STAR NAV MODULE

DESIGN DOCUMENT

INTERMAP

DOC-1013
Version 2.00
June 8, 20066

DOCUMENT HISTORY

Version	Date	Comment/Description of Change	Author(s)
1.00	May 12, 2003	First Draft Release	TRM, WRT
1.02	December 4, 2003	Added IMU Alignment and Selftest design	TRM
1.10	October 19, 2004	Update to final version	ML, TRM
2.00	June 01, 2006	Updating of design doc with respect to new STAR4 module developments (05535)	PG, ML

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose

This document describes the design of the STAR navigation module as part of the STAR core technology. The STAR core technology provides the basic subsystems required for an interferometric radar system.

1.2 Scope

This document first provides a functional description and the design requirements. It then describes the detailed design in terms of hardware, software, and mechanics. Finally the theory of operation, test procedures, and calibration is included.

The document assumes that the reader has a basic understanding of interferometric radar systems, airborne remote sensing platforms, Intermap products and processes and computer systems technology.

1.3 Definitions, Acronyms, and Abbreviations

MTTR .....Mean Time To Repair
LRU.....Line Replaceable Units
TCP/IP.....Network Communication protocol
MCC.....Master Control Computer
ANT .....Antenna Module
RCVEX-RCAS .....Receiver Exciter – Radar Control and Acquisition System Module
PWRDIST .....Power Distribution Module
NAV .....Navigation Module
WGASS-XTRANS .....Wave Guide Assembly – X-Band Transmitter

1.4 References

1. DOC1000 – STAR SRS
2. DOC1002 – STAR System ICD
3. DOC1008 – STAR Physical ICD

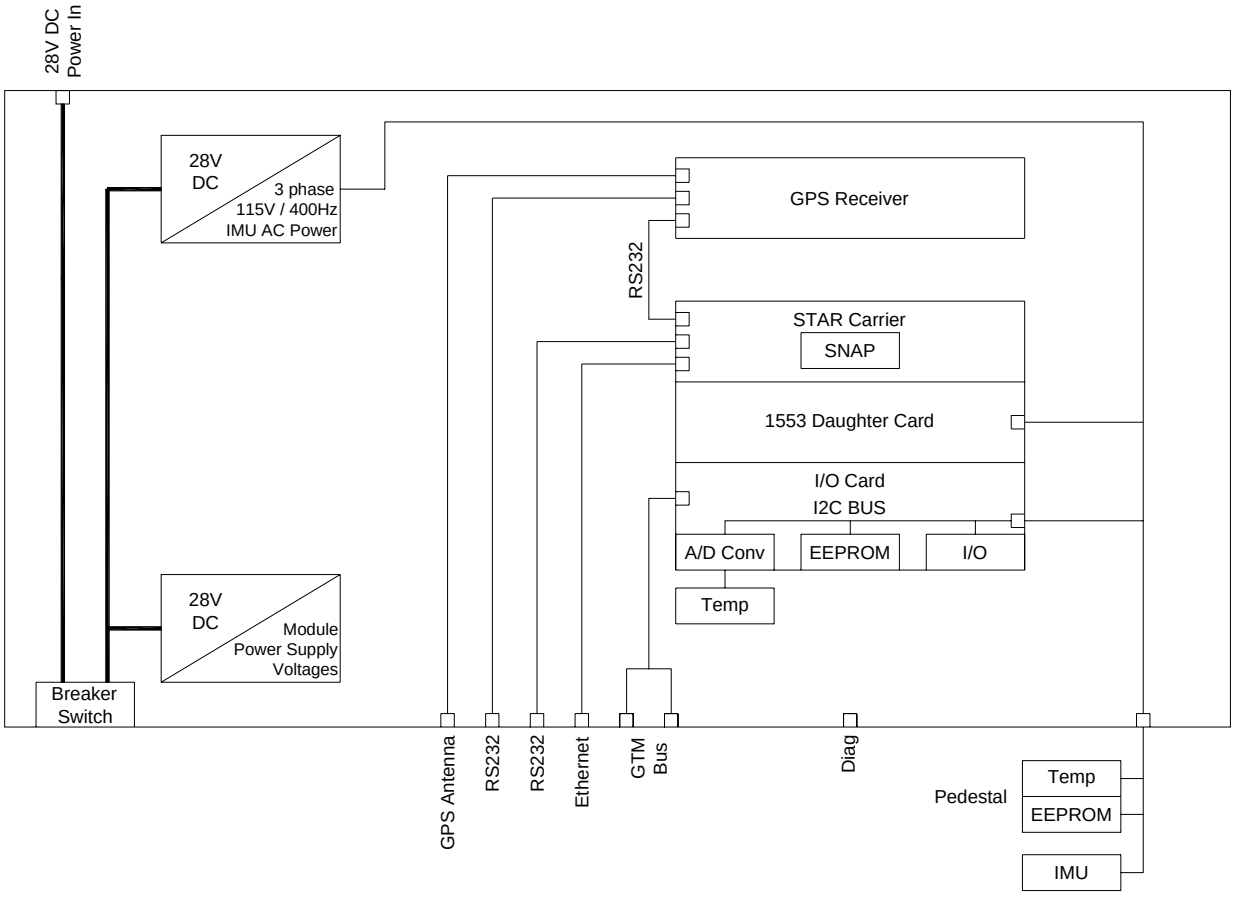
2 FUNCTIONAL DESCRIPTION

The STAR NAV Module provides an interface to the IMU and GPS. The module provides GPS time and navigation information to the STAR System.

The Module contains a Ashtech GPS receiver Z-Eurocard which is connected to the aircraft GPS Antenna and communicates with the SNAP microcontroller via an RS232 link. Additionally, the NAV module will provide a 1553 communication interface and power for a Honeywell H770 IMU.

The NAV module receives commands over the Ethernet and translates them to the navigation peripherals. The NAV module retrieves current IMU and GPS raw data and makes it available on the Ethernet. Additionally the NAV module parses out current GPS and IMU information and sends it out in a comprehensive navigation status packet. All data sent from the module will be time stamped with GPS time.

2.1 Functional Blockdiagram



3 HARDWARE DESIGN

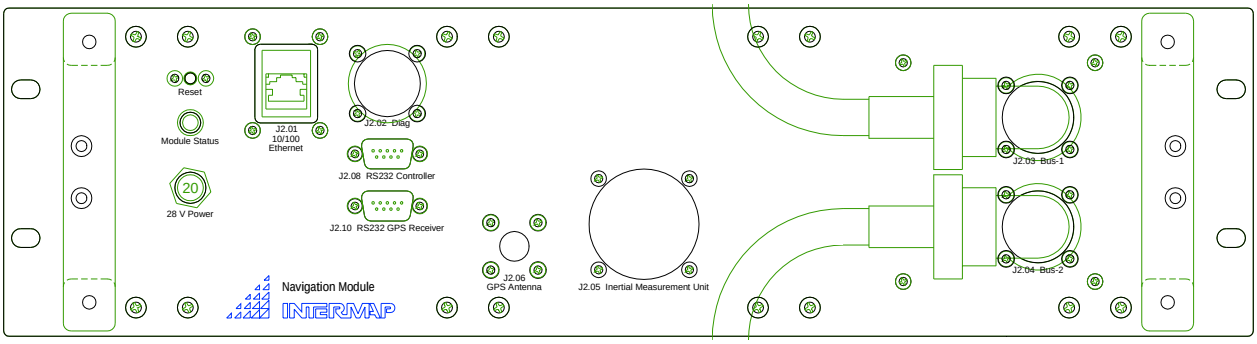
3.1 Dimensions

Height: 118 mm
Depth: 550 mm
Width: 440 mm

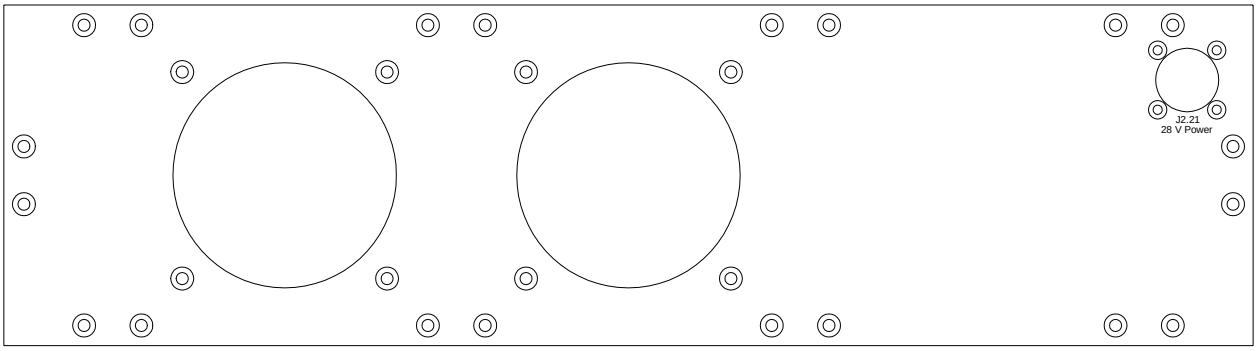
For dimension details see: DOC1008 - STAR System Physical ICD.doc

For weigths see: DOC1008 - STAR System Physical ICD.doc

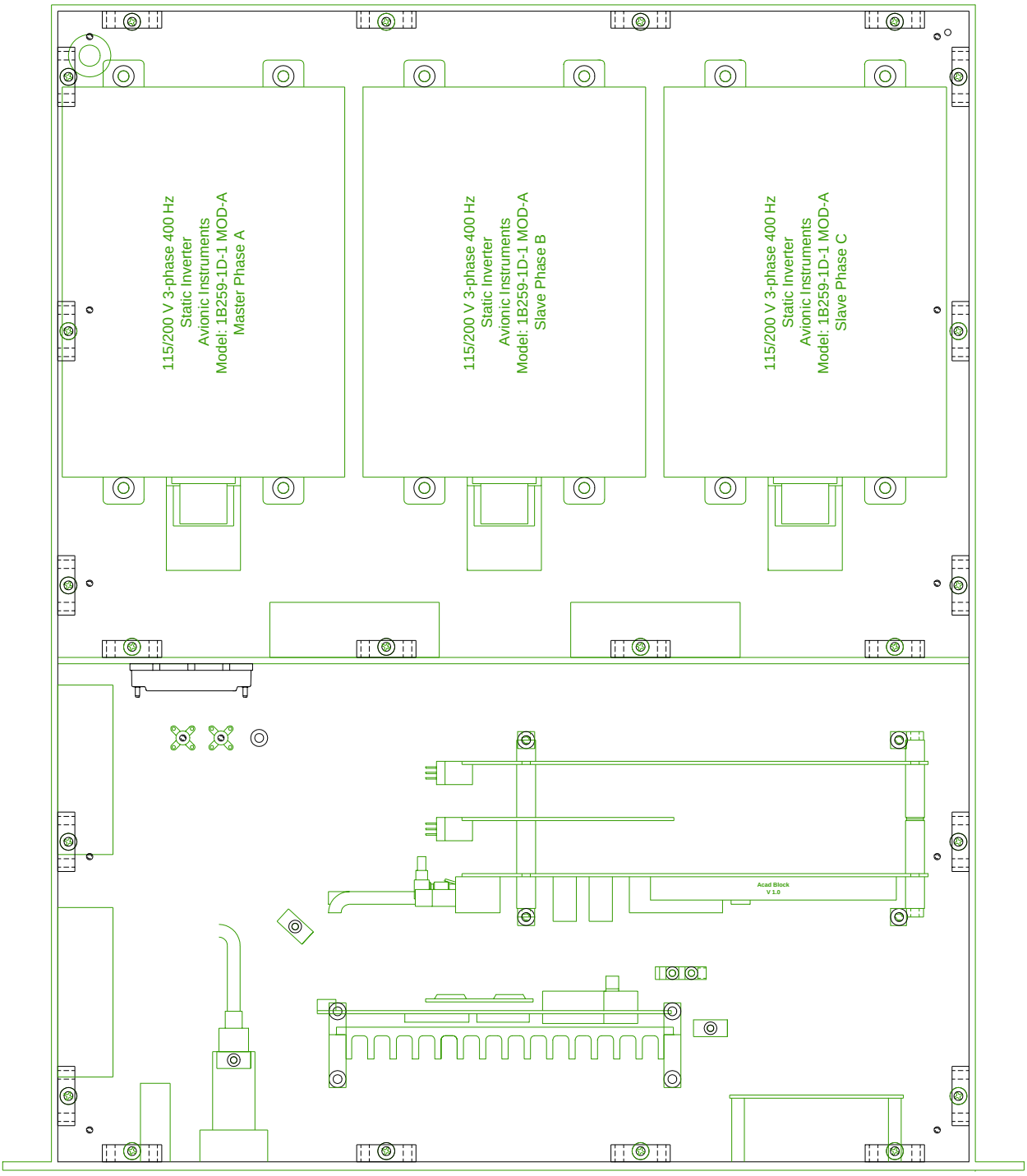
3.2 Front Panel Layout



3.3 Rear Panel Layout

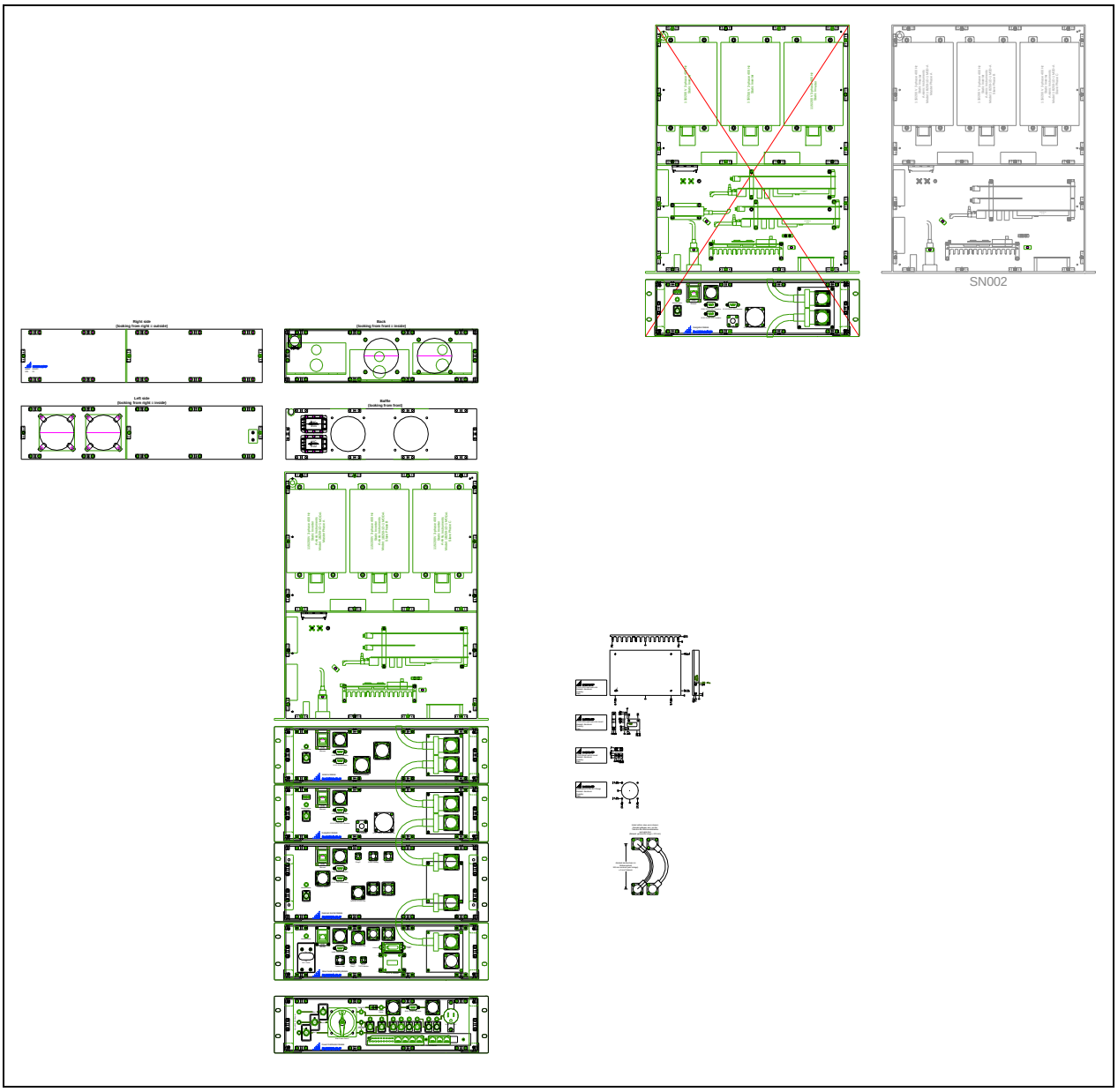


3.4 Chassis Layout

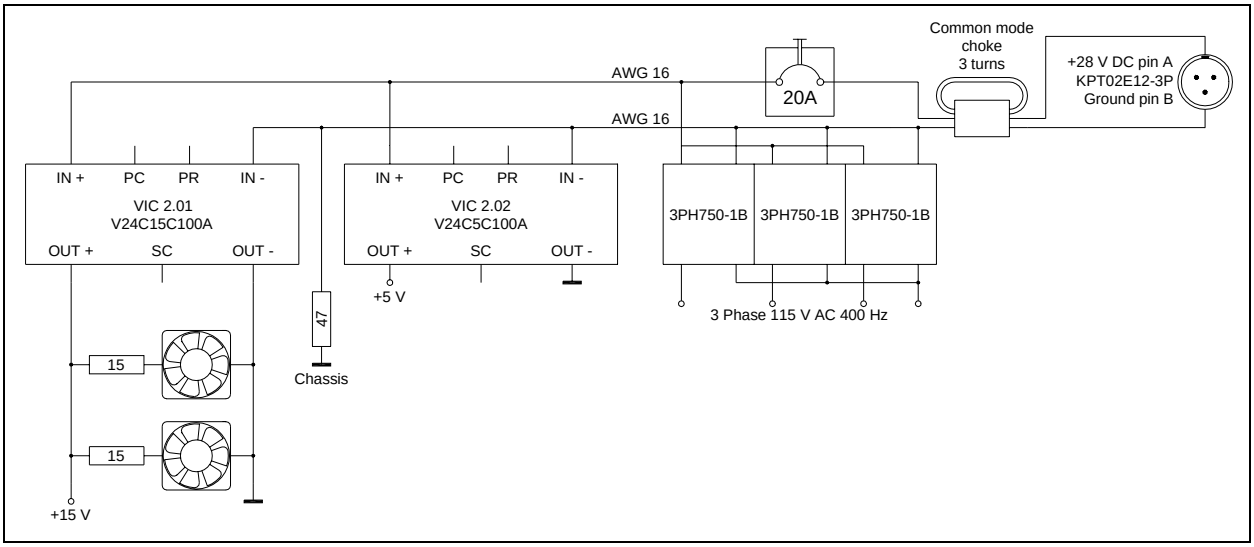


3.5 NAV Reference Drawing

The embedded AutoCad file below (STAR-NAV.DWG) is the primary reference file for the power distribution module.



3.6 Power Supply



3.7 Connectors

All power supply connectors:	DOC1008 - STAR System Physical ICD.doc
RS232 and Ethernet connector:	DOC1008 - STAR System Physical ICD.doc
All MIL connectors:	Connectors-MIL.XLS
All header connectors:	Connectors-headers.XLS

3.8 IO-Card

Parts list for assembly:	IO-Card-parts-list.xls
Schematics:	IO-CARD-Schematics.pdf
Board layout:	IO-CARD-Board-Layout.pdf

3.9 STAR-Bus

Schematics:	STAR-Bus-Schematics.pdf

3.10 IMU Interface Box

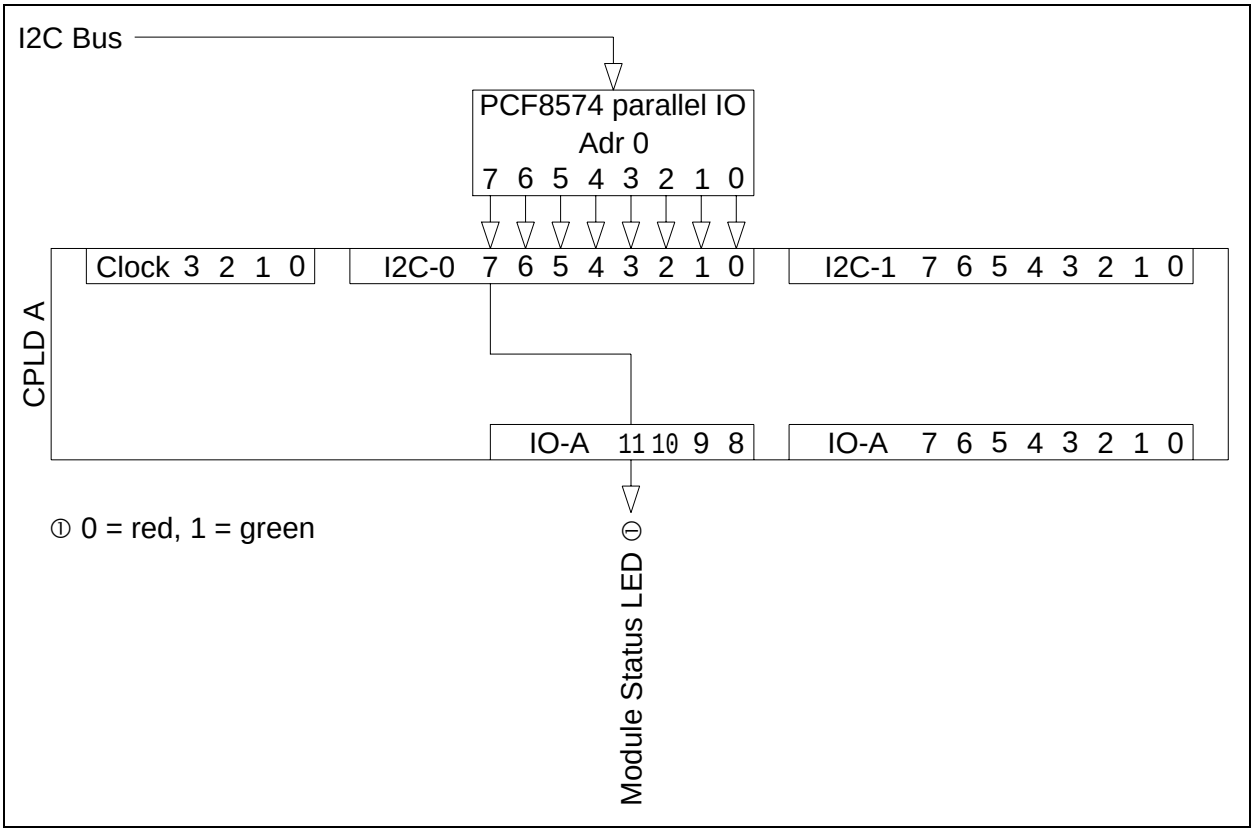
Schematics:	IMU-Interface-Box-Schematics.pdf
Wiring:	IMU-Interface-Box-Wiring.pdf

Sensor assignment: temperature sensor 1: IMU (location undefined)
temperature sensor 2: IMU (location undefined)
temperature sensor 3: IMU (location undefined)
temperature sensor 4: IMU (location undefined)
humidity sensor 1: IMU (location undefined)
humidity sensor 2: IMU (location undefined)

3.11 1553 Interface Board

Schematics: 1553-Interface-Board-Schematics.pdf
Board layout: 1553-Interface-Board-Layout.pdf

3.12 CPLD and I2C Schematic



4 SOFTWARE DESIGN

This section outlines some of the design decisions made specifically of the NAV module. For details please refer to the JavaDocs.

4.1 SelfTest

1. Start of self test:
2. Test SNAP / FPGA Communication – retrieve version number from FPGA. Verify that 0xff is not read.
3. Switch to internal clock.
4. Test I^2C Parallel I/O - toggle LED for ¼ second.
5. Test I^2C A/D – read module temperature. Verify within [-30,+100].
6. Test I^2C EEPROM – read and write last two bytes in EEPROM.
7. Test IRQ, enable interrupts and wait for 1PPS.
8. Open serial port to GPS. Configure GPS port settings. Send a 'Request RID' command and wait for the appropriate response.
9. Test I^2C Parallel I/O - toggle LED for ¼ second.
10. End of self test

4.2 GPS Serial Communication

The Ashtech serial data, has a transmit delay of 9ms from the PPS.

4.3 IMU Communication

The following commands are sent to the IMU:

50Hz Data

ICD Requirement	M-STD 1553 Command
Request Sub Address 1	0x2C36
Request Sub Address 2	0x2C54
Request Sub Address 3	0x2C74
Request Sub Address 4	0x2C94
Request Sub Address 5	0x2CB4
Request Sub Address 6	0x2CF4

Request Sub Address 7	0x2CF4
Request Sub Address 8	0x2D14
Request Sub Address 9	0x2D14
Request Sub Address 10	0x2D5F
Request Sub Address 11	0x2D7D
Request Sub Address 16	0x2E00
Request Sub Address 29	0x2FBD

1Hz Data

ICD Requirement	**M-STD 1553 Command**
Request Sub Address 12	0x2D9E
Request Sub Address 13	0x2DA0
Request Sub Address 19	0x2E60
Request Sub Address 23	0x2EE0
Request Sub Address 27	0x2F7A
Request Sub Address 28	0x2F9C
Request Sub Address 24	0x2F0E
Additional…..	

All Alignment / update commands will be appended to the 1Hz data. Thus the *IMUAdapter* consists of a realtime statemachine which is clocked to the PPS interrupt.

Sub Address 24 contains the Alignment quality (see the ICD). The quality is always zero on power up and after alignment. This value is monitored during alignment.

4.3.1 Alignment

The Alignment consists of two commands

Baro-Altitude Command (SA04):

1) Orientation of the IMU
2) Mode of the IMU (Nav, Align, Off, etc…)
3) Update of alititude.

Position Update Command (SA02)

1) Updates Position, Latitude and Longitude, of the IMU.

Example,

Command	**M-1553-Command**
Transmit Data Sub Address 04	**0x2883**
- Data 1: Set Mode to Align (0x0060) + Orientation (ex, 0x0680) + Alt valid (0x8000)	0x86C0
- Data 2: Altitude	(altitude (ft) /2 – 32768)
- Data 3: Simulation Mode	0x0000
Transmit Data Sub Address 02	**0x2844**
- Lat (Lat (degrees) x * 683302675.3)	Upper word
	Lower word
- Lon (Lon (degrees) x * 683302675.3)	Upper word
	Lower word

Table 1 - NAV Module Error flag source list

Condition	**Source**	**Error flags**
Cannot read the full command packet, or sync field is not accurate.	CommandServer	Command, Network
Cannot send a command response packet.	CommandServer	Command, Network
Cannot register External Interrupts	SnapIRQAdapter	Firmware
Illegal Address Exception (while servicing ISR)	SnapIRQAdapter	FPGA, Firmware
Error Sending Status	StatusServer	Network, Status
Illegal Address Exception (while Collecting Status)	StatusServer	FPGA, Firmware, Status
Cannot create UDP objects / Data gram	StatusServer	Firmware, Status

5 DIAGNOSTIC UTILITY

The diagnostic utility allows monitoring and control of all functions of the module.

5.1.1 Interface

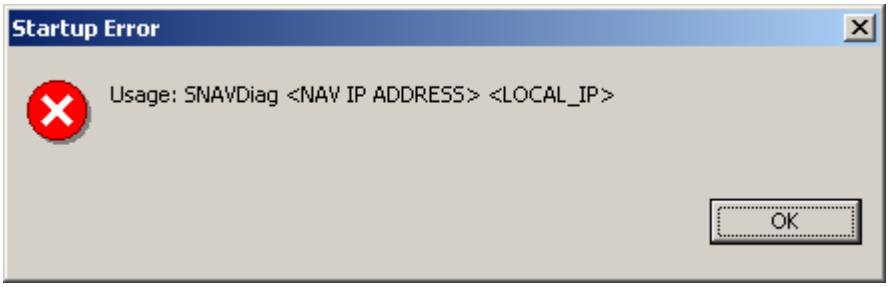
Usage:

```
NAVDiag <RCAS IP ADDRESS> <LOCAL IP ADDRESS>
```

Example,

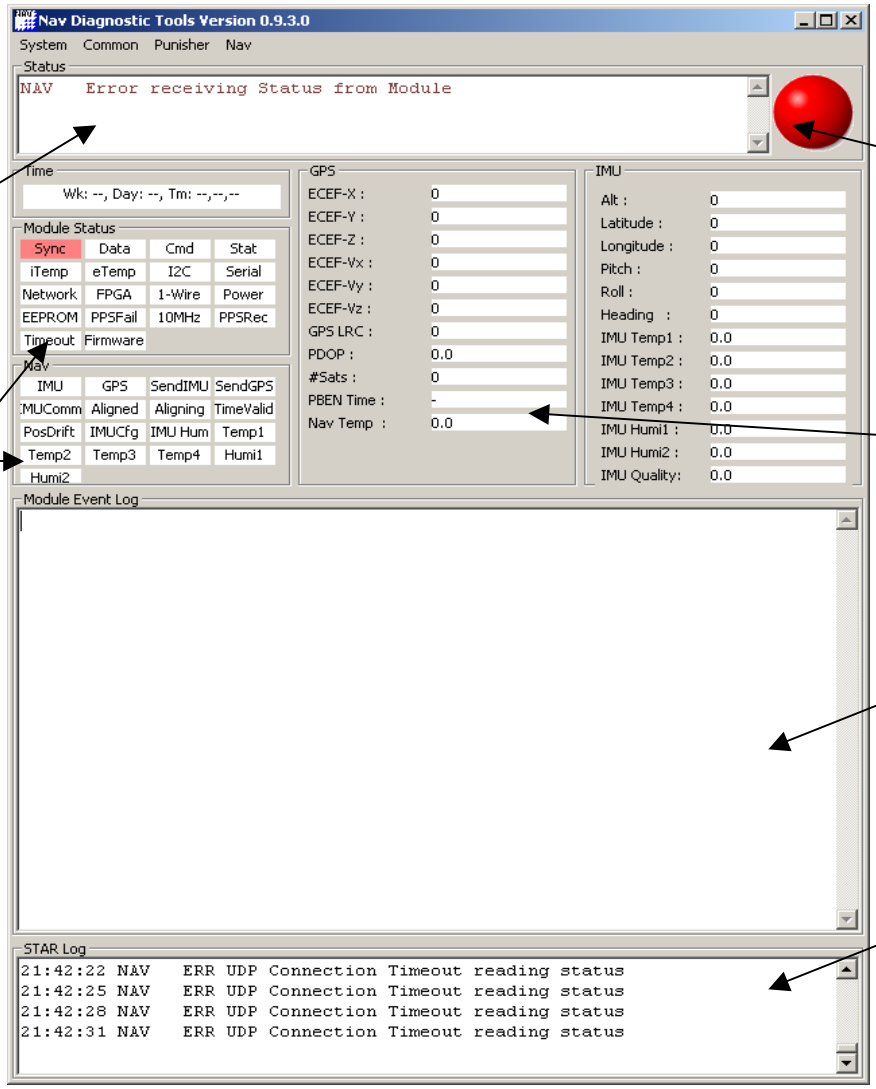
```
NAVDiag 192.168.0.45 192.168.0.3
```

If one or more arguments are missing, the following message is displayed.



Command Menu Bar: Allows you to issue commands to the module

Status Bit indicators: Shows status bits graphically



Fault Indicator: Indicates if there is a module fault, along with description

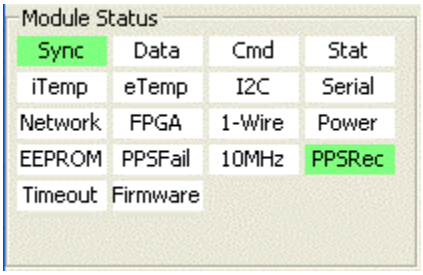
Status Value: Displays all status packet values in a GUI

Module Event Log: Displays log messages from the module

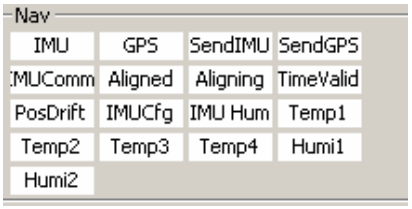
STAR Log: Displays log messages from this Diagnostic application

5.1.2 Status Values

The status bits represent all Boolean values, and the common and module status bits as outlined in the software ICD.



Green : Time is Synchronized: Red: Time is not synchronized	Red: Raw Data Stream Error: An error sending or creating the raw data stream	Red: Command Interface Error: Indicates an error occurred while processing a command	Red: Status Steam Interface Error
Red: Internal temperature probe exceeds tolerance or malfunctioning	Red: External temperature probe exceeds tolerance or malfunctioning	Red: I2C bus error: Error communicating over I2C bus (internal or external bus)	Red: Serial Port error: Error communicating to device, or bad data over serial
Red: Error reading or writing over network. This includes both UDP and TCP/IP.	Red: Error detected on FPGA: No interrupt when expected, 1-wire device detected error, etc.	Red: 1-Wire bus error: Error communicating over 1-Wire bus. Maybe a bad address, bad device, or bad bus.	Red: Power Supply error: A power supply error was detected.
Red: Error reading, or invalid values in 1 or more EEPROM	Red: Error PPS Failure: Due to no PPS, or a bad PPS signal.	Red: 10MHz clock failure: No 10MHz clock source, or a bad 10MHz clock source.	Green: Indicates that this status record is a PPS record (and sent on the PPS)
Red: Timeout Error: Indicates a timeout occurred on a command or other event.	Red: Firmware Error: Generic error used to describe all other error conditions.		



IMU: Red indicates there is an IMU error	GPS: Red indicates a GPS error	SendIMU: Green indicates IMU data is being sent	SendGPS: Green indicates GPS data is being sent
IMUComm: Red indicates there is an problem communicating to the IMU	Aligned: Green indicates the IMU is Aligned	Aligning: Green indicates IMU is Aligning	TimeValid: Green indicates that the GPSTime being broadcast is validated and accurate
PosDrift: Red indicates that the position difference between IMU and GPS exceeds tolerance	IMUCfg: Red indicates there is an IMU configuration error	IMU Hum: Red indicates there is an error reading, or an invalid humidity reading.	Temp1: Red indicates there is an error reading, or an invalid IMU temperature probe 1 reading.
Temp2: Red indicates there is an error reading, or an invalid IMU temperature probe 1 reading	Temp3: Red indicates there is an error reading, or an invalid IMU temperature probe 1 reading	Temp4: Red indicates there is an error reading, or an invalid IMU temperature probe 1 reading	Humi1: Red indicates there is an error reading, or an invalid IMU Humidity probe 1 reading.
Humi2: Red indicates there is an error reading, or an invalid IMU Humidity probe 2 reading			

The status values reflect all the non-Boolean values contained in the status packet. For specific details see the Software ICD, otherwise refer to the following summary table.

Name	Description
GPS	
ECEF-X	GPS Position ECEF-X
ECEF-Y	GPS Position ECEF-Y
ECEF-Z	GPS Position ECEF-Z
ECEF-Vx	GPS Velocity ECEF-X
ECEF-Vy	GPS Velocity ECEF-Y
ECEF-Vz	GPS Velocity ECEF-Z
GPS LRC	GPS Lost Record Count
PDOP	Current PDOP value
# Sats	Number of satellites being tracked
PBEN Time	Last PBEN record time
Nav Temp	Nav module temperature
IMU	
Alt	Current Altitude from IMU
Latitude	Current Latitude from IMU
Longitude	Current Longitude from IMU
Pitch	Current IMU pitch (degrees, positive nose up)
Roll	Current IMU roll (degrees positive right wing up)
Heading	Current IMU heading (degrees, 0 = North)
IMU Temp1	IMU temperature 1
IMU Temp2	IMU temperature 1
IMU Temp3	IMU temperature 1
IMU Temp4	IMU temperature 1
IMU Humi1	IMU humidity 1
IMU Humi2	IMU humidity 2
IMU Quality	IMU Alignment Quality

5.2 Operation

5.2.1 Passive Mode

The Diagnostic tool automatically starts in ‘Passive’ mode when executed. This mode passively listens to the UDP status packets and event logs for the particular module. When a log message is received it is appended to the Module Event Log display on the GUI. When a new status packet is received, the values are all updated.

Since the status packets are sent over UDP, multiple diagnostic programs can be executed in passive mode at the same time and will not interfere with each other or the MCC. This has the advantage of allowing external monitoring of the system during normal operation.

5.2.2 Active Mode

Active Mode is when the diagnostic utility has direct control of the module via the command connection. Active mode can be activated / de-activated by the following system functions:

Name	Description
Start Connections	Start active connections (command / raw data) to the module. (Get control of module)
Stop Connections	Stop the active connections (command / raw data) to the module. (Release control of module)

Note: The module only allows 1 connection at any one time. Thus the Diagnostic tool will not be able to connect to the module if another application (like the MCC) already has command control.

5.3 Sending Commands

Once an Active connection is established, you can send commands to the module through the menu, the commands are divided according to their functionality:

5.3.1 Common

Common commands are consist of options and commands that are common to all modules; therefore this menu is present in all module diagnostic tools. The Common Commands are as follows:

Name	Description
Sync Time	Synchronizes the modules time to the local computer system time

Internal ROM	Allows the reading and writing of the internal module configuration EPPROM
Set Status Rate	Sets the status rate of the UDP broadcasts (in Hz)
Self Test	Instructs the module to restart the software. Once restarted, it performs the usual self test.
Init	Instructs the module to restart (re-init). The selftest is not performed. This is typically used after a new configuration ROM is written and to restart.

5.3.2 Punisher

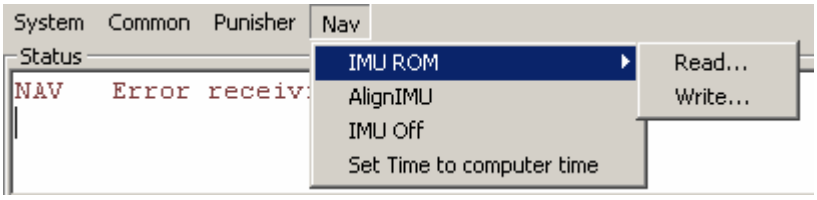
The Punisher section includes commands to 'punish' the NAV hardware / software for stress testing of the system. These operations are normally not used, and only used in development.

Name	Description
Punish…	Initiates a generic punish test

Right click to reset to original zoom.

5.3.3 NAV

The NAV section deals with commands to the NAV module as directly defined in the software ICD.



Name	Description
IMU ROM – Read	Reads IMU config attached to the module
IMU ROM – Write	Writes the IMU config attached to the module
AlignIMU	Initiates an alignment of the IMU.
IMU Off	Turns the IMU off
Set Time to Computer Time	Synchronizes the NAV time to the time on the local PC. This is useful when there is no or poor GPS reception

5.4 Configuration changes

Configuration ROMs can only be loaded using the diagnostic tools in Active Mode (refer to the above). The following procedure is followed:

1) Obtain the new configuration file(s)
2) Load the configuration file(s).

   The NAV module has two EEPROMs:

   - Module ROM – located in the module (Common->InternalRom->Write..)
   - IMUROM – located on the IMU I/F box (NAV->IMU ROM->Write..)

3) If the configuration file does not have a proper CRC stamp it is immediately rejected by the Diagnostic Utility.
4) Once the config file has been downloaded it is verified by the module. If the config file is for a different module, or has the incorrect section ID, it is rejected and an error message is displayed.
5) If the config is valid, it will be loaded. After a few seconds a 'Configuration ROM Updated' log message will appear.
6) Verify that the config file is loaded:
   a. Issuing an 'init' command (Common->Init).
   b. During the startup, check that the 'Config Date:' is the date of the new configuration file:

      i.e.

      ```
      Reading Configuration ROM from EEPROM
      Validating Configuration ROM
      ConfigRom Valid.   Config Date: 20040716
      ```

   c. Check for any error messages that are the result of bad configuration settings.

      i.e.

      ```
      ConfigRom inValid
      ```

For detailed description of the configuration files and parameters, see the System ICD.

6 INITIAL DESIGN REQUIREMENTS

6.1 GPS Interface

6.1.1 GPS Receiver

The NAV module will include an Ashtech GPS receiver with a minimum of two serial ports. The receiver must be able to produce GPS positioning and GPS Time information at a minimum data rate of 1Hz.

6.1.2 1 PPS

The GPS Receiver must generate a TTL level 1 PPS clock signal to be distributed to the STAR Bus.

6.1.3 External GPS serial

The NAV module will contain a RS232 serial port on the front panel, with direct access to a GPS receiver serial port.

6.2 IMU Interface

6.2.1 IMU Power

1. The NAV module will contain the 400Hz power supply for the H770 Inertial Measurement Unit (IMU) as well as any power up timing sequence signals required.

6.2.2 IMU Interface

1. The NAV modules will contain a communication interface and required protocol for communication to the IMU.
2. The NAV module must receive the 1200Hz and 50Hz clock input from the IMU.

6.3 STAR Software Interface

The embedded software will provide a complete IMU and GPS raw data stream. The NAV module will also provide a software command interface and a broadcasted Navigation status stream. This Status stream will include current module status, GPS Time, IMU position and attitude, and GPS position.

The NAV Status packet must be broadcast to all radar modules and the MCC at least 1 per second.

6.3.1 Inertial Data

The module must provide an inertial raw data stream over the Ethernet. The inertial data stream size and frequency varies depending on make and model of IMU. The inertial Data will be time tagged and sent the MCC.

6.3.2 GPS Data

The module must provide a GPS raw data stream over the Ethernet. The GPS data stream size and frequency varies depending on make and model of the GPS Receiver. The GPS Data will be time tagged and sent the MCC.

6.4 Fault Indicator

The red chassis fault light will illuminate under any of the following circumstances:

- The maximum temperature of the unit is exceeded.
- There is an error communicating to the GPS Receiver or IMU.
- The embedded software reports an error

6.5 Configuration / Calibration Tracking

The NAV module will contain the NAV configuration file (EEPROM) via the internal 1-wire data bus.

The NAV module will be connected to the IMU configuration file (EEPROM) via an external connection. The IMU ID will contain all IMU configuration information (lever arm, configuration, etc..). Refer to the STAR System ICD document