restart on over range setting be turned off. Handling of an inertial rate sensor over-range is controlled using the restartOnOverRange switch. ▪ If this switch is off, the system will flag the overRange status flag and continue to operate through it. ▪ If this switch is on, the system will flag a masterFail error during an over-range condition and continue to operate with this flag until a quasi-static condition is met to allow for an algorithm restart. The quasi-static condition required is that the absolute value of each low-pass rate sensor falls below 3 deg/sec to begin initialization. The system will then attempt a normal algorithm start.
Dynamic Motion	ON	The default setting is ON. Turning off the dynamic motion setting results in a higher gain state that uses the accelerometer feedback heavily. During periods of time when there is known low dynamic acceleration
Turn Switch Threshold	0.5 deg/sec	With respect to centripetal or false gravity forces from turning dynamics (or coordinated turn), the unit monitors the yaw-rate. If the yaw rate exceeds a given turnSwitch threshold, the feedback gains from the accelerometer signals for attitude correction are reduced because they are likely corrupted.

Chapter 3. Hardware Interface

This chapter provides information about the power and signal interface connectors.

J1—I/O Connector

NOTE: Signals labeled as NC have internal pull-up mechanisms. To ensure proper operation of the unit, ensure there are no connections to these pins.

Table 11 I/O Connector

Pin No.	Signal	Pin No.	Signal
1	Signal Ground	20	NC
2	Chassis Ground	21	Master_BIT_CONN
3	User RS-422 Tx (+)	22	NC
4	User RS-422 Tx (-)	23	USER_PORT_SEL_CONN
5	User RS-422 Rx (+)	24	NC
6	User RS-422 Rx (-)	25	EXT-PPS-INPUT-CONN
7	NC	26	GPS RS422 TX(+)
8	NC	27	GPS-PPS-OUT_CONN
9	10/100 Base Tx(+)	28	MAG RS422 RX(-)
10	10/100 Base Tx(-)	29	MAG RS422TX(+)
11	GPS RS422-Rx(+)	30	MAG RS422TX(-)
12	GPS RS422-Rx(-)	31	Signal Ground
13	10/100 Base Rx(+)	32	Signal Ground
14	Mag RS422 Rx(+)	33	NC
15	Mag RS422 Rx(+)	34	GPS RS422 TX(-)
16	10/100 Base Rx(-)	35	MAG RS422 RX(-)
17	Input Power (+Vin)	36	NC
18	Input Power (+Vin)	37	BOOT_SEL_CONN
19	Signal ground		

J2—GPS Antenna Connector

The GPS receiver needs to receive signals from as many satellites as possible. A GPS receiver does not work properly in narrow streets and underground parking lots or if objects or human beings cover the antenna. Poor visibility may result in position drift or a prolonged Time-To-First-Fix (TTFF). A good sky visibility is therefore a prerequisite. Even the best receiver can't make up for signal loss due to a poor antenna, in-band jamming or a poor RF cable.

The unit ships with an external active antenna that must be connected properly to SMA jack on the unit case. Placing the antenna on a 16 square inch or larger ground plane is highly recommended.

I/O Port Interface

The following ports are accessible through the J1 connector. Refer to *J1—I/O Connector* on page 35 for the pin out listing.

NOTE: The GNAV540 can be purchased with a developer's kit: a cable is provided with a 37 pin connector on one end, and five connectors on the other end to connect to external devices. This cable is designed only for laboratory use. See *Figure 31* on page 126.

Port A: User (computer), RS422 serial data interface

This serial interface is standard RS-422, 9600, 19200, 38400, or 57600 baud, 8 data bits, 1 start bit, 1 stop bit, no parity, and no flow control and will output at a user configurable output rate. These settings allow interaction via a standard PC serial port

Port B: External GPS, RS422 serial interface

This serial interface is standard RS-422, which connects to the external GPS. GNAV540 supports a GPS-ICD-153C compliant GPS receiver.

Port C: External Magnetometer, RS422 serial interface

This serial interface is standard RS-422. The settings for an external magnetometer are 38400 baud, 8 data bit, 1 start bid, 1 stop bit, no parity, no flow control.

Cable Field Requirements

CAUTION: The GNAV540 is shipped with an EMI filter attached to the Amphenol (MIL-DTL-38999-III), TVP02R Receptacle, 37 pins circular connector. This connector must remain in place to ensure proper shielding from EMI interference. The cable sent with the unit is intended to provide the user with the ability to test the unit right out of the box, and will not provide adequate shielding for all environments.

For field use, the cable must be used with the shield connected to the I/O connector shell to provide the required EMI protection. Case ground must be used to provide full EMI protection; Ensure the cable shield is grounded on only one end of the cable.

Signals

Hardware BIT Error Output

The hardware BIT error output pin is the ultimate indication of system failure. This indication is available in most software output packets as the masterFail flag. It is the logical AND of the hardwareError, comError, and softwareError flags monitored by the system. In the event of a communication failure, the hardware BIT error pin may be used to detect a masterFail assertion. This pin is open-collector and requires a 1k to 10k ohm pull-up resister. The system will drive this pin low to assert a system failure.

1 PPS Input Interface

The 1PPS input signal allows the user of the GNAV540 to force synchronization of sensor data collection to a 1Hz rising-edge signal. The signal must maintain 0.0-0.2 V zero logic and 3.0-5.0 volts high logic and stay within 100ms of the internal system 1 second timing. Sending this signal to the system will align the sensor data collection and algorithm processing to its rising edge and 10ms boundaries thereafter. When the system is synchronized to 1PPS, the hardwareStatus→unlocked1PPS flag will be *zero*; otherwise, the flag will be *one*.

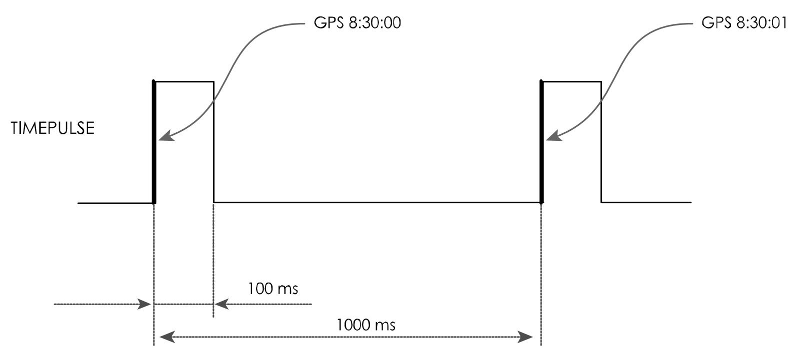
1 PPS Output Interface

The 1PPS output signal is provided by the internal GPS receiver (when GPS timing is known) on the GNAV540. The 1PPS output signal is open-collector and should be interfaced to a rising-edge trigger with pull up resistor between 1k and 10k ohms. The GNAV540 synchronizes sensor data collection to this 1PPS signal internally when available. Therefore, the 100Hz navigation algorithm will run exactly 100 times each second with no slip when locked to 1PPS.

Packet data is valid on the rising edge of 1PPS and 10ms boundaries thereafter. There is, however, up to 500µs of additional latency in sensor data collection. If 1PPS is provided by the internal GPS receiver in NAV products, then the rising edge of 1PPS will correspond to the UTC second boundary. When the system is synchronized to 1PPS, the hardwareStatus→unlocked1PPS flag will be *zero*; otherwise, the flag will be *one*.

Figure 5 below shows the sequential order of the signal present at 1 PPS OUT pin. The one PPS signal is aligned to the sampling clock of 23.104 MHz, which results in the timing resolution of 43 ns.

Figure 5 1PPS Output Signal



Chapter 4. Magnetometer Calibration and Alignment Guidelines

This chapter provides general guidelines for calibrating and aligning a magnetometer with the GNAV540 unit.

This section provides guidelines to calibrate and align the magnetometer. This information applies when implementing AHRS Function or NAV Function (*AHRS Function* on page 29, *NAV Function* on page 31).

NOTE: For effective calibration results, the GNAV540 unit must be installed in the system during the alignment process. This also applies to an external magnetometer. If calibrated outside of the system, the magnetism of the system will not be measured. Without those values, the GNAV540 will not be able to compensate magnetic readings: either heading readings will be incorrect or error messages will be displayed.

Compensation for Magnetic Fields

Magnetic sensors measure magnetic fields which are then used to compute heading. A correct heading angle is based only on the earth's magnetic field. However, the magnetic fields of the GNAV540 unit and the surroundings (such as the system/vehicle in which the unit is installed) are also measured, which affect the magnetic reading. To compensate for these magnetic fields and ensure accurate heading readings, the GNAV540 unit must be calibrated.

The GNAV540 unit compensates for the extra magnetic field(s) by taking a series of measurements and then applying those measurements to a two-dimensional algorithm. The algorithm is used to calculate the hard iron and soft iron effects, the values of which are then stored as constants in the EEPROM of the unit. Those constants are used for correcting the magnetic readings, ensuring accurate heading output. Hard iron effects are shifts in the magnetic field from ferrous objects or other magnetic material in the proximity of the magnetic sensor. Soft iron effects are the change of direction of a magnetic field; this change is caused by hard iron on the input direction. Hard iron magnetic fields are permanent whereas soft iron magnetic fields are temporary: soft iron can be magnetized and then demagnetized, or have varying effects during operation.

Following is an overview of the calibration process:

1. Install the GNAV540 in the system in which it will be used
2. If an external magnetometer is used, install that device in the system
3. Select an appropriate test location, free of magnetic interference
4. Run the calibration and alignment procedure
5. Set the calibration readings in the GNAV540

NOTE: Ensure the test location is appropriate for magnetic calibration. The calibration process provides corrections for magnetic fields from fixed locations that are relative to the position of the unit. The calibration does not compensate for time varying fields, or fields created by magnetic material that moves relative to the GNAV540 unit.

Magnetometer Alignment Using NAV-VIEW 2.2

During the calibration procedure, the unit makes a series of measurements while the user system is being turned through a complete 360 degree circle. A 360 degree rotation gives the unit visibility to hard and soft iron distortion in the horizontal plane. Using NAV-VIEW 2.2, the hard and soft iron effects can be viewed by selecting the *Misalignment* option on the *Configuration Menu*, and viewing the magnetic circle during the calibration.

For calibration instructions, refer to *Aligning the Magnetometer* on page 57.

Magnetometer Alignment Using Code

The unit provides a command interface for initiating the hard iron/soft iron calibration without using NAV-VIEW 2.2. To do so, send a `WC` command to initiate the calibration, and then rotate the user system 360 degrees. The `WC` command has two options: auto-termination and manual termination.

- With auto-termination, the unit tracks the yaw movement and after 380 degrees of rotation returns the calibration complete response, `CC`. The auto-termination sequence can falsely terminate if the 360 degree rotation is not completed within two (2) minutes of the `WC` command initiation.
- Manual termination requires sending a second `WC` command with the termination code in the payload. Manual termination is a good option when the user system moves very slowly (e.g., large marine vessel) and completing the 360 degree rotation may require more than two minutes.

The status of the magnetometer calibration is indicated by the softwareError→dataError→magAlignOutOfBounds error flag available in the `T0` packet. You can access the hardIronScaleRatio and softIronScaleRatio calibration data as configuration fields in NAV-VIEW 2.2, or by using the communication protocol. Also, the softwareError bit of the masterFail byte within the BIT word is transmitted in every measurement packet. When the unit has not been properly calibrated, this softwareError bit will be set to fail (high).

The calibration complete (`CC`) command response message contains the X and Y hard iron bias, as well as the soft iron ratio. This information can be interpreted to give an indication of the quality of the calibration. For more information on the hard iron bias and soft iron ratio effects refer to *Compensation for Magnetic Fields* on page 39. Refer to *Chapter 9. Communicated with the GNAV540 Unit* for details of `WC` and `CC` commands.

Installation Guidelines—External Magnetometer

Field Installation

- For a proper calibration and alignment, the GNAV540 unit must be installed in its operating environment, such as the land vehicle or aircraft in which it will be used.
- If using an external magnetometer:
    - The magnetometer must be mounted at least 24" away from large ferrous objects and fluctuating magnetic fields. Failure to locate the magnetometer in a clean magnetic environment will affect the attitude solution.
    - Configuring the pitch and level offsets of the magnetometer must be performed before calibrating the GNAV540 unit.

EMI Protection and Grounding

- Ensure the magnetometer is not exposed to large magnetic fields. This could permanently magnetize internal components and degrade magnetic heading accuracy.
- For EMI protection, the magnetometer must be connected with a shielded cable that is connected to the I/O connector shell.
    - Ensure the case of the magnetometer is electrically connected to the I/O connector shell.
    - The shell should be electrically connected to the user's cable shield.

Serial Data Interface

The GNA540 receives information through a serial interface that is dedicated for an external magnetometer. Refer to Table 11 on page 35 for the signal pin out of the J1 connector.

Chapter 5. Installation Guidelines

This chapter provides information to set up the GNAV540 unit and NAV-VIEW 2.2 software for laboratory test.

NOTE: Directions to install a unit in a vehicle for field use is outside the scope of this document.

Overview

The following instructions are for connecting the GNAV540 unit to a computer and using NAV-VIEW 2.2 to verify basic functions of the unit in a laboratory setting.

Installation Requirements

Computer

- CPU: ≥ 1GHz
- RAM Memory: ≥ 3GB
- Hard Drive Free Memory: ≥ 60MB
- Operating System: Windows XP, 32 bit or 64 bit; Windows 7, 32 bit or 64 bit
- Microsoft .NET 4.0 or higher

Communication Port

- For a serial connection, which COM port to use.
- For an Ethernet connection, the IP address of the GNVA540 unit and the IP port number

NOTE: The default IP address of the unit is 192.168.1.2.

Power and Hardware

Power:

- Voltage: +9 VDC to +32 VDC
- Power: > 5 W

Hardware:

- Ensure all necessary hardware has been determined and provided.
- Optional: For laboratory test, a cable is provided with the Crossbow evaluation kit. Refer to *Figure 31 on* page 126.

NOTE: The kit cable is only suitable for laboratory test; it is not designed for field use. Refer to Figure 31 on page 126.

1. Install Software—NAV-VIEW 2.2

Instructions

a. Insert the CD *GNAV540 Inertial System* in the CD-ROM drive.

b. On the CD, go to the NAV-VIEW 2.2 folder and double click the **setup.exe** file.

c. Follow the wizard instructions to install NAV-VIEW 2.2 and if necessary, the .NET 4.0 framework.

2. Prepare the Communication Port

The GNAV540 unit can communicate to the computer via Ethernet or directly to the computer via serial port: determine which communication port to use.

- For a serial port, note which COM port.
- For the Ethernet, note the port IP number and the IP address of the GNAV540.
- Ensure the switch on Port C, the serial interface for the External Magnetometer is set to **OFF**.

Setting up the port will be handled in step *4 Turn on the* GNAV540*.*

3. Connect the GPS Antenna

NOTE: The GNAV540 unit is shipped with an external active antenna.

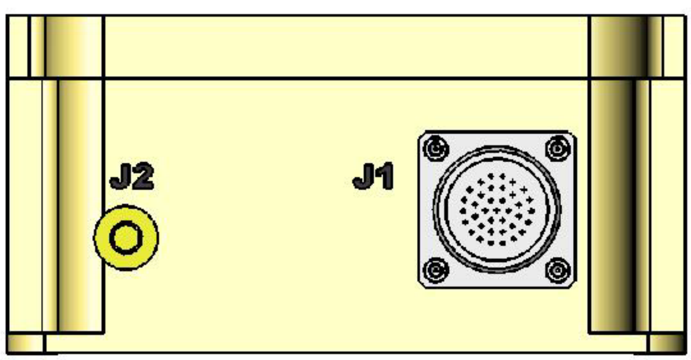
To clearly receive signals from many satellites, a *clear view* from the antenna to the sky is required.

- Poor visibility may result in position drift or a prolonged Time-To-First-Fix (TTFF). The following setups can obstruct the signal, resulting in poor results for navigation:
- The GPS receiver will not work properly if signals are blocked, such as objects cover the antenna, or the receiver is located underground or other confined area.
- Signals can also be blocked or distorted with a poor quality antenna or RF cable, or in-band jamming.
- Placing the antenna on a 16 square inch (e.g. 4” x 4”) or larger ground plane is recommended.

Instructions

- Secure the antenna to the SMA jack on the enclosure.

Figure 6 GNAV540 Unit



J1: 37 pin connector

J2: SMA connector

4. Turn on the GNAV540

Instructions

a. Ensure the voltage level of the power supply is set between +8 VDC and +32 VDC, and then turn off the power supply.

b. Secure the cable to the GNAV540 unit.

a. Connect the unit cable to the DC voltage power supply:

- Connect the red plug to the positive terminal (+).
- Connect the black plug to the ground terminal (-) ground.

CAUTION: If the input power leads are reversed, the unit may be damaged. The warranty for the unit does not cover damage caused by neglect or incorrect use; Moog, Inc. will assume no responsibility for the repair or replacement of the unit.

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b. Turn on the power supply. Ensure the total power drawn does not exceed 5 watts.

c. Start NAV-VIEW 2.2—on the computer click the NAV-VIEW 2.2 icon.

d. If the GNAV540 unit is connected directly to a computer via serial port, the unit may immediately be connected.

- If there are multiple serial ports, it may be necessary to set up the serial port. Refer to the **Serial Port Instructions** below.
- If using the Ethernet, the Ethernet connection will need to be set up. Refer to the **Ethernet Port Instructions** below.

Serial Port Instructions

a. Start NAV-VIEW 2.2 on the computer: double-click the NAV-VIEW 2.2 icon on the desktop.

b. On the menu bar click **Setup** and then select **Port** from the drop menu.

c. The *Configure Serial Port* dialog window opens:

d. Select the appropriate COM port.

e. Set the baud rate: **Auto** is recommended.

f. Click **Connect** and then click **Save and Close**.

Ethernet Port Instructions

a. Start NAV-VIEW 2.2 on the computer: double-click the NAV-VIEW 2.2 icon on the desktop.

b. On the menu bar click **Setup** and then select **Ethernet** from the drop menu.

c. The *EthernetForm* window opens:

d. Enter the IP address of the GNAV540 unit.

e. Enter the number of the IP port.

f. Click **Connect** and then click **Save and Close.**

e. If the connections are correct and the unit is functional, information should be displayed on the screen. Refer to *Chapter 6. Viewing and Logging Data with NAV-VIEW* 2.2 on page 47.

Trouble-Shooting Tips

- If the unit is connected but not working, check the following:
  - The power supply is connected and the output voltage and current levels are correct.
  - If using the serial port, verify the correct serial connector of the cable is being used. If the adaptor is being used verify the switch setting of the adaptor.
  - If using the Ethernet port, verify the IP address of the unit is correct.
- If NAV-VIEW does not display any data, and the evaluation cable is being used (Interface Cable—Accessory on page 126), ensure the switch on Port C, the serial interface that connects to the External Magnetometer is set in the OFF position.

  That switch should only be turned ON when firmware is being loaded into the unit.

NOTE: Uploading firmware (DMU upgrade) to the unit is outside the scope of this document. For information, contact Customer Service (refer to page 128).

Chapter 6. Viewing and Logging Data with NAV-VIEW 2.2

NOTE: It is assumed that GNAV540 and NAV-VIEW 2.2 have been set up, connected and turned on. For instructions, refer to *Chapter 5. Installation Guidelines* on page 43.

Figure 8 on page 48 shows the main page of NAV-VIEW.

The functions are accessed from the menu bar at the top of the page.

The graphs are displayed in the main body of the page.

- Multiple graphs are available, which can be selected for viewing, such as Angles, Angular Rate, Accel, Velocity and GPS POS. Which graphs are available is related to the selected packet type. For details about packet types, refer to *Chapter 9. Communicating with the GNAV540 Unit*.
- The time range (speed) of viewing the graphs can be selected: 2, 5, 10, 20, or 50 seconds per time frame.

The bottom of the page indicates information about the unit and connection to the unit

- How the unit is connected, COM or Ethernet
- The baud rate
- If the unit is connected and working, the following messages will be displayed:

  "Unit Connected"

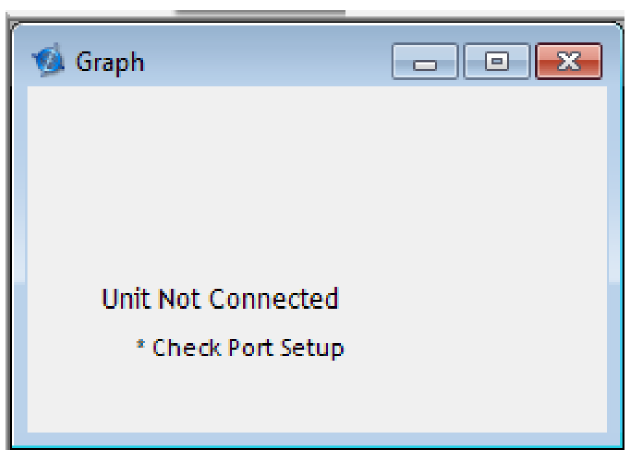
  Packet Rate

  The serial number of the GNAV540 unit

  The version of NAV-VIEW 2.2

If the unit is not connected, the following message will be displayed:

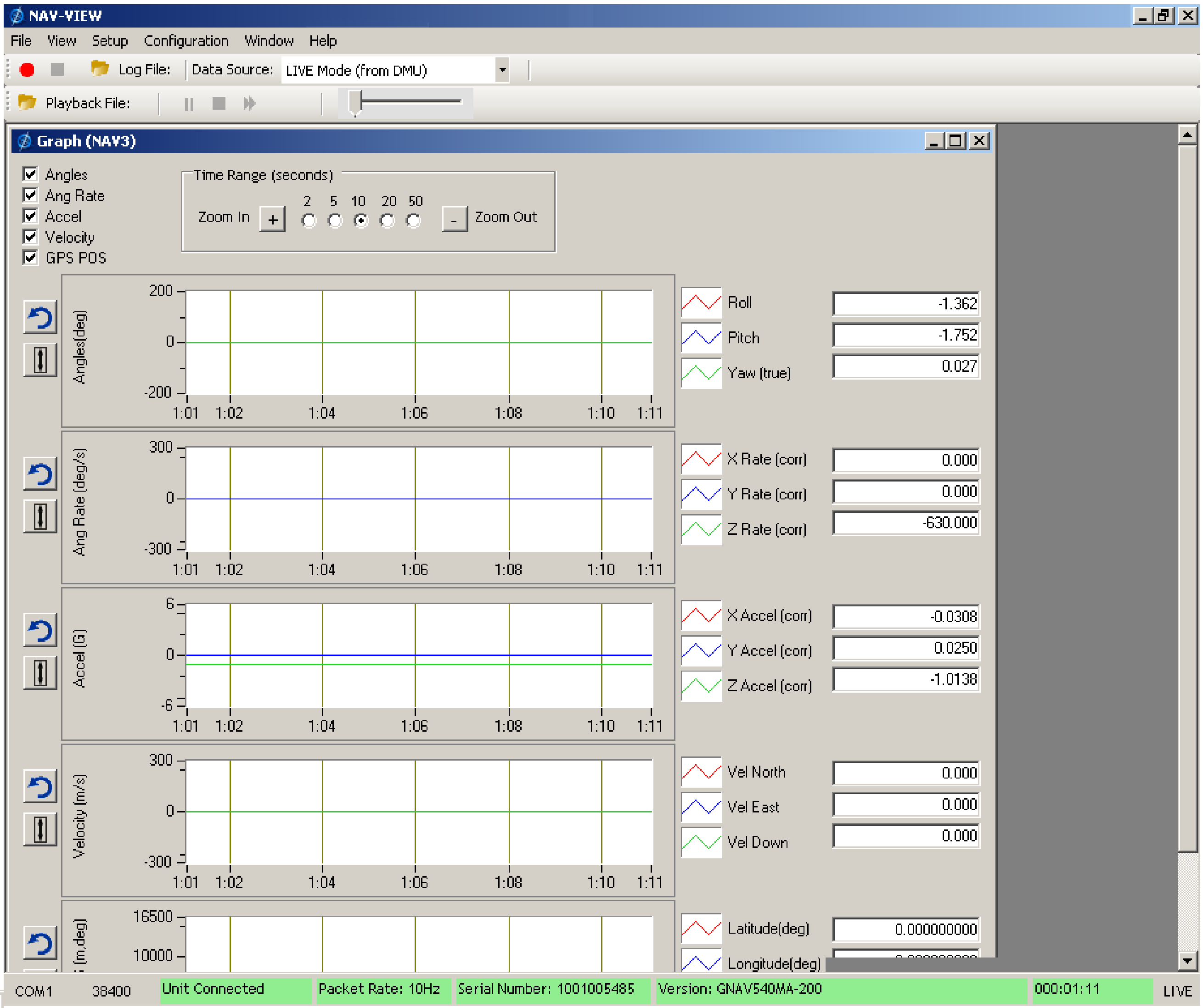
Figure 7 No Display



If *Unit Not Connected* is displayed, check the following:

- Are the power supply levels are correct.
- If using the serial port, verify that the correct serial connector of the cable is being used, and if used, the setting of the RS422 / RS 232 adaptor.
- If using the Ethernet port, verify the IP address and the Port number are correct.

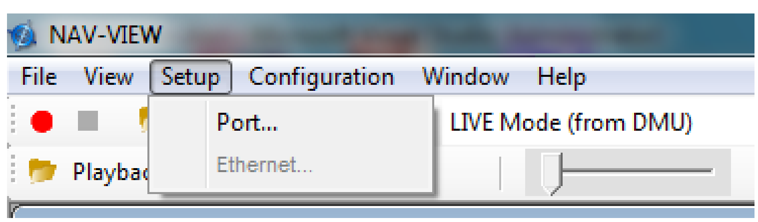
Figure 8 Main Screen



Communication Port

The GNAV540 can be accessed via serial or Ethernet port, which is selected in the Setup menu.

To select a port, click Setup and then select the desired port from the drop menu. A dialog window then opens, enabling configuration.

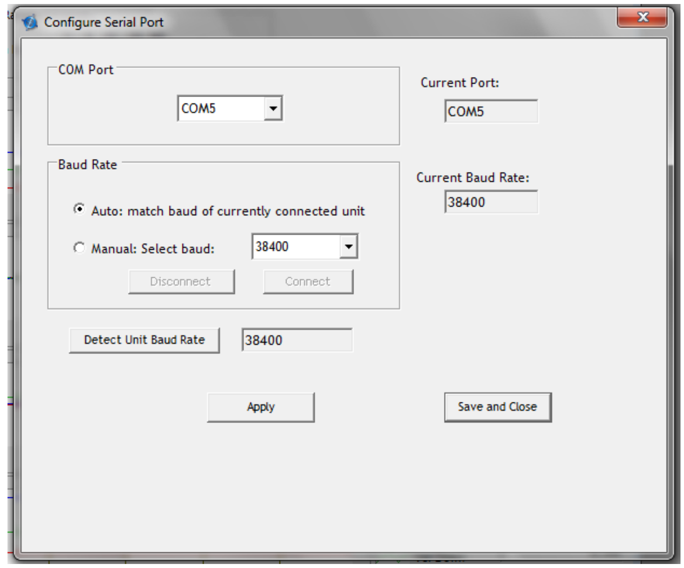


Serial Port

The *Configure Serial Port* dialog shows the current Port and Baud rate, which can both be configured. To do so:

1. Select the desired **COM Port**.
2. Either manually select the desired **Baud Rate** or select **Auto.**
3. To apply the configuration, click **Apply**.
4. To ensure the configuration is saved in NAV-VIEW, click **Save and Close**.

Figure 9 Configure Serial Port

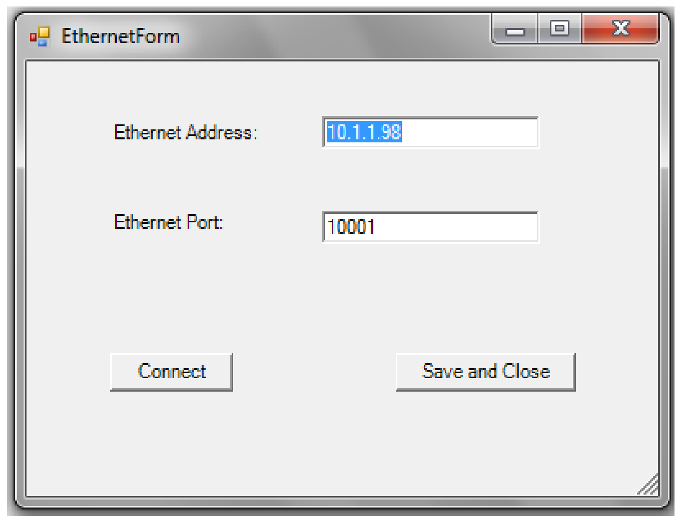


Ethernet Port

The Ethernet settings are configured in the *EthernetForm* dialog. To do so:

1. Enter the Ethernet address of the GNAV540 unit.
2. Enter the Ethernet Port number
3. To apply the configuration and activate the connection, click **Connect**.
4. To ensure the configuration is saved after rebooting the unit, click **Save and Close**.

Figure 10 Configure Ethernet Port



Record Data

NAV-VIEW 2.2 can be used to log data to a text file (.txt). How data is logged can be configured: data type; logging rate; recording length. The instructions follow:

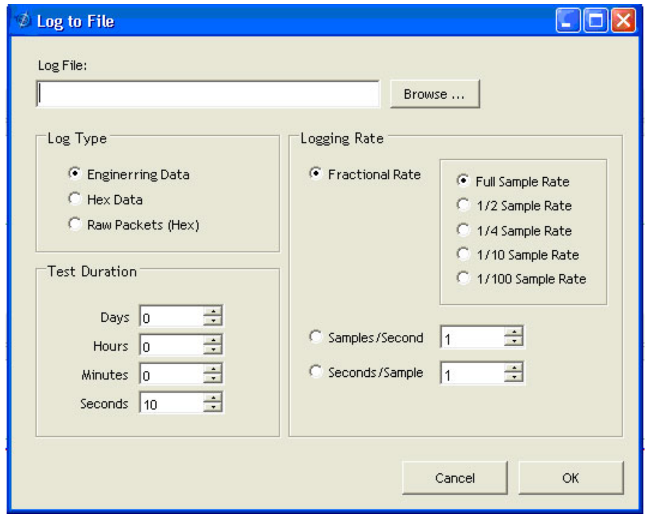
1. Locate the icon at the top of the page, or click **File** and then select **Log to File** from the drop down menu. The dialog window opens.
2. Click the **Browse** button and select the location for saving data.
3. In the **Log Type** section, select the type of data to record:

   Engineering Data records the converted values provided from the system in engineering units (default selection).

   Hex Data provides the raw hex values separated into columns displaying the value.

   Raw Packets records the hex strings as they are sent from the unit.

Figure 11 Log to File Menu



4. In the **Logging Rate** section, the following options are available:
   - Fractional Rate
   - Sample Rates
5. In the **Test Duration** section, define the desired duration of the data logging in terms of **Days**, **Hours**, **Minutes**, and/or **Seconds**. The default setting is 10 seconds.
6. After setting all the options, click the **OK** button. The display will return to the main window.

   To start the recording process, press the button at the top of the window, click **File** and then select **Start Logging** from the drop menu. Refer to *Figure 8* on page 48.

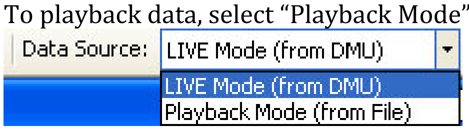
   To stop the recording the data early, press the button. Afterwards, when you select **Start Logging**, the new information will be appended.

   To pause the recording, press the button.

Playback Data

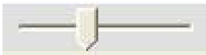
In addition to data recording, NAV-VIEW 2.2 allows the user to replay saved data that has been stored in a log file.

1. To playback data, select “Playback Mode” from the “Data Source” drop down menu at the top.



   Selecting Playback mode will open a text prompt which will allow users to specify the location of the file they wish to play back. All three file formats are supported (Engineering, Hex, and Raw) for playback. In addition, each time recording is stopped/started a new section is created. These sections can be individually played back by using the drop down menu and associated VCR controls.

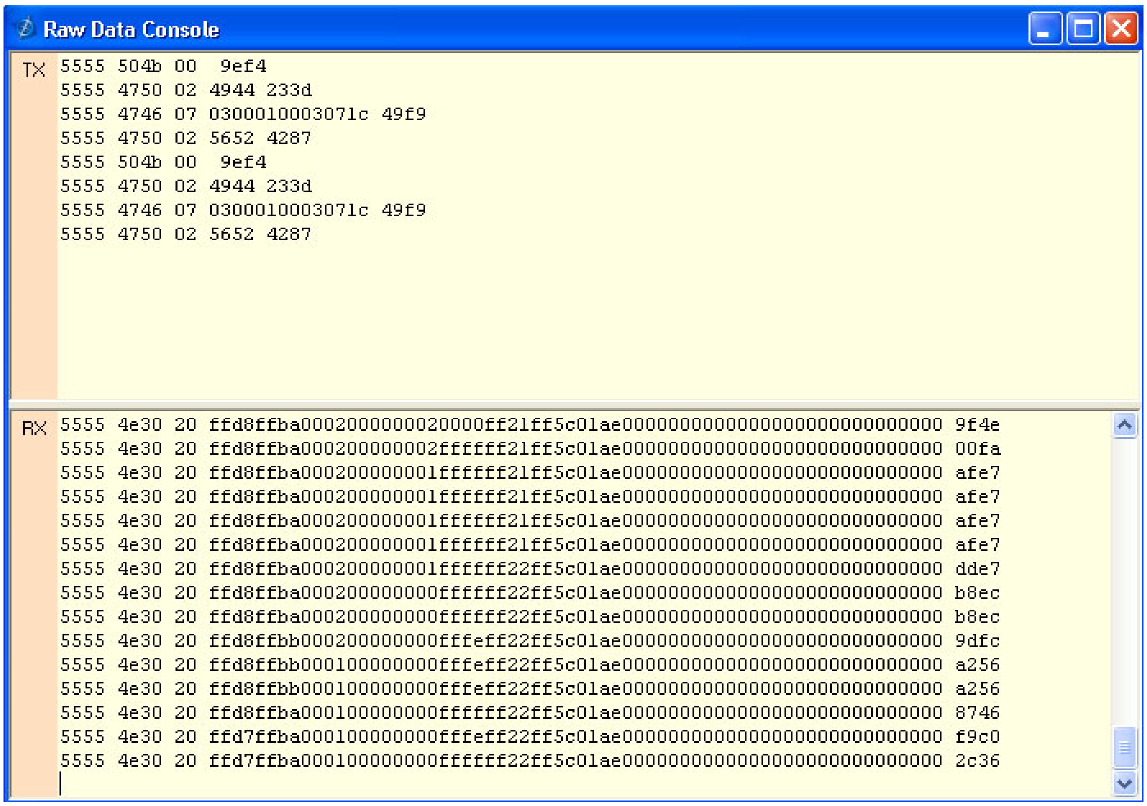
2. Once the file is selected, users can utilize the VCR style controls at the top of the page to start, stop, or pause the playback of the data.

   NAV-VIEW 2.2 also provides users with the ability to alter the start time for data playback. The  slide bar at the top of the page can be used to adjust the starting time.

Raw Data Console

NAV-VIEW 2.2 offers some unique debugging tools that may assist programmers in the development process. One such tool is the Raw Data Console. From the "View" drop down menu, simply select the "Raw Data Console". This console provides users with a simple display of the packets that have been transmitted to the unit (Tx) and the messages received (Rx). An example is provided below.

Figure 12 Raw Data Console

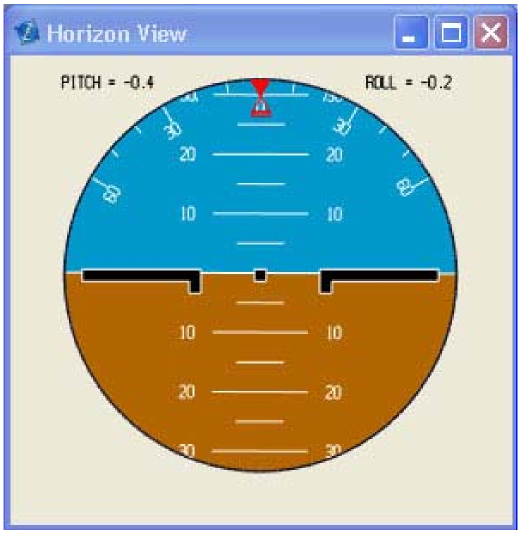


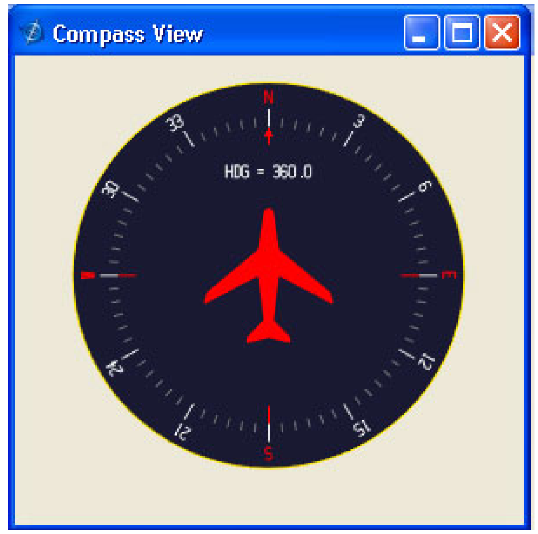
Horizon and Compass Views

NAV-VIEW 2.2 provides a compass and a simulated artificial horizon view.

- To activate these views, click **View** at the menu bar, and then select **Horizon View** and/or **Compass View** from drop down menu.

Figure 13 Horizon and Compass Views



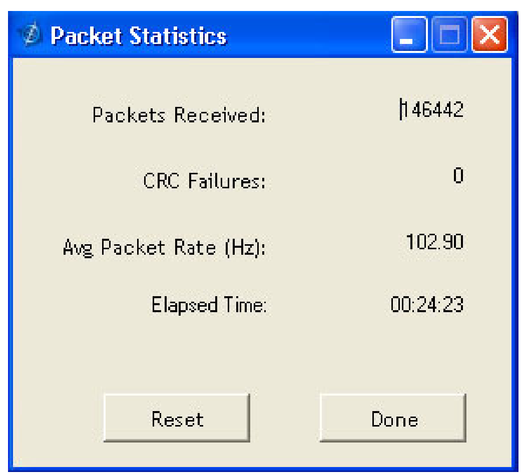


Packet Statistics View

To view packet statistics, click **View** at the menu bar and then select the **Packet Statistics**.

This view provides a short list of vital statistics (including Packet Rate, CRC Failures, and overall Elapsed Time) that are calculated over a one second window. This tool should be used to gather information regarding the overall health of the user configuration. Incorrectly configured communication settings can result in a large number of CRC Failures and poor data Transfer.

Figure 14 Packet Statistics



Chapter 7. Configuring GNAV540 with NAV-VIEW 2.2

It is assumed the GNAV540 unit and NAV-VIEW 2.2 have been set up. For instructions, refer to *Chapter 5. Installation Guidelines*.

This section provides instructions to configure the unit via NAV-VIEW 2.2, a GUI application. For information about configuring the unit via programming code, refer to *Chapter 10. Programming Guidelines.*

NOTE: It is recommended to read and thoroughly understand the effects of altering the settings in the **Advanced** tab before making changes to the unit configuration. Refer to *Chapter 2. GNfAV540* Functions*.*

- Viewing Current Configurations, page 53
- Configuring the Unit, page 54

  The configuration tabs:

  - General, page 54
  - Advanced, page 56
  - BIT Configuration, page 56
  - Aligning the Magnetometer, page 57

NOTE: To implement a configuration, save the configuration in EEPROM and recycle the power of the GNAV540 unit. Until the power is recycled, the new configuration will not be implemented.

Viewing Current Configurations

NAV-VIEW 2.2 enables viewing the current settings and calibration data. The displayed information can be printed.

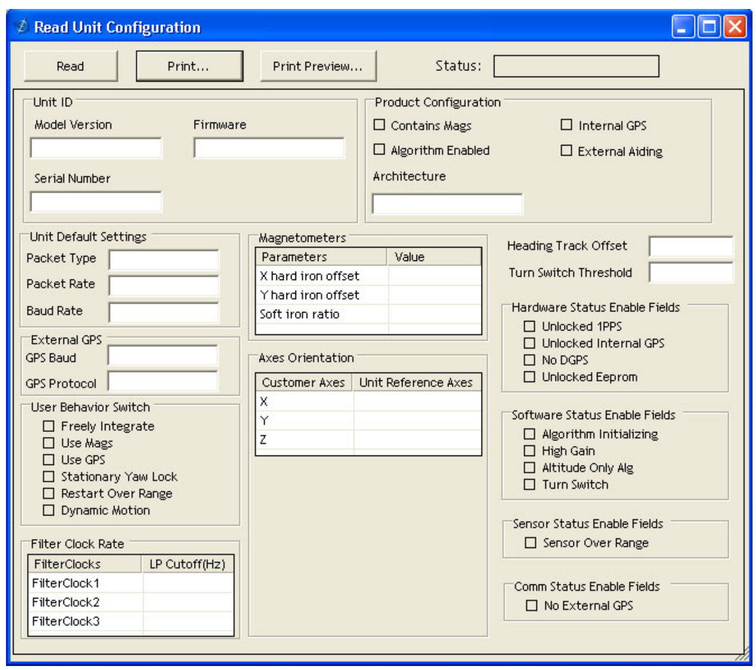
There are two methods to view current configuration.

Method 1:

- At the main screen, select **Unit Configuration** from the menu bar, then select **Print** from the drop menu.

  The dialog window opens (*Figure 15*).

Figure 15 Current Configuration



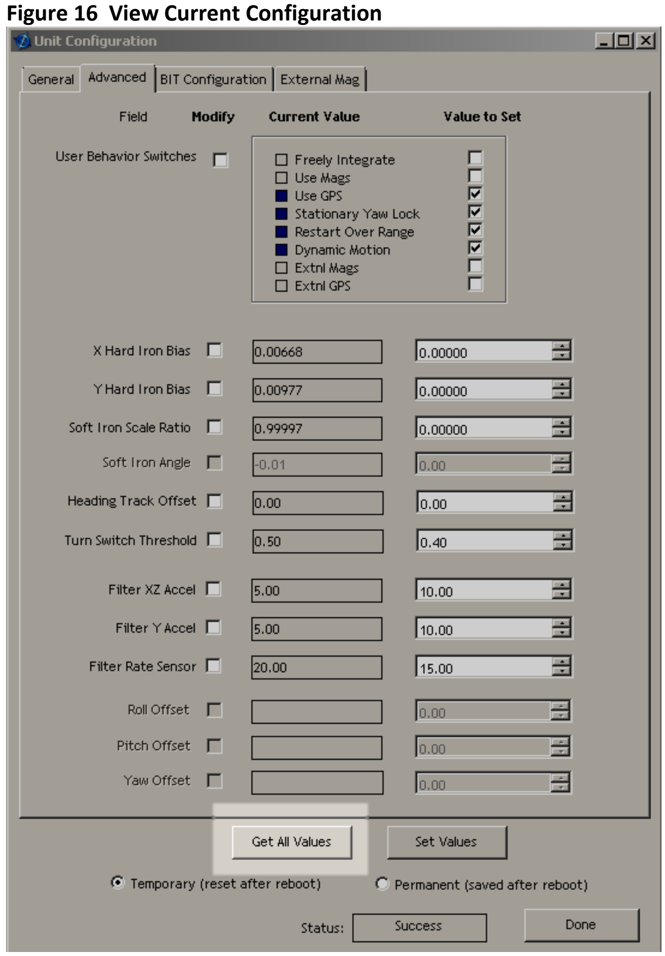
Method 2:

1. At the main screen, select **Unit Configuration** from the menu bar, then select **Configuration** from the drop menu.

   The dialog window opens (Figure 16).

2. Click **Get All Values** at the bottom of the screen. The current configuration values will be displayed.

Figure 16 View Current Configuration



Configuring the Unit

The Unit Configuration window enables viewing and configuring the system configurations.

There are five tabs within the **Unit Configuration** menu;

- General, page 54
- Advanced, page 56
- BIT Configuration, page 56

General

The **General** tab provides quick access to the most frequently used configuration features. To view *all* current configurations on one page, refer to *Viewing* Current Configuration on page 53. Additional configuration options are described in the following sections.

Viewing Current Configuration

To view the current configuration, click the **Get All Values** button. The current settings will be displayed in the text fields.

Changing Configurations

To change a configuration setting:

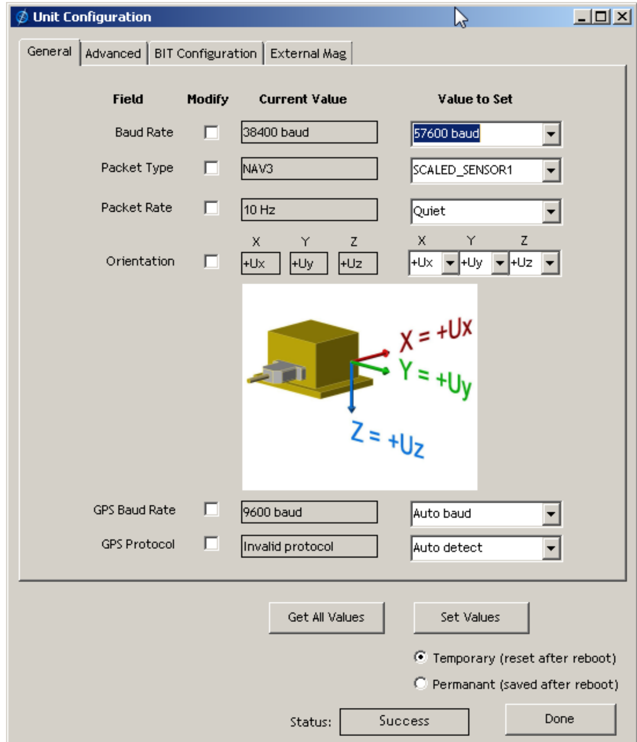
1. Checkmark the desired item(s) in the left Colum
2. Using the drop menus in the right column, select the new values.
3. Select either **Temporary** or **Permanent**.

   Temporary: The configuration will not be stored in non-volatile memory (EEPROM). The configuration will be applied, but the unit will return to the *Permanent* configuration when it is rebooted.

   Permanent: The configuration will be stored in non-volatile memory. The unit will continue to use the configuration after being rebooted.
4. Click the **Set Values** button.

   The configuration values will be saved as specified: *Temporary* or *Permanent*.

Figure 17 Unit Configuration



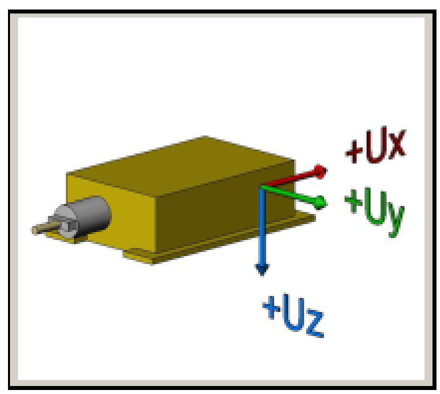
Orientation

Orientation refers to the magnetic orientation of the unit to the body of the system in which the unit is installed. The axes of the unit should be positioned as illustrated:

- The GNVA540 is displayed when the magnetometer is internal (Figure 17)
- The magnetometer is displayed when the magnetometer is external (Figure 18).

The directions of the axes are related to how the unit was physically installed. If necessary, select the appropriate values under X, Y and Z to position the axes correctly. For more information, refer to *GNAV540 Default Coordinate System* on page 24.

Figure 18 Orientation - External Magnetometer



NOTE: Ensure that the settings selected are compatible with the system that is being configured. In most cases a **FAIL** message will appear if incompatible selections are made.

NOTE: Unit orientation selections must conform to the right hand coordinate system as noted in *GNAV540 Default Coordinate System*, page 24. Selecting orientations that do not conform to these criteria are not allowed.

Advanced

The **Advanced** tab provides access to more complex configurations, such as user behavior settings.

Viewing Current Configuration

To view the current configuration, click the **Get All Values** button. The current settings will be displayed in the text fields.

A box filled with blue color indicates the behavior switch is enabled. Refer to *Figure 19.*

Changing Configurations

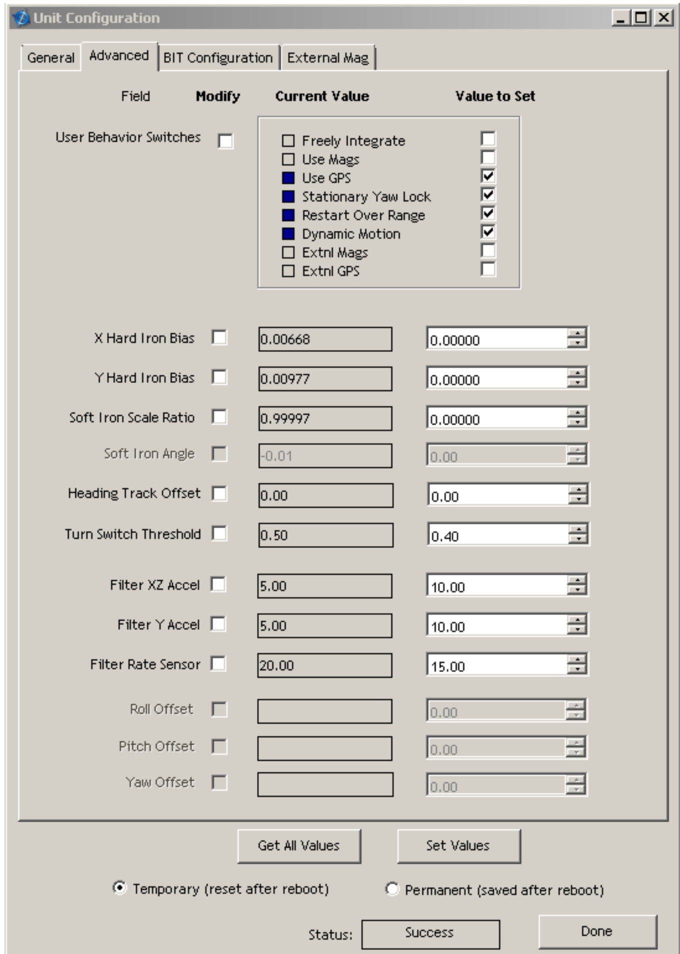
1. To enable a switch:
   a. Checkmark the desired item under **Value to Set.**
2. To set a value, under **Value to Set**:
   a. Checkmark the box of the desired item(s).
   b. For each item, checkmark the box under **Modify** and enter the new value under **Value to Set.**
   c. Select either **Temporary** or **Permanent**.

      Temporary: The configuration will not be stored in non-volatile memory (EEPROM). The configuration will be applied, but the unit will return to the *Permanent* configuration when it is rebooted.

      Permanent: The configuration will be stored in non-volatile memory. The unit will continue to use the configuration after being rebooted.
3. Click the **Set Values** button.

   The configuration values will be saved as specified: *Temporary* or *Permanent*.

Figure 19 Advanced Settings



BIT Configuration

BIT Configuration enables configuring the logic of individual status flags that affect the masterStatus flag in the master BITstatus field. Enabling individual status flags determines which flags are logically OR'ed to generate the masterStatus flag. This provides the flexibility to listen to the indications that affect specified applications. For more information about BIT status fields, refer to *BIT Status Fields* on page 98.

Viewing Current Configuration

To view the current configuration, click the **Get All Values** button. The current settings will be displayed in the text fields.

Under **Current Value**, a box filled with blue color indicates the status field is enabled. Refer to *Figure 20.*

Changing Configurations

To view the current settings, click the **Get All Values** button.

To modify Status Field(s):

1. Checkmark the desired item(s) under **Modify**.
2. For each Status, check or uncheck the item (status bit) under **Enable/Disable**
3. Select either **Temporary** or **Permanent**.

   Temporary: The configuration will not be stored in non-volatile memory (EEPROM). The configuration will be applied, but the unit will return to the *Permanent* configuration when it is rebooted.

   Permanent: The configuration will be stored in non-volatile memory. The unit will continue to use the configuration after being rebooted.
4. Click the **Set Values** button.

   The configuration values will be saved as specified: *Temporary* or *Permanent*.

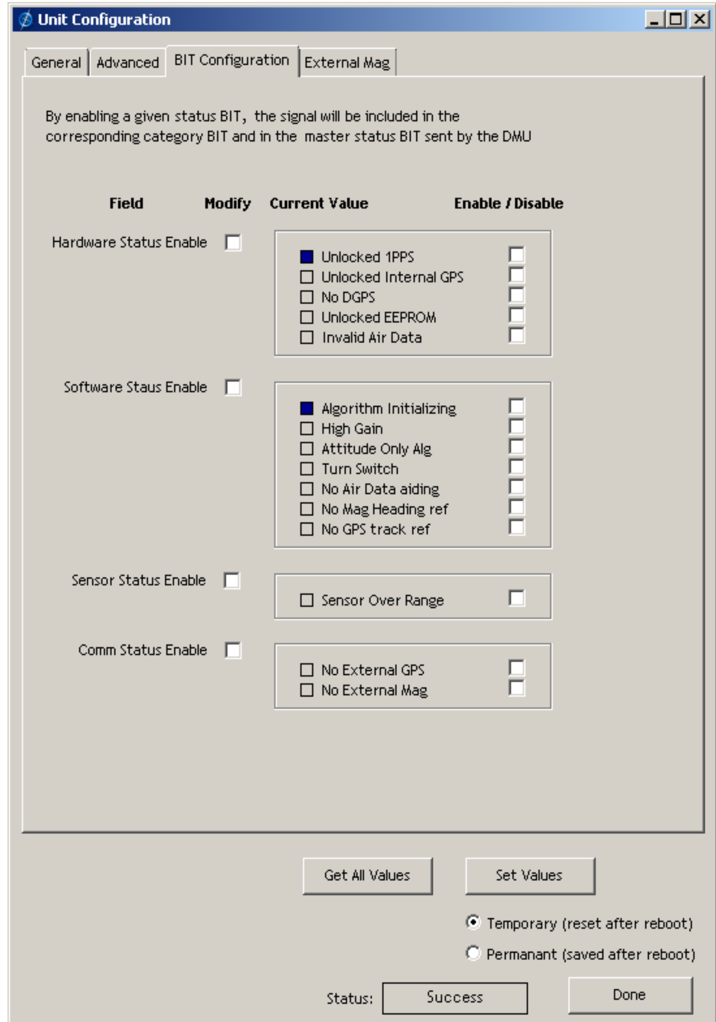


Figure 20 BIT Configuration

Aligning the Magnetometer

This section provides technical information about aligning the magnetometer as well as the instructions.

- Technical Overview, page 57
- Alignment Instructions, 58

Technical Overview

For proper alignment, the GNAV540 unit must be installed in the system; the same ruling applies for an external magnetometer.

If the calibration process is run with the GNAV540 by itself, not installed in the field system, there will be no corrections for the magnetism in the field system. Afterwards, when the GNAV540 unit is installed in the system (such as a vehicle) and if magnetic fields are present in the system, errors will occur due to the magnetism of the system.

After completing the alignment procedure, the heading accuracy should be verified with all third party systems actively using a known reference such as a compass rose, GPS track or a calibrated compass. Heading inaccuracies greater than the values specified on the data sheet or fluctuating heading performance may indicate magnetic field disturbances near the unit.

NOTE: An acceptable calibration will provide X and Y Hard Iron Offset Values of <0.1 and a Soft Iron Ratio >0.95. If this procedure generates calibration parameters significantly outside of this range, the system will assert the softwareError→dataError→magAlignOutOfBounds error flag. Refer to *Chapter 11. Built In Test (BIT)*) for details about error flag handling.

For more information about magnetic fields and the effects on readings and alignment, refer to *Chapter 4. Magnetometer Calibration and Alignment Guidelines* on page 39.

Alignment Instructions

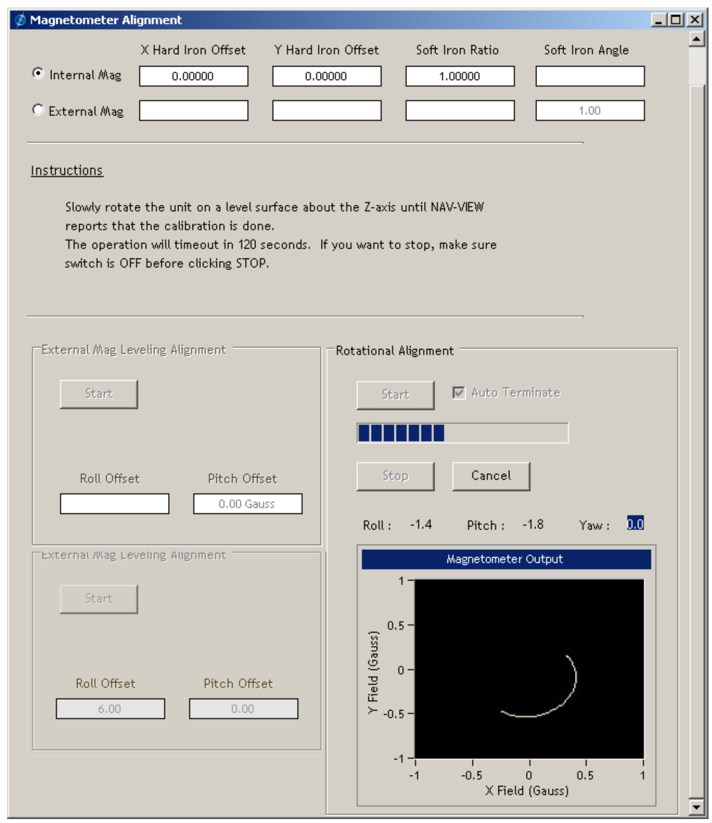
Following are the magnetometer alignment instructions using NAV-VIEW 2.2.

- Aligning Internal Magnetometer, page 58
- Aligning External Magnetometer, page 59

Aligning Internal Magnetometer

1. Ensure the unit is configured to use the internal magnetometer. Refer to *Advanced* on page 56.
2. On the menu bar (see *Figure 8*), click **Configuration** and then select **Magnetometer Alignment** from the drop menu.
3. If the 360 degree turn can be completed within 120 seconds, check **Auto-Terminate.**
4. Under *Rotational Alignment*, select the **Start** button to begin the alignment. Follow the instructions displayed in the screen. Refer to Figure 21.
5. Rotate the GNAV540 for 380 degrees of rotation or until the message is displayed that alignment is complete.

Figure 21 Internal Magnetometer Alignment Dialog



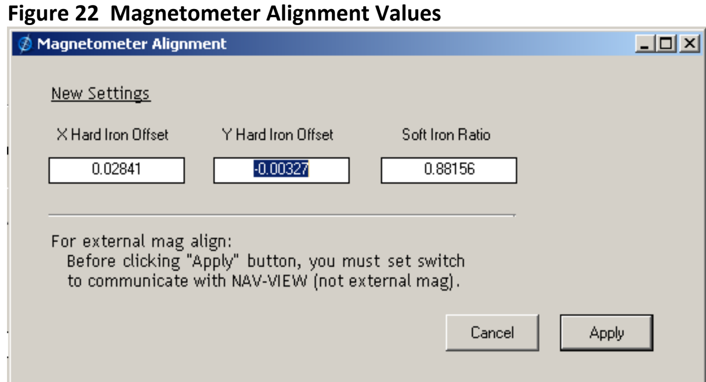
After completing the rotation, data will be displayed with the calibration values. The X and Y offset values indicate how far the magnetic field has been shifted due to hard iron affects from components surrounding the unit.

The soft iron ratio will also be displayed, which is the effect of soft iron on the GNAV540 unit.

6. The save the calibration values, click the **Apply** button.

The new configuration settings will be saved, but they will not be implemented until either a soft reset (via software—see *Interactive Commands* on page 68) or a hard reset (recycle power of the GNAV540 unit) takes place.

Figure 22 Magnetometer Alignment Values



Aligning External Magnetometer

NOTE: By default, the GNAV540 uses the internal magnetometer. To use and configure an external magnetometer, it must be selected under the *Advanced* configuration tab. Refer to *Advanced* on page 56.

NOTE: Two configurations must be applied when using an external magnetometer: *Leveling* and *Rotational*. Configuring the Leveling must be performed before the Rotational alignment.

Leveling Alignment

Leveling (roll and pitch) alignment is data that must be manually entered: the offset of the magnetometer related to the axes of the system in which it is installed.

1. Ensure the unit is configured to use the external magnetometer. Refer to *Advanced* on page 56.

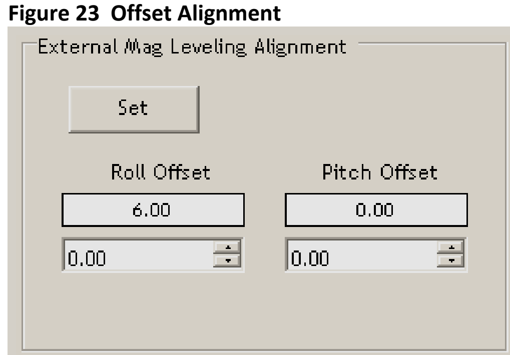
2. Under *External Mag Leveling Alignment*, enter the Roll Offset and Pitch Offset in the data fields, and then click the Set button.

NOTE: The features of the secondary leveling interface are not available. (Refer to Figure 24.)

To save the values in the EEPROM, click the **Apply** button. Refer to *Figure 25* on page 60.

The new configuration settings will be saved and immediately implemented.

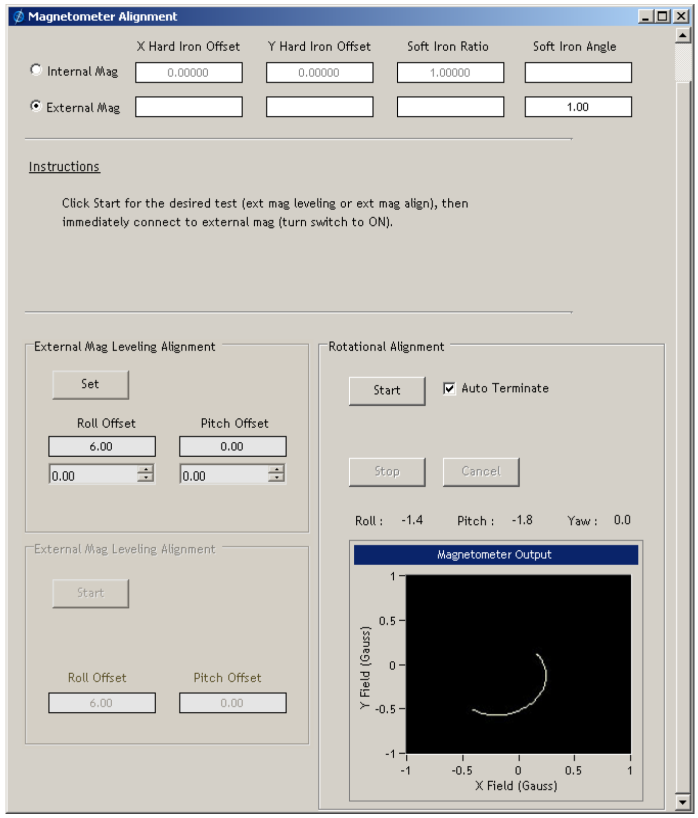
Figure 23 Offset Alignment



Rotational Alignment

1. Ensure the unit is configured to use the external magnetometer. Refer to *Advanced* on page 56.
2. Ensure the leveling alignment of the magnetometer has been configured (*Leveling Alignment*, page 59).
3. Click **Configuration** and then select **Magnetometer Alignment** from the drop menu.
4. If the 360 degree turn can be completed within 120 seconds, check **Auto-Terminate**.
5. Under *Rotational Alignment*, select the **Start** button to begin the alignment. Follow the instructions displayed in the screen. Refer to *Figure* 21.
6. Rotate the GNAV540 for 380 degrees of rotation until the message is displayed that alignment is complete.

Figure 24 External Magnetometer Alignment Dialog

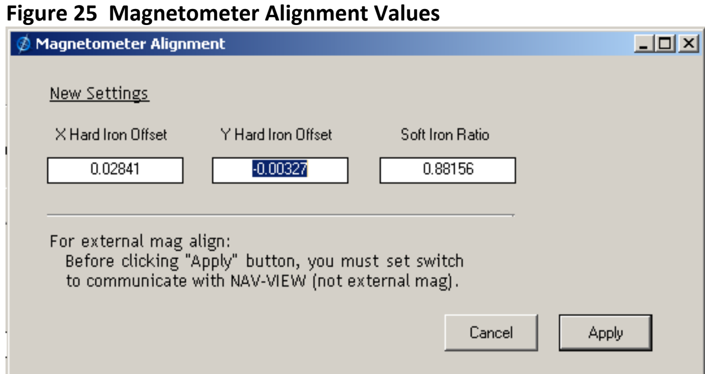


7. After completing the rotation, data will be displayed with the calibration parameters. The X and Y offset values indicate how far the magnetic field has been offset due to hard iron affects from components surrounding the unit.

   The soft iron ratio will also be displayed, which is the effect of soft iron on the GNAV540 unit.
8. The save the offset values, click the **Apply** button.

The new configuration settings will be saved, but they will not be implemented until either a soft reset (via software—see *Interactive Commands* on page 68) or a hard reset (recycle power of the GNAV540 unit) takes place.

Figure 25 Magnetometer Alignment Values



Chapter 8. Data Packet Structure

NOTE: This section of the manual assumes the reader is familiar with ANSI C programming language and data type conventions.

The unit supports a common packet structure that includes both command or input data packets, and measurement output or response packet formats. This section of the manual explains these packet formats as well as the supported commands. NAV-VIEW 2.2 also features a number of tools that can help a user understand the packet types available and the information contained within the packets. For an example of the code required to parse input data packets, please see refer to *Appendix B. Sample Packet—Parser Code*.

General Settings

The serial port settings are RS232 with 1 start bit, 8 data bits, no parity bit, 1 stop bit, and no flow control. Standard baud rates supported are: 9600, 19200, 38400, and 57600.

Common definitions include:

- A word is defined as 2 bytes, which are 16 bits.
- All communications to and from the unit are packets that start with a single word alternating bit preamble 0x5555. This is the ASCII string "UU".
- All multiple byte values are transmitted Big Endian (Most Significant Byte First).
- All communication packets end with a single word CRC (2 bytes). CRC's are calculated on all packet bytes excluding the preamble and CRC itself. Input packets with incorrect CRC's will be ignored.
- Each complete communication packet must be transmitted to the GNAV540 inertial system within a four (4) second period.

Number Formats

Number Format Conventions include:

- 0x as a prefix to hexadecimal values
- Single quotes ('') to delimit ASCII characters
- No prefix or delimiters to specify decimal values.

The following table defines number formats:

Table 12 Number Formats

Descriptor	Description	Size (bytes)	Comment	Range
U1	Unsigned Char	1	—	0 to 255
U2	Unsigned Short	2	—	0 to 65535
U4	Unsigned Int	4	—	0 to 2^32-1
I2	Signed Short	2	2's Complement	-2^15 to 2^15-1
I2*	Signed Short	2	Shifted 2's Complement	Shifted to specified range
I4	Signed Int	4	2's Complement	-2^31 to 2^31-1

Descriptor	Description	Size (bytes)	Comment	Range
F4	Floating Point	4	IEEE754 Single Precision	-1*2^127 to 2^127
SN	String	N	ASCII	

Packet Format

All of the Input and Output packets, except the Ping command, conform to the following structure:

0x5555	<2-byte packet type (U2)>	<payload byte-length (U1)>	<variable length payload>	<2-byte CRC (U2)>

The Ping Command does not require a CRC, so a GNAV540 unit can be pinged from a terminal emulator. To Ping a GNAV540 unit, type the ASCII string 'UUPK'. If properly connected, the GNAV540 unit will respond with 'PK'. All other communications with the GNAV540 unit require the 2-byte CRC.

NOTE: A GNAV540 unit will also respond to a ping command using the full packet formation with payload 0 and correctly calculated CRC. Example: 0x5555504B009ef4.

Packet Header

The packet header is always the bit pattern 0x5555.

Packet Type

The packet type is always two bytes long in unsigned short integer format. Most input and output packet types can be interpreted as a pair of ASCII characters. As a semantic aid consider the following single character acronyms:

Table 13 Character Acronyms

Acronym	Description
P	Packet
F	Fields: Refers to Fields which are settings or data contained in the unit
E	EEPROM Refers to factory data stored in EEPROM
R	Read: Reads default non-volatile fields
G	Get: Gets current volatile fields or settings
W	Write: Writes default non-volatile fields. These fields are stored in non-volatile memory and determine the unit's behavior on power up. Modifying default fields take effect on the next power up and thereafter.
S	Set: Sets current volatile fields or settings. Modifying current fields will take effect immediately by modifying internal RAM and are lost on a power cycle.

Payload Length

The payload length is always a one byte unsigned character with a range of 0-255. The payload length byte is the length (in bytes) of the <*variable length payload*> portion of the packet ONLY, and does not include the CRC.

Payload

The payload is of variable length based on the packet type.

16-Bit CRC-CCITT

Packets end with a 16-bit CRC-CCITT calculated on the entire packet excluding the 0x5555 header and the CRC field itself. A discussion of the 16-bit CRC-CCITT and sample code for implementing the computation of the CRC is included at the end of this document. This 16-bit CRC standard is maintained by the International Telecommunication Union (ITU).

Width: 16 bits

Polynomial: 0x1021

Initial value: 0xFFFF

No XOR is performed on the final value.

Refer to *Appendix B. Sample Packet—Parser Code* for sample code that implements the 16-bit CRC algorithm.

Messaging Overview

The following table summarizes the messages available with the GNAV540 unit. Packet types are assigned mostly using the ASCII mnemonics defined above and are indicated in the summary table below and in the detailed sections for each command. The payload byte-length is often related to other data elements in the packet as defined in the table below. The referenced variables are defined in the following sections.

Output messages are sent from the GNAV540 inertial system to the user system as a result of a poll request or a continuous packet output setting. Input messages are sent from the user system to the GNAV540 inertial system and will result in an associated Reply Message or NAK message. Reply messages typically have the same *<2-byte packet type (U2)>* as the input message that evoked it but with a different payload.

Table 14 Message Table

ASCII Mnemonic	<2-byte packet type (U2)>	<payload byte-length (U1)>	Description	Type	Available Functions
Link Test					
PK	0x504B	0	Ping Command and Response	Input/Reply Message	ALL
CH	0x4348	N	Echo Command and Response	Input/Reply Message	ALL
Interactive Commands					
GP	0x4750	2	Get Packet Request	Input Message	ALL
AR	0x4152	0	Algorithm Reset	Input/Reply Message	VG,AHRS, NAV
SR	0x5352	0	Software Reset	Input/Reply Message	ALL
NAK	0x1515	2	Error Response	Reply Message	ALL

ASCII Mnemonic	<2-byte packet type (U2)>	<payload byte-length (U1)>	Description	Type	Available Functions
WC	0x5743	2	Calibrate Command and Response	Input/Reply Message	AHRS, NAV
CC	0x4343	8	Calibration Completed	Reply Message	AHRS, NAV
Output Messages: Status and Other, (Polled Only)					
ID	0x4944	5+N	Identification Data	Output Message	ALL
VR	0x5652	5	Version Data	Output Message	ALL
T2	0x5432	30	Test 0 (Detailed BIT and Status)	Output Message	ALL
Output Messages: Measurement Data (Continuous or Polled)					
S0	0x5330	30	Scaled Sensor 0 Data	Output Message	NAV
S1	0x5331	24	Scaled Sensor 1 Data	Output Message	ALL
S2	0x5332	28	Scaled Sensor 2 Data	Output Message	ALL
A0	0x4130	30	Angle 0 Data	Output Message	AHRS, NAV
A1	0x4131	32	Angle 1 Data	Output Message	AHRS, NAV
A2	0x4132	30	Angle 2 Data	Output Message	AHRS, NAV
N0	0x4E30	32	Nav 0 Data	Output Message	AHRS, NAV
N1	0x4E31	42	Nav 1 Data	Output Message	AHRS, NAV
N2	0x4E32	54	Nav 2 Data	Output Message	NAV
N3	0x4E33	48	Nav 3 Data	Output Message	NAV
N4	0x4E34	44	Nav 4 Data	Output Message	NAV
Advanced Commands					
WF	0x5746	numFields*4+1	Write Fields Request	Input Message	ALL
WF	0x5746	numFields*2+1	Write Fields Response	Reply Message	ALL
SF	0x5346	numFields*4+1	Set Fields Request	Input Message	ALL
SF	0x5346	numFields*2+1	Set Fields Response	Reply Message	ALL

ASCII Mnemonic	<2-byte packet type (U2)>	<payload byte-length (U1)>	Description	Type	Available Functions
RF	0x5246	numFields*2+1	Read Fields Request	Input Message	ALL
RF	0x5246	numFields*4+1	Read Fields Response	Reply Message	ALL
GF	0x4746	numFields*2+1	Get Fields Request	Input Message	ALL
GF	0x4746	numFields*4+1	Get Fields Response	Reply Message	ALL

Chapter 9. Communicating with the GNAV540 Unit

Communication commands are used to verify a unit is present and alive.

Ping Command

Table 15 Ping Command

Ping ('PK' = 0x504B)			
Preamble	***Packet Type***	***Length***	***Termination***
0x5555	0x504B	-	-

The ping command has no payload. Sending the ping command will cause the unit to send a ping response. To facilitate human input from a terminal, the length and CRC fields are not required.

Example: 0x5555504B009ef4 or 0x5555504B

Ping Response

Ping ('PK' = 0x504B)			
Preamble	***Packet Type***	***Length***	***Termination***
0x5555	0x504B	0x00	<CRC (U2)>

The unit will send this packet in response to a ping command.

Echo Command

Table 16 Echo Command

Echo ('CH' = 0x4348)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4348	N	<echo payload>	<CRC (U2)>

The echo command allows testing and verification of the communication link. The unit will respond with an echo response containing the *echo data*. The *echo data* is N bytes long.

Echo Response

Table 17 Echo Response

Echo Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	echoData0	U1	—	—	first byte of echo data
1	echoData1	U1	—	—	Second byte of echo data
...	...	U1	—	—	Echo data
N-2	echoData...	U1	—	—	Second to last byte of echo data
N-1	echoData...	U1	—	—	Last byte of echo data

Interactive Commands

Interactive commands are used to interactively request data from the GNAV540 unit, and to calibrate or reset the unit.

Get Packet Request

Table 18 GP Request

Get Packet (‘GP’ = 0x4750)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4750	0x02	<GP payload>	<CRC (U2)>

This command allows the user to poll for both measurement packets and special purpose output packets including *T0*, *VR*, and *ID*.

Table 19 GP Payload

GP Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	requestedPacketType	U2	—	—	The requested packet type

Refer to the sections below for Packet Definitions sent in response to the ‘GP’ command

Algorithm Reset Command

Table 20 Algorithm Reset Command

Algorithm Reset (‘AR’ = 0x4152)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4152	0x00	—	<CRC (U2)>

This command resets the state estimation algorithm without reloading fields from EEPROM. All current field values will remain in effect. The unit will respond with an algorithm reset response.

Algorithm Reset Response

Table 21 Algorithm Reset Response

Algorithm Reset (‘AR’ = 0x4152)			
Preamble	***Packet Type***	***Length***	***Termination***
0x5555	0x4152	0x00	<CRC (U2)>

The unit will send this packet in response to an algorithm reset command.

Software Reset Command

Table 22 Software Reset Command

Software Reset (‘SR’ = 0x5352)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5352	0x00	—	<CRC (U2)>

This command performs a core CPU reset, functionally equivalent to a power cycle. All default power-up field settings will apply. The unit will respond with software reset response before the system goes down.

Software Reset Response

Table 23 Software Reset Response

Software Reset ('SR' = 0x5352)			
Preamble	***Packet Type***	***Length***	***Termination***
0x5555	0x5352	0x00	<CRC (U2)>

The unit will send this packet in response to a software reset command.

Calibrate Command

Table 24 Calibrate Command

Calibrate ('WC' = 0x5743)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5743	0x02	<WC payload>	<CRC (U2)>

This command allows the user to perform various calibration tasks with the GNAV540 unit. See the calibration command table below for details. The unit will respond immediately with a calibrate response containing the *calibrationRequest* received or an error response if the command cannot be performed.

Table 25 WC Payload

WC Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	calibrationRequest	U2	—	—	The requested calibration task

Currently, magnetic alignment is the only function supported by the calibrate command. There are two magnetic alignment procedures supported; (1) magnetic alignment with automatic yaw tracking termination, and magnetic alignment without automatic termination.

Table 26 Magnetic Alignment

calibrationRequest	**Description**
0x0009	Begin magnetic alignment without automatic termination. Rotate vehicle through >360 degrees yaw and then send 0x000B calibration request for termination.
0x000B	Terminate magnetic alignment. The unit will send a CC response containing the hard-iron and soft-iron values. To accept the parameters, store them using the write magnetic calibration command.
0x000C	Begin magnetic calibration with automatic termination. Rotate the unit through 380 degrees in yaw. The unit will send a CC response containing the hard-iron and soft-iron values upon completion of the turn. To accept the parameters, store them using the write magnetic

calibrationRequest	Description
	calibration command.
0x000E	Write magnetic calibration. The unit will write the parameters to EEPROM and then send a calibration response.

Calibrate Acknowledgement Response

Table 27 Calibrate WC ACK Response

Calibrate ('WC' = 0x5743)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5743	0x02	<WC payload>	<CRC (U2)>

The unit will send this packet in response to a calibrate request if the procedure can be performed or initiated.

Table 28 WC Payload

WC Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	calibrationRequest	U2	—	—	The requested calibration task

Calibration Completed Parameters Response

Table 29 Calibration Completed

Calibrate Completed ('CC' = 0x4343)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4343	0x08	<CC payload>	<CRC (U2)>

The unit sends this packet after a calibration has been completed. Currently, there is only one message of this type sent after a magnetic calibration has been completed (with or without automatic termination) and the parameters have been calculated. The calibrationRequest field will be 0x000B or 0x000C.

Table 30 CC Payload Contents

CC Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	calibrationRequest	U2	—	—	The requested calibration task
2	xHardIron	I2	2/2^16	G	The x hard iron bias
4	yHardIron	I2	2/2^16	G	The y hard iron bias
6	softIronScaleRatio	U2	2/2^16	—	The scaling ratio between the x and y axis

Error Response

Table 31 Error Response

Error Response (ASCII NAK, NAK = 0x1515)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x1515	0x02	<NAK payload>	<CRC (U2)>

The unit will send this packet in place of a normal response to a *failedInputPacketType* request if it could not be completed successfully.

NAK Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	failedInputPacketType	U2	—	—	the failed request

Output Packets (Polled)

The following packet formats are special informational packets which can be requested using the GP command.

Identification Data Packet

Table 32 ID Data Packet

Identification Data (‘ID’ = 0x4944)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4944	5+N	<ID payload>	<CRC (U2)>

This packet contains the unit *serialNumber* and *modelString*. The model string is terminated with 0x00. The model string contains the programmed *versionString* (8-bit ASCII values) followed by the firmware part number string delimited by a whitespace.

Table 33 ID Payload Contents

ID Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	serialNumber	U4	—	—	Unit serial number
4	modelString	SN	—	—	Unit Version String
4+N	0x00	U1	—	—	Zero Delimiter

Version Data Packet

Table 34 Version Data PKT

Version Data (‘VR’ = 0x5652)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5652	5	<VR payload>	<CRC (U2)>

This packet contains firmware version information. *majorVersion* changes may introduce serious incompatibilities. *minorVersion* changes may add or modify functionality, but maintain backward compatibility with previous minor versions. *patch* level changes reflect bug fixes and internal modifications with little effect on the user. The build stage is one of the following: 0=release candidate, 1=development, 2=alpha, 3=beta.

The *buildNumber* is incremented with each engineering firmware build. The *buildNumber* and *stage* for released firmware are both zero. The final beta candidate is v.w.x.3.y, which is changed to v.w.x.0.1 to create the first release candidate. The last release candidate is v.w.x.0.z, which is changed to v.w.x.0.0 for release.

Table 35 VR Payload

VR Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	majorVersion	U1	—	—	Major firmware version
1	minorVersion	U1	—	—	Minor firmware version
2	patch	U1	—	—	Patch level
3	stage	-	—	—	Development Stage (0=release candidate, 1=development, 2=alpha, 3=beta)
4	buildNumber	U1	—	—	Build number

Test 2 (Detailed BIT and Status) Packet

Test ('T2' = 0x5432)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
03.3x5555	0x5432	0x1E	<T2 payload>	<CRC (U2)>

This packet contains detailed BIT and status information. Full BIT Status details are described in *Chapter 11. Built In Test (BIT)*).

Table 36 T2 Payload

T2 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	BITstatus	U2	—	—	Master BIT and Status Field
2	hardwareBIT	U2	—	—	Hardware BIT Field
4	hardwarePowerBIT	U2	—	—	Hardware Power BIT Field
6	hardwareEnvironmentalBIT	U2	—	—	Hardware Environmental BIT Field
8	comBIT	U2	—	—	communication BIT Field
10	comSerialABIT	U2	—	—	Communication Serial A BIT Field
12	comSerialBBIT	U2	—	—	Communication Serial B

T2 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
					BIT Field
14	comSerialCBIT	U2	—	—	Communication Serial C BIT Field
16	softwareBIT	U2	—	—	Software BIT Field
16	softwareAlgorithmBIT	U2	—	—	Software Algorithm BIT Field
20	softwareDataBIT	U2	—	—	Software Data BIT Field
22	hardwareStatus	U2	—	—	Hardware Status Field
24	comStatus	U2	—	—	Communication Status Field
26	softwareStatus	U2	—	—	Software Status Field
28	sensorStatus	U2	—	—	Sensor Status Field

Output Packets (Polled or Continuous)

Scaled Sensor Data Packet 0

Table 37 SO Data Packet

Scaled Sensor Data ('S0' = 0x5330)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5330	0x1E	<S0 payload>	<CRC (U2)>

This packet contains scaled sensor data. The scaled sensor data is fixed point, 2 bytes per sensor, MSB first, for 13 sensors in the following order: accels(x,y,z); gyros(x,y,z); mags(x,y,z); temps(x,y,z,board). Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10) g
- Magnetometers: scaled to a range of (-1,+1) Gauss
- Temperature: scaled to a range of (-100, +100)°C

Table 38 S0 Payload

S0 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	xAccel	I2	20/2^16	g	X accelerometer
2	yAccel	I2	20/2^16	g	Y accelerometer
4	zAccel	I2	20/2^16	g	Z accelerometer
6	xRate	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular rate

S0 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
8	yRate	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate
10	zRate	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate
12	xMag	I2	2/2^16	Gauss	X magnetometer
14	yMag	I2	2/2^16	Gauss	Y magnetometer
16	zMag	I2	2/2^16	Gauss	Z magnetometer
18	xRateTemp	I2	200/2^16	deg. C	X rate temperature
20	yRateTemp	I2	200/2^16	deg. C	Y rate temperature
22	zRateTemp	I2	200/2^16	deg. C	Z rate temperature
24	boardTemp	I2	200/2^16	deg. C	CPU board temperature
26	GPSITOW	U2	truncated	ms	GPS ITOW (lower 2 bytes)
28	BITstatus	U2	—	—	Master BIT and Status

Scaled Sensor Data Packet 1 (Default IMU Data)

Table 39 S1 Data Packet

Scaled Sensor Data ('S1' = 0x5331)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5331	0x18	<S1 payload>	<CRC (U2)>

This packet contains scaled sensor data. Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10)g
- Temperature: scaled to a range of (-100, +100)°C

Table 40 S1 Payload

S1 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	xAccel	I2	20/2^16	g	X accelerometer
2	yAccel	I2	20/2^16	g	Y accelerometer
4	zAccel	I2	20/2^16	g	Z accelerometer
6	xRate	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular rate
8	yRate	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate

S1 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
10	zRate	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate
12	xRateTemp	I2	200/2^16	deg. C	X rate temperature
14	yRateTemp	I2	200/2^16	deg. C	Y rate temperature
16	zRateTemp	I2	200/2^16	deg. C	Z rate temperature
18	boardTemp	I2	200/2^16	deg. C	CPU board temperature
20	Counter	U2	—	packets	Output packet counter
22	BITstatus	U2	—	—	Master BIT and Status

Scaled Sensor Data Packet 2 (Delta-Theta, Delta-V)

Table 41 S2 Data Packet

Scaled Sensor Data ('S2' = 0x5332)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5332	0x1C	<S2 payload>	<CRC (U2)>

This packet contains scaled sensor data in the traditional delta-theta and delta-velocity format with integration time equivalent to the packet rate. Changes in body axis angles and velocities are accumulated during the interval between successive packets as determined by the packet rate. Polled requests for this packet will produce values accumulated since the last poll request, and thus, are subject to overflow (data type wrap around).

- Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.
- Delta Angle: scaled to range of 3.5* (-pi, +pi) Δ radians or (-630, +630) Δ degrees.
- Delta Velocity: scaled to a range of (-100, +100) Δ m/s.

Table 42 S2 Payload

S2 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	xDeltaVel	I4	200/2^32	Δ m/s	X delta velocity
4	yDeltaVel	I4	200/2^32	Δ m/s	Y delta velocity
8	zDeltaVel	I4	200/2^32	Δ m/s	Z delta velocity
12	xDeltaAngle	I4	7*pi/2^32 (1260°/2^32)	Δ rad (Δ °)	X delta angle
16	yDeltaAngle	I4	7*pi/2^32 (1260°/2^32)	Δ rad (Δ °)	Y delta angle
20	zDeltaAngle	I4	7*pi/2^32 (1260°/2^32)	Δ rad (Δ °)	Z delta angle
24	Counter	U2	—	packets	Output packet counter
26	BITstatus	U2	—	—	Master BIT and Status

Angle Data Packet 0

Table 43 A0 Data Packet

Angle Data ('A0' = 0x4130)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4130	0x1E	<A0 payload>	<CRC (U2)>

This packet contains angle data and selected sensor data scaled in most cases to a signed 2^16 2's complement number. Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angles: scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10)g
- Magnetometers: scaled to a range of (-1,+1) Gauss
- Temperature: scaled to a range of (-100, +100) °C

Table 44 A0 Payload

A0 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	rollAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Roll angle
2	pitchAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Pitch angle
4	yawAngleMag	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Yaw angle (magnetic north)
6	xRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular RateCorrected
8	yRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular Rate Corrected
10	zRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular Rate Corrected
12	xAccelCorrected	I2	20/2^16	g	X Accel Corrected
14	yAccelCorrected	I2	20/2^16	g	Y Accel Corrected
16	zAccelCorrected	I2	20/2^16	g	Z Accel Corrected
18	xMag	I2	2/2^16	Gauss	X magnetometer
20	yMag	I2	2/2^16	Gauss	Y magnetometer
22	zMag	I2	2/2^16	Gauss	Z magnetometer
24	xRateTemp	I2	200/2^16	deg C	X rate temperature

A0 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
26	GPSITOW	U2	truncated	ms	GPS ITOW (lower 2 bytes)
28	BITstatus	U2	—	—	Master BIT and Status

Angle Data Packet 1 (Default AHRS Data)

Table 45 A1 Data Packet

Angle Data ('A1' = 0x4131)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4131	0x20	<A1 payload>	<CRC (U2)>

This packet contains angle data and selected sensor data scaled in most cases to a signed 2^16 2's complement number. Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angles: scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10) g
- Magnetometers: scaled to a range of (-1,+1) Gauss
- Temperature: scaled to a range of (-100, +100) °C

Table 46 A1 Payload

A1 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	rollAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Roll angle
2	pitchAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Pitch angle
4	yawAngleMag	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Yaw angle (magnetic north)
6	xRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular rate Corrected
8	yRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate Corrected
10	zRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate Corrected
12	xAccel	I2	20/2^16	g	X accelerometer
14	yAccel	I2	20/2^16	g	Y accelerometer
16	zAccel	I2	20/2^16	g	Z accelerometer

A1 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
18	xMag	I2	2/2^16	Gauss	X magnetometer
20	yMag	I2	2/2^16	Gauss	Y magnetometer
22	zMag	I2	2/2^16	Gauss	Z magnetometer
24	xRateTemp	I2	200/2^16	Deg C	X rate temperature
26	timeITOW	U4	1	ms	DMU ITOW (sync to GPS)
30	BITstatus	U2	—	—	Master BIT and Status

Nav Data Packet 0

Table 47 N0 Data Packet

Nav Data ('N0' = 0x4E30)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4E30	0x20	<N0 payload>	<CRC (U2)>

This packet contains navigation data and selected sensor data scaled in most cases to a signed 2^16 2's complement number. Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angles: scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10) g
- Temperature: scaled to a range of (-100, +100) °C
- Velocities: scaled to a range of (-256,256) m/s
- Altitude: scaled to a range of (-100, 16284) m using a shifted 2's complement representation.
- Longitude and latitude: scaled to a range of (-pi, pi) or (-180 deg to +180 deg)

Table 48 N0 Payload

N0 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	rollAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Roll angle
2	pitchAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Pitch angle
4	yawAngleTrue	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Yaw angle (true north)
6	xRateCorrected	I2	7*pi/2^16	rad/s	X angular rate corrected

N0 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
			(1260°/2^16)	(°/sec)	
8	yRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate corrected
10	zRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate corrected
12	nVel	I2	512/2^16	m/s	North velocity
14	eVel	I2	512/2^16	m/s	East velocity
16	dVel	I2	512/2^16	m/s	Down velocity
18	longitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Longitude
22	latitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Latitude
26	altitudeGPS	I2*	2^14/2^16	m	GPS altitude (-100,16284)
28	GPSITOW	U2	truncated	ms	GPS ITOW (lower 2 bytes)
30	BITstatus	U2	—	—	Master BIT and Status

Nav Data Packet 1

Table 49 N1 Data Packet

Nav Data (‘N1’ = 0x4E31)				
Preamble	**Packet Type**	**Length**	**Payload**	**Termination**
0x5555	0x4E31	0x2A	<N1 payload>	<CRC (U2)>

This packet contains navigation data and selected sensor data scaled in most cases to a signed 2^16 2’s complement number. Data involving angular measurements include the factor **pi** in the scaling and can be interpreted in either radians or degrees.

- Angles: scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10) g
- Temperature: scaled to a range of (-100, +100) °C
- Velocities: scaled to a range of (-256,256) m/s
- Altitude: scaled to a range of (-100, 16284) m using a shifted 2’s complement representation.
- Longitude and latitude: scaled to a range of (-pi, pi) or (-180 deg to +180 deg)

Table 50 N1 Payload

N1 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	rollAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Roll angle
2	pitchAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Pitch angle
4	yawAngleTrue	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Yaw angle (true north)
6	xRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular rate corrected
8	yRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate corrected
10	zRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate corrected
12	xAccel	I2	20/2^16	g	X accelerometer
14	yAccel	I2	20/2^16	g	Y accelerometer
16	zAccel	I2	20/2^16	g	Z accelerometer
18	nVel	I2	512/2^16	m/s	North velocity
20	eVel	I2	512/2^16	m/s	East velocity
22	dVel	I2	512/2^16	m/s	Down velocity
24	longitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Longitude
28	latitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Latitude
32	altitudeGPS	I2*	2^14/2^16	m	GPS altitude (-100,16284)
34	xRateTemp	I2	200/2^16	deg C	X rate sensor temperature
36	timeITOW	U4	1	ms	DMU ITOW (sync to GPS)
40	BITstatus	U2	—	—	Master BIT and Status

Nav Data Packet 3 (default packet)

Table 51 Data Packet

Nav Data ('N3' = 0x4E33)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4E33	0x30	*<N3 payload>*	*<CRC (U2)>*

This packet contains navigation data and selected sensor data scaled in most cases to a signed 2^16 2's complement number. Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angles: scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10) g
- Temperature: scaled to a range of (-100, +100) °C
- GPS Velocities: scaled to a range of (-256,256) m/s
- Altitude: scaled to a range of (-100, 16284) m using a shifted 2's complement representation.
- Longitude and latitude: scaled to a range of (-pi, pi) or (-180 deg to +180 deg)
- GPS heading are scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- The GPS velocity components are directly from GPS measurements. No inertial Measurements are involved in its computation.

Table 52 N3 Payload

N3 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	rollAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Roll angle
2	pitchAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Pitch angle
4	yawAngleTrue	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Yaw angle (true north)
6	xRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular rate corrected
8	yRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate corrected
10	zRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate corrected
12	xAccel	I2	20/2^16	g	X accelerometer
14	yAccel	I2	20/2^16	g	Y accelerometer
16	zAccel	I2	20/2^16	g	Z accelerometer
18	nVel	I2	512/2^16	m/s	GPS North velocity

N3 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
20	eVel	I2	512/2^16	m/s	GPS East velocity
22	dVel	I2	512/2^16	m/s	GPS Down velocity
24	longitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Longitude
28	latitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Latitude
32	altitudeGPS	I2*	2^14/2^16	m	GPS altitude (-100,16284)
34	GPS heading	I2	2*pi/2^16 (360°/2^16)	Radians (°)	heading angle from GPS measurement
36	xRateTemp	I2	200/2^16	deg C	X rate sensor temperature
38	UTCTime OfDay	U4		Milli-sec	UTC time of the day
42	UTC Day of Year	U2			
44	UTC Year	U2			
46	BITstatus	U2	—	—	Master BIT and Status

NOTE: If no GPS available the UTC time second and UTC ms are the time since the unit is powered on. The year and day will be set to 0.

Nav Data Packet 4

Table 53 N4 Data Packet

Nav Data ('N4' = 0x4E34)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4E34	0x2C	*<N4 payload>*	*<CRC (U2)>*

This packet is identical to the NAV1 packet with the exception of having a 4-byte output of altitude, which allows for altitudes greater than 8192 meters. This packet contains navigation data and selected sensor data scaled in most cases to a signed 2^16 2's complement number. Data involving angular measurements include the factor pi in the scaling and can be interpreted in either radians or degrees.

- Angles: scaled to a range of (-pi, +pi) or (-180 deg to +180 deg)
- Angular rates: scaled to range of 3.5* (-pi,+pi) or (-630 deg/sec to +630 deg/sec)
- Accelerometers: scaled to a range of (-10,+10) g
- Temperature: scaled to a range of (-100, +100) °C
- Velocities: scaled to a range of (-256,256) m/s
- Altitude: scaled to a resolution of 0.125 meters
- Longitude and latitude: scaled to a range of (-pi, pi) or (-180 deg to +180 deg)

Table 54 N4 Payload

N4 Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	rollAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Roll angle
2	pitchAngle	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Pitch angle
4	yawAngleTrue	I2	2*pi/2^16 (360°/2^16)	Radians (°)	Yaw angle (true north)
6	xRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	X angular rate corrected
8	yRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Y angular rate corrected
10	zRateCorrected	I2	7*pi/2^16 (1260°/2^16)	rad/s (°/sec)	Z angular rate corrected
12	xAccel	I2	20/2^16	g	X accelerometer
14	yAccel	I2	20/2^16	g	Y accelerometer
16	zAccel	I2	20/2^16	g	Z accelerometer
18	nVel	I2	512/2^16	m/s	North velocity
20	eVel	I2	512/2^16	m/s	East velocity
22	dVel	I2	512/2^16	m/s	Down velocity
24	longitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Longitude
28	latitudeGPS	I4	2*pi/2^32 (360°/2^32)	Radians (°)	GPS Latitude
32	altitudeGPS	I4	2^29/2^32	m	GPS altitude
36	xRateTemp	I2	200/2^16	deg C	X rate sensor temperature
38	timeITOW	U4	1	ms	DMU ITOW (sync to GPS)
42	BITstatus	U2	—	—	Master BIT and Status

Chapter 10. Programming Guidelines

The advanced commands allow users to programmatically change the GNAV540 settings. This section of the manual documents all of the settings and options contained under the Unit Configuration tab within NAV-VIEW 2.2. Using these advanced commands, the settings of a GNAV540 unit can be modified without NAV-VIEW 2.2.

Configuration Fields

Configuration fields determine various behaviors of the unit that can be modified by the user. These include settings like baud rate, packet output rate and type, algorithm type, etc. These fields are stored in EEPROM and loaded on power up. These fields can be read from the EEPROM using the RF command. These fields can be written to the EEPROM affecting the default power up behavior using the WF command.

The current value of these fields (which may be different from the value stored in the EEPROM) can also be accessed using the GF command. All of these fields can also be modified immediately for the duration of the current power cycle using the SF command. The unit will always power up in the configuration stored in the EEPROM. Configuration fields can only be set or written with valid data from *Table 55* below.

Table 55 Configuration Fields

index	Configuration fields	Field ID	Valid Values	Description
1	packet rate divider	0x0001	0,1,2,4,5,10, 20, 25, 50	quiet, 100Hz, 50Hz, 25Hz, 20Hz, 10Hz, 5Hz, 4Hz, 2Hz
2	Serial Port A BAUD rate	0x0002	0,1,2,3	9600, 19200, 38400, 57600
3	Continuous packet type	0x0003	Any output packet type	Not all output packets available for all products. See detailed field descriptions below.
4	Reserved	0x0004		N/A
5	Reserved	0x0005		N/A
6	Reserved	0x0006		N/A
7	Orientation	0x0007	See below	Determine forward, rightward, and downward facing sides
8	User Behavior Switches	0x0008	Any	Refer to *User Behavior Switches*, page 88
9	X Hard Iron Bias	0x0009	Any	I2 scaled from (-1,1)
10	Y Hard Iron Bias	0x000A	Any	I2 scaled from (-1,1)
11	Soft Iron Scale Ratio	0x000B	Any	U2 scaled from (0,2)
12	Heading Track Offset	0x000C	Any	Heading-Track Offset to use in NAV filter track update mode.
13	Turn Switch Threshold	0x000D	73-65535 (0.4-360 °/s)	Sets yaw rate above which tilt feedback is attenuated.
14	Soft Iron Angle	0x000E	($-\pi$ π)	Angle of major axis of the ellipse generated by 360 degree swing in radian
15	reserved	0x000F		
16	hardwareStatusEnable	0x0010	Any	Bit mask of enabled hardware status signals

index	Configuration fields	Field ID	Valid Values	Description
17	comStatusEnable	0x0011	Any	Bit mask of enabled communication status signals
18	softwareStatusEnable	0x0012	Any	Bit mask of enabled software status signals
19	sensorStatusEnable	0x0013	Any	Bit mask of enabled sensor status signals
20	Serial Port B BAUD rate	0x0014	-1,0,1,2,3	Auto baud, 9600, 19200, 38400, 57600
21	Serial Port B Protocol	0x0015	-1,0,1,2,3	GPS support protocol, ICD-153
22	reserved	N/A	N/A	N/A
23	Roll offset external Mag	0x0017	Any	Roll offset from external Mag to AHRS body frame
24	Pitch offset external Mag	0x0018	Any	Pitch offset from external Mag to AHRS body frame
25	Reserved	N/A	N/A	N/A
26	Reserved	N/A	N/A	N/A
27	Reserved	N/A	N/A	N/A
28	X Hard Iron Bias Ext	0x001C	Any	I2 scaled from (-1,1)
29	Y Hard Iron Bias Ext	0x001D	Any	I2 scaled from (-1,1)
30	Soft Iron Scale Ratio Ext	0x001E	Any	U2 scaled from (0,2)
31	Soft Iron Angle Ext	0x001F	$(-\pi \quad \pi)$	Angle of major axis of the ellipse generated by 360 degree swing in radian
32	Orientation Ext	0x0020	See below	Determine forward, rightward, and downward facing sides of external magnetometer
33	Reserved	N/A	N/A	N/A
34	Reserved	N/A	N/A	N/A
	User Packet Data	TBD		

NOTE: BAUD rate SF has immediate effect. Some output data may be lost. Response will be received at new BAUD rate.

NOTE: Only configuration fields 1, 2, 3, 7, 8, 13, 16, 17, 18, 19, 22, 25, 26, 27, and 34 are applicable for "architectures 4 and 5."

Continuous Packet Type Field

This packet type is continually output. The supported packet depends on the model number. Refer to *Output Packets (Polled or Continuous)* on page 73 for a complete list of the available packet types.

Orientation Field

This field defines the rotation from the factory to user axis sets. This rotation is relative to the default factory orientation (connector aft, base plate down). The default factory axis set is (Ux, Uy, Uz) defined by the connector pointing in the –Ux direction and the baseplate pointing in the +Uz direction. The user axis set is (X, Y, Z) as defined by this field. An example of the factory axis set is shown below:

Figure 26 Orientation Fields

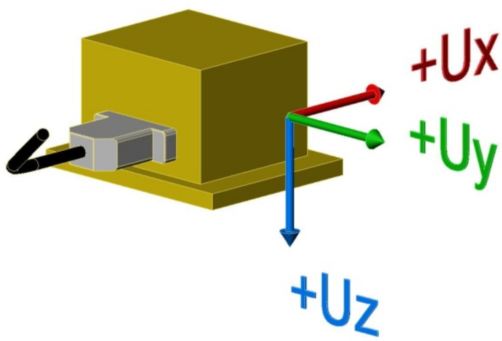


Table 56 Orientation Fields

Axis	Bits	Values
X Axis Sign	0	0 = positive, 1 = negative
X Axis	1:2	0 = Ux, 1 = Uy, 2 = Uz, 3 = N/A
Y Axis Sign	3	0 = positive, 1 = negative
Y Axis	4:5	0 = Uy, 1 = Uz, 2 = Ux, 3 = N/A
Z Axis Sign	6	0 = positive, 1 = negative
Z Axis	7:8	0 = Uz, 1 = Ux, 2 = Uy, 3 = N/A
Reserved	9:15	N/A

There are 24 possible orientation configurations. Setting/Writing the field to anything else generates a NAK and has no effect.

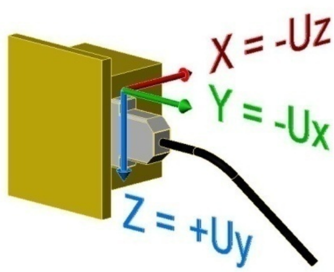
Table 57 Orientation Field Values

Orientation Field Value	X Axis	Y Axis	Z Axis
0x0000	+Ux	+Uy	+Uz
0x0009	-Ux	-Uy	+Uz
0x0023	-Uy	+Ux	+Uz
0x002A	+Uy	-Ux	+Uz
0x0041	-Ux	+Uy	-Uz
0x0048	+Ux	-Uy	-Uz
0x0062	+Uy	+Ux	-Uz
0x006B	-Uy	-Ux	-Uz
0x0085	-Uz	+Uy	+Ux
0x008C	+Uz	-Uy	+Ux
0x0092	+Uy	+Uz	+Ux

Orientation Field Value	X Axis	Y Axis	Z Axis
0x009B	-Uy	-Uz	+Ux
0x00C4	+Uz	+Uy	-Ux
0x00CD	-Uz	-Uy	-Ux
0x00D3	-Uy	+Uz	-Ux
0x00DA	+Uy	-Uz	-Ux
0x0111	-Ux	+Uz	+Uy
0x0118	+Ux	-Uz	+Uy
0x0124	+Uz	+Ux	+Uy
0x012D	-Uz	-Ux	+Uy
0x0150	+Ux	+Uz	-Uy
0x0159	-Ux	-Uz	-Uy
0x0165	-Uz	+Ux	-Uy
0x016C	+Uz	-Ux	-Uy

An example of orientation field value 0x12D is shown in the figure below.

Figure 27 Orientation Field



User Behavior Switches

This field allows on the fly user interaction with aspects of the algorithm.

Table 58 Behavior Aspects

Algorithm Aspect	Bits	Values
Free Integrate	0	0: use feedback to stabilize the algorithm 1: 6DOF inertial integration without stabilized feedback

Algorithm Aspect	Bits	Values
Use Mags	1	0: Do not use mags to stabilize heading (heading will run open loop or be stabilized by GPS track) 1: Use mags to stabilize heading
Use GPS	2	0: Do not use GPS to stabilize the system, 1: Use GPS when available
Stationary Yaw Lock	3	0: Do not lock yaw when GPS speed is near zero (<0.75 m/s) 1: Lock yaw when GPS speed is near zero
Restart on Over-range	4	0: Do not restart the system after a sensor over-range, 1: restart the system after a sensor over-range
Dynamic Motion	5	0: vehicle is static, force high gain corrections 1: vehicle is dynamic, use nominal corrections
Reserved	6	N/A
Internal / External Mags	7	0: use the internal magnetometer 1: use the external magnetometer **NOTE:** whether or not the magnetometer is used to update the heading is set in the Use Mags bit of the User Behavior configuration.
Internal / External GPS	8	0: use the internal GPS 1: use the external GPS **Note**: whether or not the GPS input is used in the algorithm is set in the *Use GPS* bit of the User Behavior configuration
Reserved	9:15	N/A

The following table clarifies the relationship of the Use Mags bit and the Internal / External Mags bit

Table 59 Internal External Mags Bit

Use Mags	Internal / External Mags	Result
0	0	The magnetometer is not used
0	1	The magnetometer is not used
1	0	The heading is updated with the internal magnetometer
1	1	The heading is updated with the external magnetometer

Hard and Soft Iron Values

These fields allow access to hard iron bias and soft iron scale ratio values for magnetometer alignment. The calibration values for the internal magnetometer:

Table 60 Internal Magnetometer Calibration Values

Field Name	Field ID	Format	Scaling	Units
X Hard Iron Bias	0x0009	I2	2/2^16	Gauss

Y Hard Iron Bias	0x000A	I2	2/2^16	Gauss
Soft Iron Scale Ratio	0x000B	U2	2/2^16	-
Soft Iron Angle	0x000E	I2	2*pi/2^16	Radians

Note that the calibration values for an external magnetometer are contained in distinct fields:

Table 61 External Magnetometer Calibration Values

Field Name	Field ID	Format	Scaling	Units
X Hard Iron Bias	0x001C	I2	2/2^16	Gauss
Y Hard Iron Bias	0x001D	I2	2/2^16	Gauss
Soft Iron Scale Ratio	0x001E	U2	2/2^16	-
Soft Iron Angle	0x001F	I2	2*pi/2^16	Radians

For an external magnetometer, there are also configuration fields that allow a user to specify roll and pitch offsets (0x0017, 0x0018), and magnetometer orientation (0x0020).

The hard iron bias values are scaled from (-1, 1) Gauss. These values are subtracted from the tangent plane magnetometer vector before heading is calculated. The soft iron scale ratio is scaled from (0, 2) and is multiplied by the tangent plane x magnetometer value before heading is calculated.

Heading Track Offset

This field is used to set the offset between vehicle heading and vehicle track to be used by the navigation mode filter when no magnetometer heading measurements are available.

Field Name	Field ID	Format	Scaling	Units
Heading Track Offset	0x000C	I2	2*pi/2^16 (360°/2^16)	Radians (heading-track) (°)

Commands to Program Configuration

Write Fields Command

Table 62 WF Command

Write Fields (‘WF’ = 0x5746)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5746	1+numFields*4	<WF payload>	<CRC (U2)>

This command allows the user to write default power-up configuration fields to the EEPROM. Writing the default configuration will not take effect until the unit is power cycled. *NumFields* is the number of words to be written. The *field0, field1, etc.* are the field IDs that will be written with the *field0Data, field1Data, etc.*, respectively. The unit will not write to calibration or algorithm fields.

- If at least one field is successfully written, the unit will respond with a write field response containing the field IDs of the successfully written fields.
- If any field is unable to be written, the unit will respond with an error response.

Both write fields and an error response may be received as a result of a write fields command. Attempts to write a field with an invalid value is one way to generate an error response. To view a table of field IDs and valid field values, refer to *Configuration Fields* on page 85.

Table 63 WF Payload

WF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields to write
1	field0	U2	—	—	The first field ID to write
3	field0Data	U2	—	—	The first field ID's data to write
5	field1	U2	—	—	The second field ID to write
7	field1Data	U2	—	—	The second field ID's data
…	…	U2	—	—	…
numFields*4 -3	field…	U2	—	—	The last field ID to write
numFields*4 -1	field…Data	U2	—	—	The last field ID's data to write

Write Fields Response

Table 64 WF Response

Write Fields ('WF' = 0x5746)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5746	1+numFields*2	<WF payload>	<CRC (U2)>

The unit will send this packet in response to a write fields command if the command has completed without errors.

Table 65 WF Payload

WF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields written
1	field0	U2	—	—	The first field ID written
3	field1	U2	—	—	The second field ID written
…	…	U2	—	—	More field IDs written
numFields*2 – 1	Field…	U2	—	—	The last field ID written

Set Fields Command

Table 66 SF Commands

Set Fields ('SF' = 0x5346)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5346	1+numFields*4	<SF payload>	<CRC (U2)>

This command allows the user to set the unit's current configuration (SF) fields immediately which will then be lost on power down. *NumFields* is the number of words to be set. The *field0, field1, etc.* are the field IDs that will be written with the *field0Data, field1Data, etc.*, respectively. This command can be used to set configuration fields. The unit will not set calibration or algorithm fields. If at least one field is successfully set, the unit will respond with a set fields response containing the field IDs of the successfully set fields. If any field is unable to be set, the unit will respond with an error response.

Both a set fields and an error response may be received as a result of one set fields command. Setting a field with an invalid value will generate an error response. To view a table of field IDs and valid field values, refer to *Configuration Fields* on page 85.

Table 67 SF Payload

SF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields to set
1	field0	U2	—	—	The first field ID to set
3	field0Data	U2	—	—	The first field ID's data to set
5	field1	U2	—	—	The second field ID to set
7	field1Data	U2	—	—	The second field ID's data to set
…	…	U2	—	—	…
numFields*4 -3	field…	U2	—	—	The last field ID to set
numFields*4 -1	field…Data	U2	—	—	The last field ID's data to set

Write Fields Response

Table 68 WF Response

Write Fields ('WF' = 0x5746)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5746	1+numFields*2	<WF payload>	<CRC (U2)>

The unit will send this packet in response to a write fields command if the command has completed without errors.

Table 69 WF Payload

WF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields written

WF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
1	field0	U2	—	—	The first field ID written
3	field1	U2	—	—	The second field ID written
...	...	U2	—	—	More field IDs written
numFields*2 – 1	Field...	U2	—	—	The last field ID written

Table RF Command Read Fields Command

Read Fields ('RF' = 0x5246)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5246	1+numFields*2	<RF payload>	<CRC (U2)>

This command allows the user to read the default power-up configuration fields from the EEPROM. *NumFields* is the number of fields to read. The *field0, field1, etc.* are the field IDs to read. RF may be used to read configuration and calibration fields from the EEPROM. If at least one field is successfully read, the unit will respond with a read fields response containing the field IDs and data from the successfully read fields.

If any field is unable to be read, the unit will respond with an error response. Note that both a read fields and an error response may be received as a result of a read fields command.

Table 70 RF Payload

RF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields to read
1	field0	U2	—	—	The first field ID to read
3	field1	U2	—	—	The second field ID to read
...	...	U2	—	—	More field IDs to read
numFields*2 - 1	Field...	U2	—	—	The last field ID to read

Read Fields Response

Table 71 RF Response

Read Fields ('RF' = 0x5246)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x5246	1+numFields*4	<RF payload>	<CRC (U2)>

The unit will send this packet in response to a read fields request if the command has completed without errors.

Table 72 RF Payload

RF Payload Contents

Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	—	—	The number of fields read
1	field0	U2	—	—	The first field ID read
3	field0Data	U2	—	—	The first field ID's data read
5	field1	U2	—	—	The second field ID read
7	field1Data	U2	—	—	The second field ID's data read
…	…	U2	—	—	…
numFields*4 -3	field…	U2	—	—	The last field ID read
numFields*4 -1	field…Data	U2	—	—	The last field ID's data read

Get Fields Command

Table 73 GF Command

Get Fields ('GF' = 0x4746)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4746	1+numFields*2	<GF Data>	<CRC (U2)>

This command allows the user to get the unit's current configuration fields. *NumFields* is the number of fields to get. The *field0, field1, etc.* are the field IDs to get. GF may be used to get configuration, calibration, and algorithm fields from RAM. Multiple algorithm fields will not necessarily be from the same algorithm iteration. If at least one field is successfully collected, the unit will respond with a get fields response with data containing the field IDs of the successfully received fields.

If any field is unable to be received, the unit will respond with an error response. Note that both a *get fields* and an *error response* may be received as the result of a get fields command.

Table 74 GF Payload

GF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields to get
1	field0	U2	—	—	The first field ID to get
3	field1	U2	—	—	The second field ID to get
…	…	U2	—	—	More field IDs to get
numFields*2 – 1	Field…	U2	—	—	The last field ID to get

Get Fields Response

Table 75 GF Response

Get Fields ('GF' = 0x4746)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***

Get Fields (‘GF’ = 0x4746)				
Preamble	***Packet Type***	***Length***	***Payload***	***Termination***
0x5555	0x4746	1+numFields*4	<GF Data>	<CRC (U2)>

The unit will send this packet in response to a get fields request if the command has completed without errors.

Table 76 GF Payload

GF Payload Contents					
Byte Offset	***Name***	***Format***	***Scaling***	***Units***	***Description***
0	numFields	U1	—	—	The number of fields retrieved
1	field0	U2	—	—	The first field ID retrieved
3	field0Data	U2	—	—	The first field ID’s data retrieved
5	field1	U2	—	—	The second field ID retrieved
7	field1Data	U2	—	—	The second field ID’s data
…	…	U2	—	—	…
numFields*4 -3	field…	U2	—	—	The last field ID retrieved
numFields*4 -1	field…Data	U2	—	—	The last field ID’s data retrieved

Chapter 11. Built In Test (BIT)

The Built-In Test capability allows users to monitor health, diagnostic, and system status information of the unit in real-time. Built-In Test information is transmitted in each measurement packet.

NOTE: A diagnostic test packet (T2) can be requested via GP. To contains a complete set of status for each hardware and software subsystem. For more information, refer to *Test 2 (Detailed BIT and Status) Packet* on page 72 and *Get Packet Request* on page 68.

BIT Status Fields

A BIT word consists of two bytes: *Error byte* and *Status byte*.

The first byte (bits 0–7) is the *Error byte*: signaled results from internal checks. Four intermediate signals determine when to assert masterFail and the hardware BIT signal. These signals are controlled by three categories of systems checks: hardware (*hardwareError*), communication (*comError*) and software (*softwareError*). Instantaneous soft failures from any category triggers the signals: a flag is raised. masterFail is not triggered until persistency conditions are met or a hard failure has occurred.

The second byte (bits 8–15) is the *Status byte*: signaled status alerts. Four intermediate signals determine when to assert the *masterStatus* flag: *hardwareStatus*, *sensorStatus*, *comStatus*, and *softwareStatus*. masterStatus is the logical OR of these intermediate signals. Each intermediate signal has a separate field with an indication flag. Each indication flag can be enabled or disabled by the user. Any enabled indication flag will trigger the associated intermediate signal and masterStatus flag.

The BIT fields are summarized in *Table 77* below. *Table 78* provides additional information about the programmable status field.

Table 77 Default BIT Status Values

BITstatus Field	Bits	Value	Configurable
Error Byte fields (BIT)			N
masterFail	0	0: normal 1: fatal error The masterFail flag is thrown when either a hard failure (fatal condition) or a soft failure (persistent problem) occurs.	N
hardwareError	1	0: normal 1: internal hardware error	N
comError	2	0: normal 1: communication error	N
softwareError	3	0: normal 1: internal software error or magAlignOutofBounds **NOTE:** In AHRS and NAV modes, this bit provides information about the status of magnetic alignment. If the unit has not been properly magnetically calibrated, a softwareError will be indicated	N
GPSError	4	0: normal 1: GPS failure	N

BITstatus Field	Bits	Value	Configurable
Reserved	5:7	N/A	N
Status Byte Fields			
masterStatus	8	0: nominal 1: one or more status alerts occurred: hardware; com; software; sensor	Y
hardwareStatus	9	0: nominal 1: programmable alert (refer to *Programmable* Status below)	Y
comStatus	10	0: nominal 1: programmable alert (refer to *Programmable Status Fields* below)	Y
softwareStatus	11	0: nominal 1: programmable alert (refer to *Programmable Status Fields* below)	Y
sensorStatus	12	0: nominal 1: programmable alert (refer to *Programmable* Status *Fields* below)	Y
GPSStatus	13	0 : GPS data valid 1: GPS data not valid	Y
HeadingStatus	14	0: heading verified 1: heading not verified	Y
P/Y code detected	15	0: no P/Y code detected 1: P/Y code detected	Y

Programmable Status Fields

The BIT status fields can be configured. The operation modes, AHRS, IU, VG and NAV, affect the default value of the hardware, com, software and sensor status bits. The default settings are appropriate for most installations.

NOTE: The settings should not be configured unless determined necessary; incorrect configurations can adversely affect operations.

NOTE: Error fields cannot be configured.

The default values are listed in *Table 78* below.

Table 78 Programmable BIT Status–Default Values per Function

Status Byte Field	Default Values
masterStatus (bit 8)	The masterStatus flag is asserted when an enabled alert signal is asserted. For information about configuring this status field, refer to *BIT Configuration* on page 56 and *Configuring masterStatus* on page 106.

Status Byte Field	Default Values
hardwareStatus (bit 9)	• AHRS: disabled • IMU: disabled • VG: disabled • NAV: 0 = nominal, 1 = Internal GPS unlocked or 1PPS invalid For additional visibility or alerts relative to the GPS sensor status or algorithm status, configure additional triggers for both *softwareStatus* and *hardwareStatus*. For information about configuring this status field, refer to *BIT Configuration* on page 56, *hardwareStatus Field* on page 105 and *Configuring masterStatus* on page 106.
comStatus (bit 10)	• AHRS: 0 = nominal 1 = No External GPS Comm • IMU: disabled • VG: 0 = nominal, 1 = No External GPS Comm • NAV: disabled For information about configuring this status field, refer to *BIT Configuration* on page 56, *comStatus Field* on page 105 and *Configuring masterStatus* on page 106.
softwareStatus (bit 11)	• AHRS: 0 = nominal, 1 = Algorithm Initialization, or High Gain For additional visibility when the EFK algorithm estimates that the unit is turning about its Z or Yaw axis, the *softwareStatus* bit can be configured to go high (1) during a turn. In AHRS Function, the default value of turnSwitch is 0.5 deg/sec about the z-axis • IMU: disabled • VG: 0 = nominal, 1 = Algorithm Initialization or High Gain For additional visibility when the EFK algorithm estimates that the unit is turning about its Z or Yaw axis, the *softwareStatus* bit can be configured to go high (1) during a turn. In VG Function, the default value of turnSwitch is 10.0 deg/sec about the z-axis • NAV: 0 = nominal, 1 = Algorithm Initialization or High Gain For additional visibility or alerts relative to the GPS sensor status or algorithm status, configure additional triggers for both *softwareStatus* and *hardwareStatus*. For information about configuring this status field, refer to *BIT Configuration* on page 56 and *SoftwareStatus Field* on page 105 and *Configuring masterStatus* on page 106.

Status Byte Field	Default Values
sensorStatus (bit 12)	• AHRS: 0 = nominal 1 = Sensor Over Range • IMU: 0 = nominal 1 = Sensor Over Range *Sensor Over Range* only applies to the rotational rate sensors; over-range is not triggered for accelerometer readings. In many applications, vibration causes instantaneous acceleration levels to exceed the accelerometer sensor range. • VG: 0 = nominal 1 = Sensor Over Range • NAV: 0 = nominal 1 = Sensor Over Range For information about configuring this status field, refer to *BIT Configuration* on page 56 and *sensorStatus Field* on page 106 and *Configuring masterStatus* on page 106.
GPSStatus (bit 13)	• NAV: 0 = GPS data valid, 1 = GPS data not valid • AHRS, IMU, VG: N/A

hardwareBIT Field

The hardwareBIT field contains flags that indicate various internal hardware errors. Each hardware error has an associated message with low level error signals. The hardwareError flag in the BITstatus field is the bit-wise OR of the hardwareBIT field.

Table 79 hardwareBIT Field

hardwareBIT Field	Bits	Values	Category
powerError	0	0 = normal, 1 = error	Soft
environmentalError	1	0 = normal, 1 = error	Soft
reserved	2:15	N/A	

hardwarePowerBIT Field

The hardwarePowerBIT field contains flags that indicate low level power system errors. The powerError flag in the hardwareBIT field is the bit-wise OR of the hardwarePowerBIT field.

Table 80 hardwarePowerBIT Field

hardwarePowerBIT Field	Bit	Values	Category
inpPower	0	0 = normal, 1 = out of bounds	Soft
inpCurrent	1	0 = normal, 1 = out of bounds	Soft
inpVoltage	2	0 = normal, 1 = out of bounds	Soft
fiveVolt	3	0 = normal, 1 = out of bounds	Soft

hardwarePowerBIT Field	Bit	Values	Category
threeVolt	4	0 = normal, 1 = out of bounds	Soft
twoVolt	5	0 = normal, 1 = out of bounds	Soft
twoFiveRef	6	0 = normal, 1 = out of bounds	Soft
sixVolt	7	0 = normal, 1 = out of bounds	Soft
grdRef	8	0 = normal, 1 = out of bounds	Soft
fourVolt	9	0 = normal, 1 = out of bounds	Soft
Reserved	10:15	N/A	N/A

hardwareEnvironmentalBIT Field

The hardwareEnvironmentalBIT field contains flags that indicate low level hardware environmental errors. The environmentalError flag in the hardwareBIT field is the bit-wise OR of the hardwareEnvironmentalBIT field.

Table 81 hardwareEnvironmentalBIT Field

hardwareEnvironmentalBIT Field	Bits	Values	Category
pcbTemp	0	0 = normal, 1 = out of bounds	Soft
Reserved	9:15	N/A	

comBIT Field

The comBIT field contains flags that indicate communication errors with external devices. Each external device has an associated message with low level error signals. The comError flag in the BITstatus field is the bit-wise OR of the comBIT field.

Table 82 comBIT Field

comBIT Field	Bits	Values	Category
serialAError	0	0 = normal, 1 = error	Soft
serialBError	1	0 = normal, 1 = error	Soft
serialCError	2	0 = normal, 1 = error	
Reserved	3:15	N/A	

comBIT-Field *stickyness*:

- With each error or overflow the related comSerialBit-field flag(s) will remain sticky until reported in a packet. The algorithm task is responsible for clearing the BIT flag (void handleComBIT()).
- Requesting a packet does not clear the flag(s). Only when the unit is configured to continuously output a packet will the flag(s) be cleared
- When a substantial number of consecutive errors have occurred in a short period of time the master fail bit is set and the flags cannot be cleared without doing a reset.

comSerialABIT Field

The comSerialABIT field contains flags that indicate low level errors with external serial port A (the user serial port). The serialAError flag in the comBIT field is the bit-wise OR of the comSerialABIT field.

Table 83 comSerialABIT Field

comSerialABIT Field	Bits	Values	Category
transmitBufferOverflow	0	0 = normal, 1 = overflow	Soft
receiveBufferOverflow	1	0 = normal, 1 = overflow	Soft
framingError	2	0 = normal, 1 = error	Soft
breakDetect	3	0 = normal, 1 = error	Soft
parityError	4	0 = normal, 1 = error	Soft
Reserved	5:15	N/A	

comSerialBBIT Field

The comSerialBBIT field contains flags that indicate low level errors with external serial port B (the aiding serial port). The serialBError flag in the comBIT field is the bit-wise OR of the comSerialBBIT field.

Table 84 comSerialBBIT Field

comSerialBBIT Field	Bits	Values	Category
transmitBufferOverflow	0	0 = normal, 1 = overflow	Soft
receiveBufferOverflow	1	0 = normal, 1 = overflow	Soft
framingError	2	0 = normal, 1 = error	Soft
breakDetect	3	0 = normal, 1 = error	Soft
parityError	4	0 = normal, 1 = error	Soft
Reserved	5:15	N/A	

comSerialCBIT Field

The comSerialABIT field contains flags that indicate low level errors with external serial port c (the user serial port). The serial Error flag in the comBIT field is the bit-wise OR of the comSerialCBIT field.

Table 85 comSerialABIT Field

comSerialCBIT Field	Bits	Values	Category
transmitBufferOverflow	0	0 = normal, 1 = overflow	Soft
receiveBufferOverflow	1	0 = normal, 1 = overflow	Soft
framingError	2	0 = normal, 1 = error	Soft
breakDetect	3	0 = normal, 1 = error	Soft
parityError	4	0 = normal, 1 = error	Soft
Reserved	5:15	N/A	

softwareBIT Field

The softwareBIT field contains flags that indicate various types of software errors. Each type has an associated message with low level error signals. The softwareError flag in the BITstatus field is the bit-wise OR of the softwareBIT field.

Table 86 softwareBIT Field

softwareBIT Field	Bits	Values	Category
algorithmError	0	0 = normal, 1 = error	Soft
dataError	1	0 = normal, 1 = error	Soft
Reserved	2:15	N/A	

softwareAlgorithmBIT Field

The softwareAlgorithmBIT field contains flags that indicate low level software algorithm errors. The algorithmError flag in the softwareBIT field is the bit-wise OR of the softwareAlgorithmBIT field.

Table 87 softwareAlgorithmBIT Field

SoftwareAlgorithmBIT Field	Bits	Values	Category
initialization	0	0 = normal, 1 = error during algorithm initialization	Hard
overRange	1	0 = normal, 1 = fatal sensor over-range	Hard
missedNavigationStep	2	0 = normal, 1 = fatal hard deadline missed for navigation	Hard
Reserved	3:15	N/A	

softwareDataBIT Field

The softwareDataBIT field contains flags that indicate low level software data errors. The dataError flag in the softwareBIT field is the bit-wise OR of the softwareDataBIT field.

Table 88 softwareDataBIT Field

SoftwareDataBIT Field	Bits	Values	Category
calibrationCRCError	0	0 = normal, 1 = incorrect CRC on calibration EEPROM data or data has been compromised by a WE command.	Hard
magAlignOutOfBounds	1	0 = normal, 1 = hard and soft iron parameters are out of bounds	Hard
Reserved	2:15	N/A	

hardwareStatus Field

The hardwareStatus field contains flags that indicate various internal hardware conditions and alerts that are not errors or problems. The hardwareStatus flag in the BITstatus field is the bit-wise OR of the logical AND of the hardwareStatus field and the hardwareStatusEnable field. The hardwareStatusEnable field is a bit mask that enables selecting items of interest that will logically flow up to the masterStatus flag.

Table 89 hardwareStatus Field

hardwareStatus Field	Bits	Values
unlocked1PPS	0	0 = not asserted, 1 = asserted
unlockedInternalGPS	1	0 = not asserted, 1 = asserted
noDGPS	2	0 = DGPS lock, 1 = no DGPS
unlockedEEPROM	3	0=locked, WE disabled, 1=unlocked, WE enabled
Reserved	4:15	N/A

comStatus Field

The comStatus field contains flags that indicate various external communication conditions and alerts that are not errors or problems. The comStatus flag in the BITstatus field is the bit-wise OR of the logical AND of the comStatus field and the comStatusEnable field. The comStatusEnable field is a bit mask that enables selecting items of interest that will logically flow up to the masterStatus flag.

Table 90 comStatus Field

comStatus Field	Bits	Values
noExternalGPS	0	0 = external GPS data is being received 1 = no external GPS data is available
Reserved	1:15	N/A

SoftwareStatus Field

The softwareStatus field contains flags that indicate various software conditions and alerts that are not errors or problems. The softwareStatus flag in the BITstatus field is the bit-wise OR of the logical AND of the softwareStatus field and the softwareStatusEnable field. The softwareStatusEnable field is a bit mask that enables selecting items of interest that will logically flow up to the masterStatus flag.

Table 91 softwareStatus Field

softwareStatus Field	Bits	Values
algorithmInit	0	0 = normal, 1 = the algorithm is in initialization mode
highGain	1	0 = low gain mode, 1 high gain mode
attitudeOnlyAlgorithm	2	0 = navigation state tracking, 1 = attitude only state tracking

softwareStatus Field	Bits	Values
turnSwitch	3	0 = off, 1 = yaw rate greater than turnSwitch threshold
Reserved	4	N/A
noMagnetometerheading Reference (T0 N/A)	5	0 = aided with Magnetometer heading reference 1 = no Magnetometer heading reference
noGPSTrackReference (T0 N/A)	6	0 = aided with GPS track reference 1 = no GPS track reference
Reserved	7:15	N/A

sensorStatus Field

The sensorStatus field contains flags that indicate various internal sensor conditions and alerts that are not errors or problems. The sensorStatus flag in the BITstatus field is the bit-wise OR of the logical AND of the sensorStatus field and the sensorStatusEnable field. The sensorStatusEnable field is a bit mask that enables selecting items of interest that will logically flow up to the masterStatus flag.

Table 92 sensorStatus Fields

sensorStatus Field	Bits	Values
overRange	0	0 = not asserted, 1 = asserted
Reserved	1:15	N/A

Configuring masterStatus

The masterStatus byte and its associated programmable alerts are configured using the Read Field and Write Field command as described in *Chapter 10. Programming Guidelines.*

Table 93 below shows the definition of the bit mask for configuring the status signals.

Table 93 masterStatus Fields

Configuration Fields	Field ID	Valid Values	Description
hardwareStatusEnable	0x0010	Any	Bit mask of enabled hardware status signals
comStatusEnable	0x0011	Any	Bit mask of enabled communication status signals
softwareStatusEnable	0x0012	Any	Bit mask of enabled software status signals
sensorStatusEnable	0x0013	Any	Bit mask of enabled sensor status signals

hardwareStatusEnable Field

This field is a bit mask of the hardwareStatus field (refer to BIT Status Fields on page 98). This field allows the user to determine which low level hardwareStatus field signals will flag the hardwareStatus and masterStatus flags in the BITstatus field. Any asserted bits in this field imply that the corresponding hardwareStatus field signal, if asserted, will cause the hardwareStatus and masterStatus flags to be asserted in the BITstatus field.

comStatusEnable Field

This field is a bit mask of the comStatus field (refer to BIT Status Fields on page 98). This field allows the user to determine which low level comStatus field signals will flag the comStatus and masterStatus flags in the BITstatus field. Any asserted bits in this field imply that the corresponding comStatus field signal, if asserted, will cause the comStatus and masterStatus flags to be asserted in the BITstatus field.

softwareStatusEnable Field

This field is a bit mask of the softwareStatus field (refer to BIT Status Fields on page 98). This field allows the user to determine which low level softwareStatus field signals will flag the softwareStatus and masterStatus flags in the BITstatus field. Any asserted bits in this field imply that the corresponding softwareStatus field signal, if asserted, will cause the softwareStatus and masterStatus flags to be asserted in the BITstatus field.

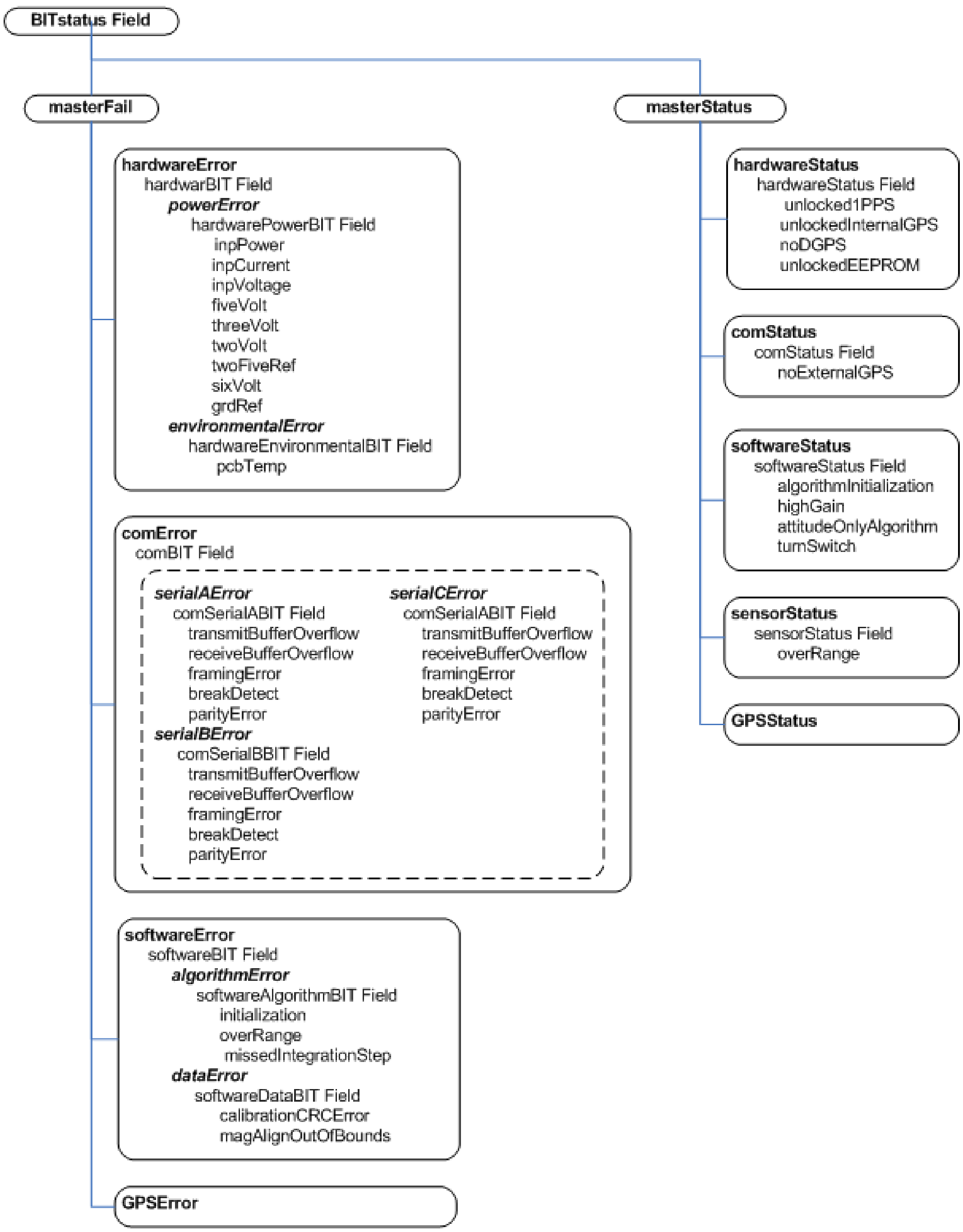
sensorStatusEnable Field

This field is a bit mask of the sensorStatus field (refer to BIT Status Fields on page 98). This field allows the user to determine which low level sensorStatus field signals will flag the sensorStatus and masterStatus flags in the BITstatus field. Any asserted bits in this field imply that the corresponding sensorStatus field signal, if asserted, will cause the sensorStatus and masterStatus flags to be asserted in the BITstatus field.

BIT Field Hierarchy

Figure 28 below illustrates the hierarchy of the BIT fields.

Figure 28 BIT Error and Status Hierarchy



Appendix A. Application Examples

This section provides recommended advanced settings for tailoring the GNAV540 unit of inertial systems to different types of application and platform requirements.

Fixed Wing Aircraft

A fixed-wing aircraft is a heavier-than-air craft where movement of the wings in relation to the aircraft is not used to generate lift. The term is used to distinguish from rotary-wing aircraft, where the movement of the wing surfaces relative to the aircraft generates lift. The fixed wing aircraft can range in size from the smallest experimental plane to the largest commercial jet.

The dynamic characteristics of the fixed wing aircraft depend on the type of aircraft (such as glider, propeller aircraft, and jet aircraft) and mission phases (such as launch, landing, and maneuver). For best results per dynamic condition, the appropriate settings must be applied. *Table 94* below shows four examples of dynamic conditions with recommended configurations.

Table 94 Recommended Settings for Fixed Wing Aircraft

Recommended Settings	**Dynamic Condition**			
	Pre-launch or known straight and level un-accelerated flight	***Launch***	***Normal Dynamics (Default)***	***High Dynamics***
UseMags	ON	ON	ON	ON
UseGPS	ON	ON (< 4g)	ON	ON (< 4g)
FreelyIntegrate	OFF	OFF[1]	OFF	OFF (< 2g)
Stationary Yaw Lock	OFF	OFF	OFF	OFF
Restart Over Range	ON	OFF	OFF	OFF
Dynamic Motion	OFF	ON	ON	ON
Turn Switch Threshold	0.5 deg/s	0.5 deg/s	0.5 deg/s	0.5 deg/s

Rotorcraft

Rotorcraft is a category of heavier-than-air flying machines that use lift generated by rotors. They may also include the use of static lifting surfaces, but the primary distinguishing feature being lift provided by rotating lift structures. Rotorcraft includes helicopters, autogyros, gyrodynes and tiltrotors.

The rotor blade dynamics are faster than the fixed wing aircraft and contain high frequency components; however, it may cause severe vibrations on the airframe. The overall dynamics (translational and rotational motion) of the rotor craft are much slower than the fixed wing aircraft. Also, the rotors generate significant aerodynamic forces and moments. *Table 95* shows two examples of dynamic conditions and the recommended configurations.

[1] FreelyIntegrate should only be set to **ON** for severe launch conditions. Normal takeoff dynamics that a standard aircraft would experience will see the best performance with this setting in the **OFF** position.

Table 95 Recommended Advanced Settings for Rotorcraft

Recommended Settings	Dynamic Condition	
	Normal Dynamics	High Dynamics (with uncoordinated tail motion)
UseMags	ON	ON
UseGPS	ON	ON (< 4g)
FreelyIntegrate	OFF	OFF (< 2g)
Stationary Yaw Lock	OFF	OFF
Restart Over Range	OFF	ON
Dynamic Motion	ON	ON
Turn Switch Threshold	1.0 deg/s §	30.0 deg/s §

§The helicopter can change its heading angle rapidly unlike the aircraft which requires banking. A turn switch threshold that is too low may cause turn switch activation with high duty cycle causing random walk in roll and pitch angles due to low feedback gains.

Land Vehicle

Some examples of land vehicles are: automobiles, trucks, heavy equipment, trains, snowmobiles, and other tracked vehicles. *Table 96* shows two examples of land vehicles and the recommended configurations.

Table 96 Recommended Advanced Settings for Land Vehicle

Recommended Settings	Dynamic Condition	
	Heavy Equipment Application	Automotive Testing
UseMags	ON§	ON§
UseGPS	ON	ON (< 4g)
FreelyIntegrate	OFF	OFF
Stationary Yaw Lock	OFF	OFF
Restart Over Range	ON	OFF
Dynamic Motion	ON	ON
Turn Switch Threshold	5.0 deg/s	10.0 deg/s

§When not in distorted magnetic environment.

Water Vehicle

Water vehicle is a craft or vessel designed to float on or submerge and provide transport over and under water. Table 97 provides the recommended advanced settings for two applications.

Table 97 Recommended Advanced Settings for Water Vehicle

Recommended Product	GNAV540
Recommended Settings	Application

	Surfaced	*Submerged*
UseMags	ON[2]	ON[3]
UseGPS	ON	OFF
FreeIntegrate	OFF	OFF
Stationary Yaw Lock	OFF	OFF
Restart Over Range	OFF	OFF
Dynamic Motion	ON	ON
Turn Switch Threshold	10 deg/s	5 deg/s

Example

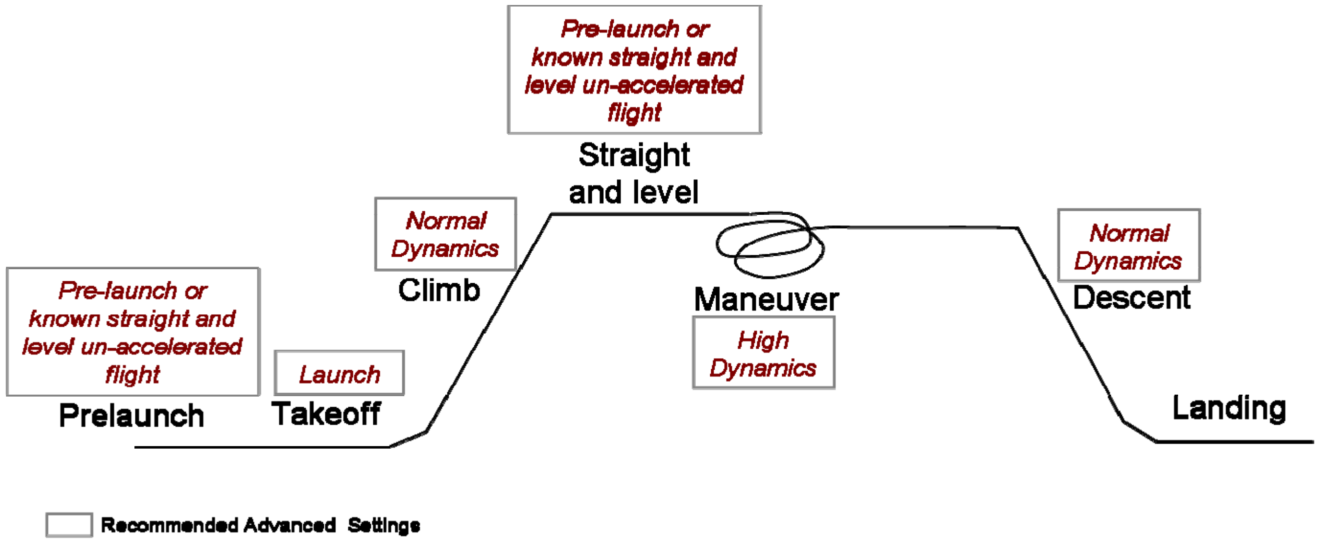
Table 98 below shows a typical flight profile of the fixed wing aircraft and the corresponding advanced settings that can be configured per flight phase.

Table 98 Flight Profile Phases

Phase	Description
Prelaunch	The phase of flight in which an aircraft goes through a series of checkups (hardware and software) on the ground before takeoff. The aircraft is a static condition,
Takeoff	The phase of flight in which an aircraft goes through a transition from moving along the ground (taxiing) to flying in the air, usually along a runway. The aircraft is under horizontal acceleration and may suffer from vibrations coming from an engine and ground contact forces transmitted from its landing gear..
Climb	The phase of a flight, after takeoff, consisting of getting the aircraft to the desired flight level altitude. More generally, the term 'climb' means increasing the altitude. The aircraft is under vertical acceleration until it reaches the steady-state climb rate.
Straight and level flight	The phase of flight in which an aircraft reaches its nominal flight altitude and maintains its speed and altitude. The aircraft is under equilibrium.
Maneuver	The phase of flight in which an aircraft accelerates, decelerates, and turns. The aircraft is under non-gravitational acceleration and/or deceleration.
Descent	The phase of flight in which an aircraft decreases altitude for an approach to landing. The aircraft is under vertical deceleration until it captures a glide slope.
Landing	The last part of a flight, where the aircraft returns to the ground.

[2] When not in distorted magnetic environment.

Figure 29 Flight Profiles: Fixed Wing Aircraft Corresponding Settings



Appendix B. Sample Packet—Parser Code

Overview

This section includes an example of code written in ANSI C for parsing packets from data sent by the GNAV540 Inertial Systems. This example is for reading data directly from the GNAV540 unit or from a log file.

Sample Code

The sample code contains the actual parser as well as several support functions for CRC calculation and circular queue access.

Table 99 Code Functions

Function	Description
process_xbow_packet	Parse out packets from a queue. Returns these fields in structure XBOW_PACKET (see below). Checks for CRC errors
calcCRC	Calculate CRC on packets.
Initialize	Initialize the queue
AddQueue	Add item in front of queue
DeleteQueue	Return an item from the queue
peekWord	Retrieve 2-bytes from the queue, without popping
peekByte	Retrieve a byte from the queue without popping
Pop	Discard item(s) from queue
Size	Return number of items in queue
Empty	Return 1 if queue is empty, 0 if not
Full	Return 1 if full, 0 if not full

The parser will parse the queue looking for packets. Once a packet is found and the CRC checks out, the packet's fields are placed in the XBOW_PACKET structure. The parser will then return to the caller. When no packets are found the parser returns the value 0 to the caller.

The XBOW_PACKET structure is defined as follows:

```
typedef struct xbow_packet
{
   unsigned short   packet_type;
   char          length;
   unsigned short   crc;
   char          data(256);
} XBOW_PACKET;
```

Typically, the parser would be called within a loop in a separate process, or in some time triggered environment, reading the queue looking for packets. A separate process might add data to this queue when it arrives. It is up to the user to ensure circular-queue integrity by using some sort of mutual exclusion mechanism within the queue access functions.

```
Code Listing#include <stdio.h>

/* buffer size */
#define MAXQUEUE 500

/*
 * circular queue
 */
typedef struct queue_tag
{
   int count;
   int front;
   int rear;
   char entry(MAXQUEUE);
} QUEUE_TYPE;

/*
 * crossbow packet
 */
typedef struct xbow_packet
{
   unsigned short   packet_type;
   char                    length;
   unsigned short   crc;
   char                    data(256);
} XBOW_PACKET;

QUEUE_TYPE circ_buf;

/*******************************************************************************
 * FUNCTION:  process_xbow_packet looks for packets in a queue
 * ARGUMENTS: queue_ptr: is pointer to queue to process
 *                  result: will contain the parsed info when return value is 1
 * RETURNS:      0 when failed.
 *                  1 when successful
 *******************************************************************************/
int process_xbow_packet(QUEUE_TYPE *queue_ptr, XBOW_PACKET *result)
{
   unsigned short myCRC = 0, packetCRC = 0, packet_type = 0, numToPop=0, counter=0;
   char packet(100), tempchar, dataLength;

   if(Empty(queue_ptr))
   {
      return 0; /* empty buffer */
   }

   /* find header */
   for(numToPop=0; numToPop+1<Size(queue_ptr) ;numToPop+=1)
   {
      if(0x5555==peekWord(queue_ptr, numToPop)) break;
   }
```

```
    Pop(queue_ptr, numToPop);

    if(Size(queue_ptr) <= 0)
    {
        /* header was not found */
        return 0;
    }

   /* make sure we can read through minimum length packet */
   if(Size(queue_ptr)<7)
   {
    return 0;
   }

   /* get data length (5th byte of packet) */
   dataLength = peekByte(queue_ptr, 4);

   /* make sure we can read through entire packet */
   if(Size(queue_ptr) < 7+dataLength)
   {
    return 0;
    }


    /* check CRC */
    myCRC = calcCRC(queue_ptr, 2,dataLength+3);
    packetCRC = peekWord(queue_ptr, dataLength+5);

    if(myCRC != packetCRC)
    {
        /* bad CRC on packet – remove the bad packet from the queue and return */
        Pop(queue_ptr, dataLength+7);
        return 0;
    }

    /* fill out result of parsing in structure */
    result->packet_type = peekWord(queue_ptr, 2);
    result->length      = peekByte(queue_ptr, 4);
    result->crc         = packetCRC;
    for(counter=0; counter < result->length; counter++)
    {
        result->data(counter) = peekByte(queue_ptr, 5+counter);
    }

    Pop(queue_ptr, dataLength+7);

    return 1;
}

/*******************************************************************************
 * FUNCTION:  calcCRC calculates a 2-byte CRC on serial data using
 *            CRC-CCITT 16-bit standard maintained by the ITU
 *                  (International Telecommunications Union).
```

```
 * ARGUMENTS: queue_ptr is pointer to queue holding area to be CRCed
 *                  startIndex is offset into buffer where to begin CRC calculation
 *                  num is offset into buffer where to stop CRC calculation
 * RETURNS:      2-byte CRC
 ******************************************************************************/
unsigned short calcCRC(QUEUE_TYPE *queue_ptr, unsigned int startIndex, unsigned int num) {
   unsigned int i=0, j=0;
   unsigned short crc=0x1D0F; //non-augmented inital value equivalent to augmented initial
value 0xFFFF

   for (i=0; i<num; i+=1) {
      crc ^= peekByte(queue_ptr, startIndex+i) << 8;

      for(j=0;j<8;j+=1) {
         if(crc & 0x8000) crc = (crc << 1) ^ 0x1021;
         else crc = crc << 1;
      }
   }
   return crc;
}


/*******************************************************************************
 * FUNCTION:  Initialize - initialize the queue
 * ARGUMENTS: queue_ptr is pointer to the queue
 ******************************************************************************/
void Initialize(QUEUE_TYPE *queue_ptr)
{
   queue_ptr->count =  0;
   queue_ptr->front =  0;
   queue_ptr->rear  = -1;
}

/*******************************************************************************
 * FUNCTION:  AddQueue - add item in front of queue
 * ARGUMENTS: item holds item to be added to queue
 *                  queue_ptr is pointer to the queue
 * RETURNS:      returns 0 if queue is full. 1 if successful
 ******************************************************************************/
int AddQueue(char item, QUEUE_TYPE *queue_ptr)
{
   int retval = 0;
   if(queue_ptr->count >= MAXQUEUE)
   {
      retval = 0;  /* queue is full */
   }
   else
   {
      queue_ptr->count++;
      queue_ptr->rear = (queue_ptr->rear + 1) % MAXQUEUE;
      queue_ptr->entry(queue_ptr->rear) = item;
      retval = 1;
   }
   return retval;
}
```

```
/******************************************************************************
 * FUNCTION:  DeleteQeue - return an item from the queue
 * ARGUMENTS: item will hold item popped from queue
 *                  queue_ptr is pointer to the queue
 * RETURNS:      returns 0 if queue is empty. 1 if successful
 *****************************************************************************/
int DeleteQueue(char *item, QUEUE_TYPE *queue_ptr)
{
   int retval = 0;
   if(queue_ptr->count <= 0)
   {
      retval = 0; /* queue is empty */
   }
   else
   {
      queue_ptr -> count--;
      *item = queue_ptr->entry(queue_ptr->front);
      queue_ptr->front = (queue_ptr->front+1) % MAXQUEUE;
      retval=1;
   }
   return retval;
}

/******************************************************************************
 * FUNCTION:  peekByte returns 1 byte from buffer without popping
 * ARGUMENTS: queue_ptr is pointer to the queue to return byte from
 *                  index is offset into buffer to which byte to return
 * RETURNS:      1 byte
 * REMARKS:      does not do boundary checking. please do this first
 *****************************************************************************/
char peekByte(QUEUE_TYPE *queue_ptr, unsigned int index) {
   char byte;
   int firstIndex;

   firstIndex = (queue_ptr->front + index) % MAXQUEUE;

   byte = queue_ptr->entry(firstIndex);
   return byte;
}


/******************************************************************************
 * FUNCTION:  peekWord returns 2-byte word from buffer without popping
 * ARGUMENTS: queue_ptr is pointer to the queue to return word from
 *                  index is offset into buffer to which word to return
 * RETURNS:      2-byte word
 * REMARKS:      does not do boundary checking. please do this first
 *****************************************************************************/
unsigned short peekWord(QUEUE_TYPE *queue_ptr, unsigned int index) {
   unsigned short word, firstIndex, secondIndex;

   firstIndex = (queue_ptr->front + index) % MAXQUEUE;
```

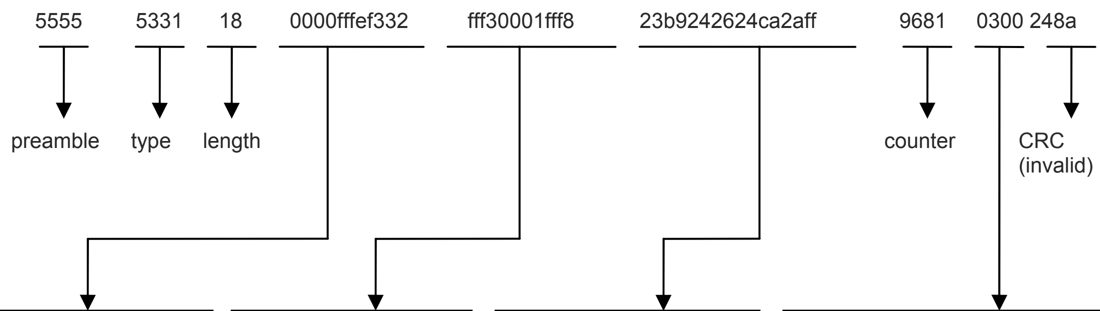
```
   secondIndex = (queue_ptr->front + index + 1) % MAXQUEUE;
   word = (queue_ptr->entry(firstIndex) << 8) & 0xFF00;
   word |= (0x00FF & queue_ptr->entry(secondIndex));
   return word;
}

/*******************************************************************************
 * FUNCTION:  Pop - discard item(s) from queue
 * ARGUMENTS: queue_ptr is pointer to the queue
 *                  numToPop is number of items to discard
 * RETURNS:     return the number of items discarded
 *******************************************************************************/
int Pop(QUEUE_TYPE *queue_ptr, int numToPop)
{
   int i=0;
   char tempchar;
   for(i=0; i<numToPop; i++)
   {
      if(!DeleteQueue(&tempchar, queue_ptr))
      {
         break;
      }
   }
   return i;
}
/*******************************************************************************
 * FUNCTION:  Size
 * ARGUMENTS: queue_ptr is pointer to the queue
 * RETURNS:     return the number of items in the queue
 *******************************************************************************/
int Size(QUEUE_TYPE *queue_ptr)
{
   return queue_ptr->count;
}

/*******************************************************************************
 * FUNCTION:  Empty
 * ARGUMENTS: queue_ptr is pointer to the queue
 * RETURNS:     return 1 if empty, 0 if not
 *******************************************************************************/
int Empty(QUEUE_TYPE *queue_ptr)
{
   return queue_ptr->count <= 0;
}
/*******************************************************************************
 * FUNCTION:  Full
 * ARGUMENTS: queue_ptr is pointer to the queue
 * RETURNS:     return 1 if full, 0 if not full
 *******************************************************************************/
int Full(QUEUE_TYPE *queue_ptr)
{
   return queue_ptr->count >= MAXQUEUE;
}
```

Appendix C. Sample Packet Decoding

Example payload from Scaled Sensor 1 data packet (S1)



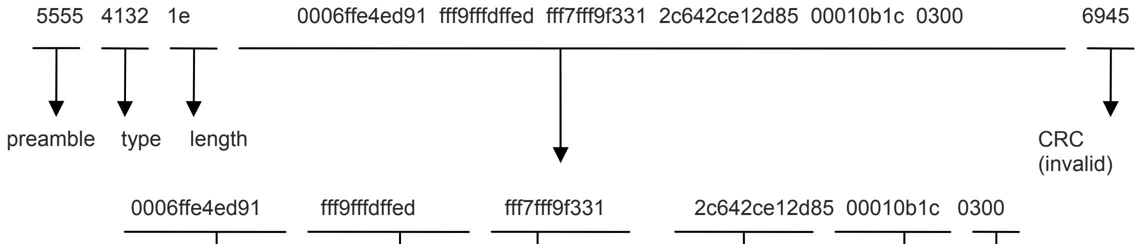
Accelerometers	
Hex Data	Value (g)
0000	0
FFFE	-0.001
F332	-1

Angular Rates	
Hex Data	Value (deg/s)
FFF3	-0.25
0001	0.02
FFF8	-0.15

Temperature	
Hex Data	Value (deg. C)
23B9	28.241
2426	28.741
24CA	33.591
2AFF	38.968

BIT status Field	
Field	Value
masterFail	0
hardwareError	0
comError	0
softwareError	0
reserved	0000
masterStatus	1
hardwareStatus	1
comStatus	0
softwareStatus	0
sensorStatus	0
reserved	000

Example payload from Angle Data Packet 2 (A2)



Angles

Hex Data	Value (deg)
0006 (roll)	0.033
FFE4 (pitch)	-0.154
ED91 (yaw)	-25.922

Accelerometers

Hex Data	Value (g)
FFF7 (x)	-0.0027
FFF9 (y)	-0.0021
F331 (z)	-1.0007

timeITOW

Hex Data	Value (s)
00010b1c	68380

Angular Rates

Hex Data	Value (deg/s)
FFF9 (roll)	-0.13
FFFD (pitch)	-0.06
FFED (yaw)	-0.37

Temperature

Hex Data	Value (deg. C)
2C64	34.680
2CE1	35.062
2D85	35.562

BIT status Field

Field	Value
masterFail	0
hardwareError	0
comError	0
softwareError	0
reserved	0000
masterStatus	1
hardwareStatus	1
comStatus	0
softwareStatus	0
sensorStatus	0
reserved	000

Example payload from Nav Data Packet 1 (N1)

5555 4e31 2a 001bffdf3a5bfffe0000ffe . . . fff8fff70000002d1900288a3e0300 a3ad

preamble | type | length | CRC (invalid)

001bffdf3a5b | fffe0000ffea | fff8fff7f337 | 0015fda9fd4f | 00000000000000000000 | 2d19 | 00288a3e | 0300

Angles	
Hex Data	Value (deg)
001b	0.148
FFFD	-0.181
3A5B	82.062

Accelerometers	
Hex Data	Value (g)
FFF8	-0.0024
FFF7	-0.0027
F337	-0.9988

Temperature	
Hex Data	Value (deg. C)
2D19	35.233

timeITOW	
Hex Data	Value (s)
00288a3e	2656830

Velocity	
Hex Data	Value (m/s)
0015	0.164
FDA9	-4.680
FD4F	-5.383

Angular Rates	
Hex Data	Value (deg/s)
FFFE	-0.04
0000	0.00
FFEA	-0.42

GPS	
Hex Data	Value
00000000	0.000000000 Rad
00000000	0.000000000 Rad
0000	0.0 m

BIT status Field	
Field	Value
masterFail	0
hardwareError	0
comError	0
softwareError	0
reserved	0000
masterStatus	1
hardwareStatus	1
comStatus	0
softwareStatus	0
sensorStatus	0
reserved	000

Appendix D. Mechanical Specifications

J1 Connector Interface

J1 is a 37 pin circular connector. Recommended plug and backshell to interface to J2:

- D38999/26FD35SN: *Circular mil-spec connectors, straight plug, 37 pin, size 15; AERO ELECTRIC*

Specifications

Environment

Operating Temperature -40° to +71°C

Enclosure IP66 compliant

Electrical

Input Voltage 9 to 32 VDC

Power Consumption < 4 W

Digital Interface 10/100 Ethernet or RS-422

Physical

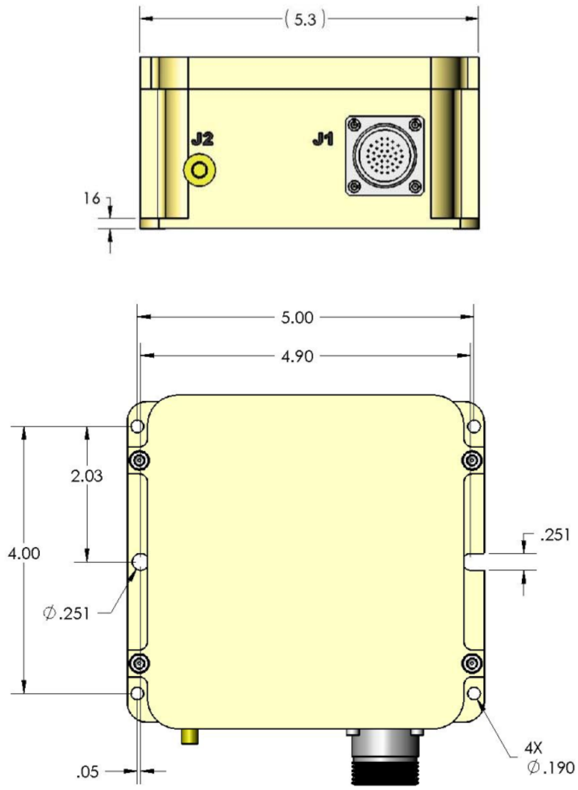
Size 5.3"w x 4.8"l x 2.7"h

Weight 2.7 lbs (1.2 kg)

Interface Connector Mil-C-38999, 37

Mechanical Drawings

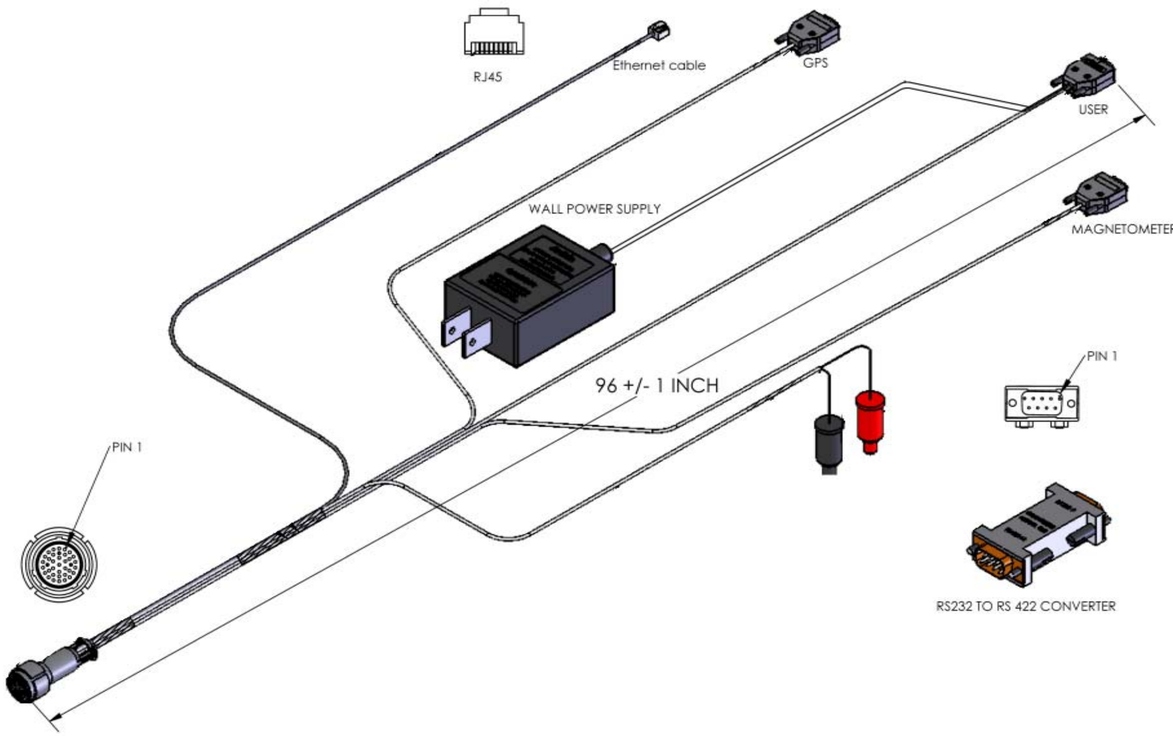
Figure 30 GNAV540 Casing



Interface Cable—Accessory

NOTE: This cable is provided when the GNAV540 is purchased with the developer's kit.

Figure 31 Interface Cable—Accessory



NOTE: The ON/OFF switch on the MAGNETOMETER port is normally switched OFF. It is only switched ON for upgrading firmware.

Appendix E. Crossbow Service Policies

Customer Service

Moog customers have access to product support services:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide Crossbow representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

Warranty

The Crossbow product warranty is one year from the date of shipment.

Returning Equipment

Before returning any equipment, please contact Crossbow to obtain a Returned Material Authorization number (RMA).

Provide the following information when requesting a RMA:

Contact Point

- Company
- Address
- Contact name
- Telephone, Fax, Email

Product Details

- Equipment Model Number
- Equipment Serial Number
- Installation Date
- Failure Date
- Description of Failure
- Does the device connect to NAV-VIEW 2.2

Packing Item for Return

If the equipment is to be shipped to Crossbow for service or repair:

- In all correspondence, refer to the equipment by the model number, the serial number, and the RMA number.

- Attach a tag to the equipment, as well as the shipping container(s): on the tab, include the RAM and the owner.
- Include a description of the service or repair required, a description of the problems with the unit, and the conditions that the problems occurred, such what function was being used.
- Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.
- On each side of the container, clearly label the container with "FRAGILE – HANDLE WITH CARE".
- Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

Return Address

Use the following address for all returned products:

Moog, Inc.
1421 McCarthy Blvd.
Milpitas, CA 95035
Attn: RMA Number (XXXXXX)

Source Code License

For qualified commercial OEM users, a source code license of NAV-VIEW 2.2 can be made available under certain conditions. Please contact your Moog representative for more information.

Contact Information

United States	Phone:	1-408-965-3300 (8 AM to 5 PM PST)
	Fax:	1-408-324-4840 (24 hours)
	Email:	techsupport@moog-crossbow.com
Outside of the United States	Visit website	www.moog-crossbow.com

Appendix F. Revision History

Table 100 Document Revision History

Revision	Date	Contributor(s)	Comments
A	26 May 2011	S. McGuigan R. Ayeras	First release
B	25 Sept 2011	J. Zhang S. McGuigan R. Ayeras A. Malerich	Add information about USER_PORT_SEL_CONN (p. 35, 46) Update logo and business name Technical corrections, per ECO 2023

Moog, Inc.
Navigation, Guidance and Sensors
1421 McCarthy Blvd.
Milpitas, CA 95035
Phone: 408.965.3300
Fax: 408.324.4840
Email: info@moog-crossbow.com
Website: www.moog-crossbow.com