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Jupiter 20

Dead Reckoning Application note

This application note provides instructions on the installation and operation of the Navman Jupiter 20 DR (Dead Reckoning) system, which features the SiRFStarIIe/LP chipset and the SiRFDRive navigation software.

Related documents

- Jupiter 20 Product brief LA000509
- Jupiter 20 Data sheet LA000507
- Jupiter 20 Integrator's manual LA000508
- Jupiter 20 Development Kit guide LA000510
- Navman Binary Protocol reference manual MN000314
- Navman NMEA reference manual MN000315
- SiRFDemo and SiRFflash user guides
- Panasonic EWTS series Angular Rate Sensor Product Brief
- Fujitsu S1BG series Gyro Product Brief

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1.0 Dead Reckoning overview

Dead Reckoning (DR) navigation is a method of predicting the current position of a vehicle by starting with a known position and keeping track of changes in heading and velocity through time. The results can be very accurate if the means to observe velocity and heading are accurate and the precise position is entered into the system as an update. This is required because any slight error in DR will accumulate and compound itself over time.

For the purpose of this application, the precise position will be supplied by a GPS solution. GPS solutions alone are subject to errors introduced by a number of factors. Among these factors are clock errors, atmospheric effects, and obstacles on the ground, which may block or reflect the GPS signal.

Under ideal conditions a GPS solution can provide a position with an expected horizontal accuracy of < 5 metres. However in real-life situations, a vehicle will often experience less-than-ideal conditions resulting in the need for assistance to maintain this accuracy. This is especially true at times when the GPS signals are blocked. This assistance will come in the form of heading and velocity information enabling the overall system to predict its current position accurately. The source of the heading and velocity aiding will be provided by angular rate gyroscopes, and speed pulses (wheel ticks) generated by the rotation of the vehicle wheels used for such purposes as operating ABS brakes, digital speedometers or engine emissions controls. The vehicle (forward or reverse) direction is sensed by logic high or low on the GPIO15 (pin 27) connection.

These sources of navigation, (GPS plus heading and velocity aiding) together are referred to as 'combined navigation'.

2.0 Implementation

2.1 GPS & DR combined navigation

Typical GPS receivers provide outputs of position, time, and velocity using information obtained from GPS satellites. During periods of interference or satellite blockages, the GPS receiver must estimate the next update until the necessary signals can be tracked again. One way in which the GPS receiver can do this is by use of external DR sensors. These sensors provide heading and velocity information.

The integration of the GPS measurements and sensor information (combined navigation) is accomplished with the use of a Kalman filter. The Kalman filter is an estimator that can compute a smooth navigation solution during periods when the GPS measurements are interrupted. The GPS measurements are the primary determinants of the solution while the DR sensors are the secondary.

DR sensor information is combined with GPS measurement information and fed into the navigation processor containing the Kalman filter, producing position, velocity, time, and heading updates. The output of these updates are at a rate of 1 Hz (once per second).

2.2 Equipment required

The following equipment is required to perform GPS & DR navigation:

- Jupiter 20 DR Receiver Development kit (for details of equipment supplied with this kit, refer to the Jupiter 20 Development kit guide)
- acceptable angular rate gyro
- wheel tick/speed pulse input
- forward/reverse input (optional)
- IBM compatible PC with Windows ME or later
- 9-pin serial data cable
- acceptable GPS antenna

2.3 Software

The receiver must have SiRFDRive software installed, and the PC must have SiRFDemo installed.

3.0 Hardware description

The gyro signal (0–5 VDC) is fed into an internal ADC (Analogue to Digital Converter). The Jupiter 20 DR receiver uses the Linear Technology LTC1860L 12-bit ADC for this conversion and is interfaced via the SPI (three wire synchronous serial interface). The ADC operates on a 2.8 VDC (VCC_RF, i.e. pin 20) reference voltage.

The system uses GPIO15 for the forward/reverse input. This is normally low indicating a forward direction of travel. A logic high signal indicates a reverse direction of travel. If this input is not used, a pull-down resistor or short to ground is recommended to indicate forward direction of travel.

The wheel tick/speed pulse input connects to a counter internal to the Jupiter 20 (GPIO01, pin 28).

3.1 Gyro information

The standard gyro used is identical to that used in the historical Jupiter 12 DR systems (the Panasonic EWTS series of gyros). These gyros operate at 5 VDC and output a voltage from 0-5 VDC depending on angular velocity.

The Jupiter 20 DR receiver meets the following design specifications:

- A/D input range of 0-5 VDC
- at zero angular velocity (ω = 0 degrees/second) the null voltage output is 2.5 VDC
- scale factor (sensitivity S_v) of 25 mV/degrees/second
- CW (clockwise) rotation causes the output to increase
- CCW (counter clockwise) rotation causes the output to decrease
- gyro dynamic range (maximum angular velocity ω_{max}) of ±90 degrees/second
- linearity of ±0.5% maximum

Note: The gyro is sensitive to mounting alignment (placement relationship to vertical axis). It should be mounted vertically and securely. Any misalignment can cause turn-rate errors. An upside down installation will not function properly and will have a direct effect on calibration.

The Panasonic EWTS4 angular rate sensor included in historical Jupiter DR Development kits is now obsolete. The equivalent functional replacement is one-fifth the size and available as a leaded/through-hole (Panasonic EWTS82) or surface mount device (Panasonic EWTS84).

The Panasonic EWTS series angular rate sensor is highly recommended. The Fujitsu S1BG series gyro is a suitable ‘form, fit and functional’ alternative.

3.2 Wheel tick/speed pulse inputs

The SiRFDRive system will interpret the speed information over time to determine the distance travelled. The distance travelled is calculated by counting the number of wheel ticks and multiplying it by the number of metres per tick, which is determined during calibration. The Jupiter 20 has a 16-bit dedicated counter which is used to count the wheel tick. The wheel tick count is latched in the 100 ms interrupt (10 Hz), along with the ADC measurement and reverse state, to produce speed and heading information into the combined solution.

The specification of the wheel tick is:

- 3.3 VDC typical for the 'logic high'
- 0.7 VDC minimum for the 'logic low'
- 5.0 VDC maximum for the 'logic high' before damage will result to the receiver

The conditioning circuitry specified by the Jupiter 20 DR reference design (see Appendix A), may be required to step-down the wheel tick and forward/reverse inputs from automotive levels

(12 VDC) to meet the specifications above. The interface circuits should include some low pass filtering to avoid false triggering of the wheel tick due to electrical noise on the vehicle wiring. The filter characteristic should attenuate wheel tick pulses above 4 kHz.

The system is capable of operating properly up to a maximum wheel tick rate of 4 kHz and to a minimum of 1 Hz. For vehicles with 48 pulses per metre, the upper limit is equivalent to 300 km/h. For vehicles with 2 pulses per metre, the minimum limit equates to 1.8 km/h. Wheel ticks must be available whenever the vehicle moves and the minimum resolution must be at least 0.5 metres per pulse. Failure to output wheel ticks at low speeds will cause incorrect calibration and result in poor performance.

Note: Changes in conditions, such as road grade and variations in tyre size due to temperature, can have an effect on the accuracy of the wheel tick input.

4.0 System hardware interface and connections

4.1 Input power

The Jupiter 20 DR Development unit requires a 12 VDC power supply. For normal vehicle operation an automotive adapter is recommended (provided with the Development kit). Connect this adapter to the DC input on the rear of the Development unit. For any custom installation, ensure that 12 VDC is present from a power supply or battery. Polarity is centre conductor to negative, outer to positive.

4.2 Serial communication

Connect Serial port 1 (COM 1) on the Development unit to the serial port of a PC using the serial interface cable provided.

4.3 Connecting the DR sensors

The following guidelines must be taken into consideration when connecting the DR sensors:

- Gyro mounting should be vertical and securely fixed.
- After connecting the gyro, use SiRFDemo to check the connection. A nearly constant gyro heading rate value should be seen in the DR Data Block section of SiRFDRive View.
- Rotate the gyro to observe the heading rate value change.
- Clockwise rotation will generate a heading rate change in the positive direction while counter clockwise rotation will generate a heading rate change in the negative direction.
- Wheel tick should be connected to pin 5 of the DR interface connector on the rear of the Development unit.
- The wheel tick can be provided from the speed pulse connection to the speedometer. This connection can be shared by the vehicle radio in some cases.

Note: An optional connection is a 'reverse signal', which is an input signal allowing the DR system to know when the vehicle is reversing. The default is forward, a ground on the input is required if this input is not used.

- Logic High = Reverse
- Logic Low = Forward

4.4 Antenna mounting

The GPS antenna provided in the Development kit is a magnetic mount 3 VDC active antenna. To ensure proper operation of the GPS system, the following guidelines need to be taken into consideration:

1. Choose a mounting location that has a clear view of the sky. The optimum location is the roof of the test vehicle where a maximum view of the sky is possible.
3. An alternative mounting location is on top of the dashboard. The placement should be as close to the front and centre as possible. A location other than the dashboard (glove compartment, on top of the seat headrest, under seat) is **not** recommended and will create an obstructed view of the sky with uncontrolled signal attenuation.

4. Avoid mounting the antenna near electrical wires, other antennas, or potential sources of jamming or EMI (electromagnetic interference).
5. Connecting extra antenna cable length or operating multiple receivers on the same antenna could reduce C/No value of the received signals. At least four satellites with a C/No value of ≥45 dBHz is the recommended minimum.

5.0 Starting SiRFDemo

The SiRFDemo software is provided to simplify real-time monitoring, enable configuration and provide an efficient way of logging data in the field for further analysis.

When the hardware connections have been made, start SiRFDemo on your PC by double-clicking on the program icon or on the *sirfdemo.exe* file.

When connected, SiRFDemo attempts to identify the connected product and software release. To ensure that SiRFDRive is enabled:

1. Select Target S/W from the Setup menu. See Figure 5-1.

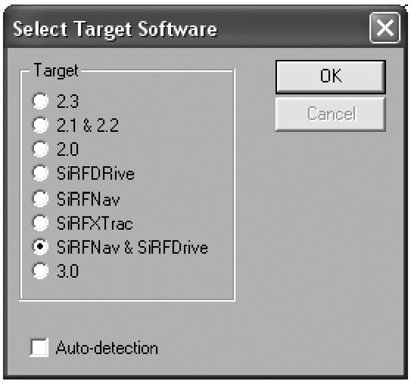

Figure 5-1: Select target software

2. Select SiRFDRive, and make sure the Auto-detection check box is deselected.

With SiRFDRive enabled, you can view the DR status and state:

1. Select Switch to SiRF Protocol from the Action menu.
2. Select Messages from the View menu. Enable the Geodetic Nav and SiRFDRive options. The windows shown in Figures 5-2 and 5-3 will become available.

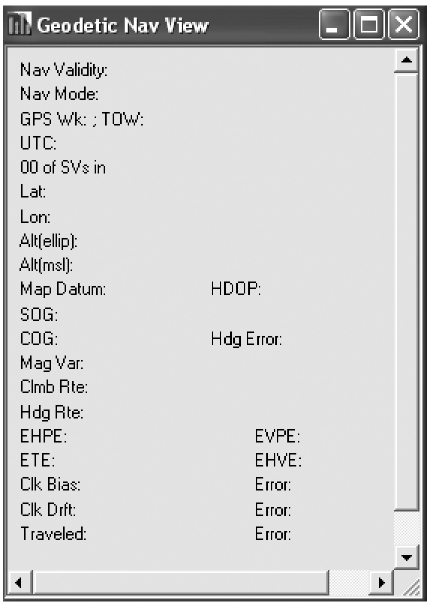

Figure 5-2: Geodetic Nav View

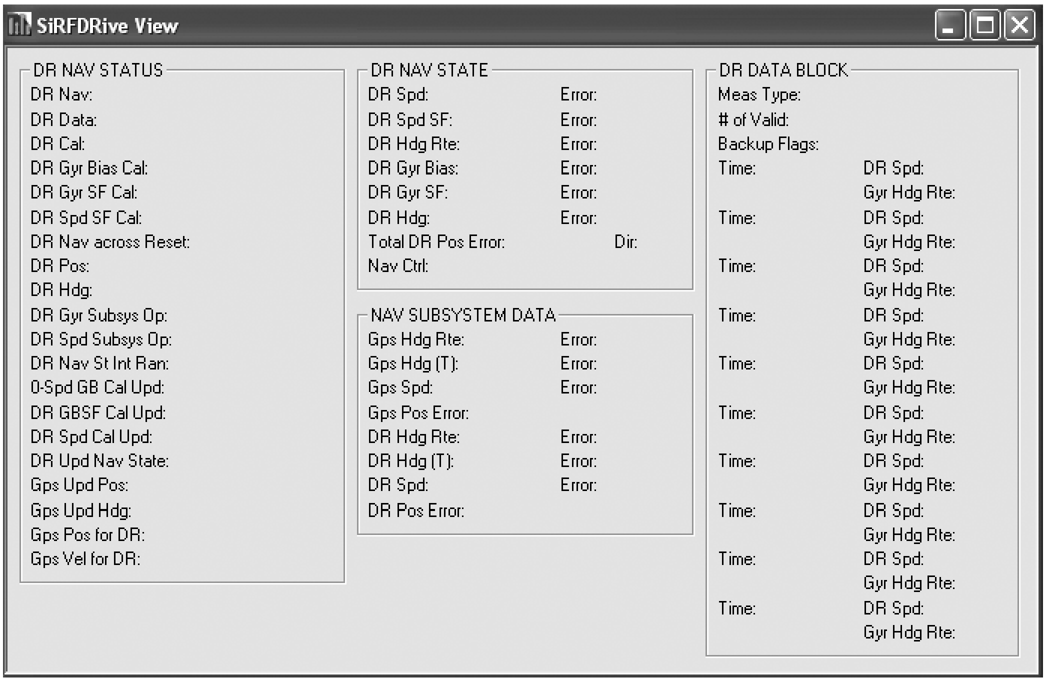

Figure 5-3: SiRFDRive View

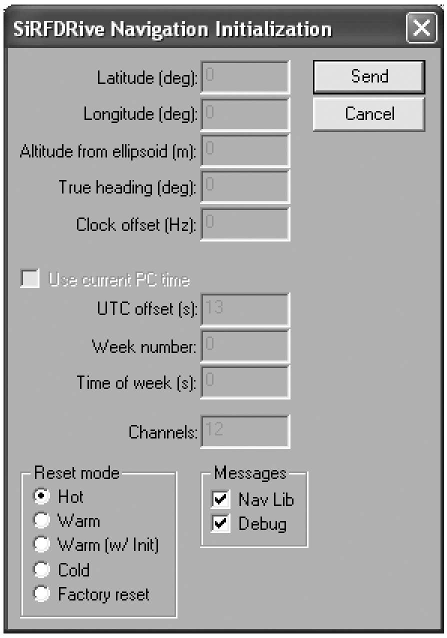

Figure 5-4: SiRFDRive Navigation Initialization

Select Initialize Data Source from the Action menu, then activate the following messages (see Figure 5-4):

- Nav Lib
- Debug

When DR is working correctly with the GPS system, proceed to log a file by selecting Open Log File from the Action menu. Assign a file name with a '.gps' extension, select messages to record, 'Select All' is recommended, and press OK.

To stop the data logging process, close SiRFDemo.

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6.0 Evaluation toolset

6.1 Data Collection

The Jupiter 20 DR Development kit includes the SiRFDemo software. This software can be used to monitor real-time operation of the receiver, log data for analysis, and configure the receiver operation.

Refer to the SiRFDemo and SiRFflash user guides for further information.

6.2 Reference data

The advantage of a GPS DR system is its ability to continue navigating accurately during satellite blockages. We recommend that you evaluate and test your DR system in areas with tunnels or obstructions overhead. If these areas are not available, the antenna can be disconnected for short periods of time to simulate a complete satellite blockage.

Note: Over time a 'DR only' navigation system will incur some error. This error in position will increase if GPS updates are not received. The GPS solution will provide this position update, however if the antenna is disconnected, or satellites are blocked for an unreasonable amount of time, the error will compound.

As an indication of receiver performance under a DR evaluation we recommend that the collected navigation data be compared to a more accurate navigation data source such as map data or plot.

6.3 Calibration procedure

For correct SiRFDRive operation it is imperative that proper DR calibration be performed. DR calibration is performed automatically from GPS processing. As the GPS system computes velocity and change of heading from information from the satellite solutions, it is compared to the information obtained from the DR sensors. The system will calibrate the resulting sensor information from the GPS data and store appropriate calibration factors. Calibration data, which is stored in SRAM, includes gyro bias and scale factor along with a speed scale factor. This calibration data will only be retained if the battery backup supply is provided to the receiver.

To ensure proper calibration, perform the following steps:

1. Power up the Development unit and gyro. Check that the LED's on the front panel are lit.
2. Ensure SiRFDemo reports a Valid Nav Status.
3. With the vehicle stationary and engine running, observe a DR Speed of zero in the DR Data Block section of the SiRFDRive View screen. This ensures there is no noise on the wheel tick signal.
4. Drive the vehicle at a speed of at least 8 km/h and observe a DR Speed in the DR Data Block section of the SiRFDRive View screen.
5. Drive the vehicle through a course that includes turns in both right and left directions of at least 90 degrees, with a straight run in between. These turns should be at a speed of at least 8 km/h. The course should also include some straight line travel as well and at least one full stop lasting five seconds or more. This should be done in an area with good satellite visibility and minimum obstructions.

The DR calibration can be monitored in the DR Nav Status block of the SiRFDRive View screen. Ideally all entries should show 'Valid'.

6.4 Evaluating performance

The performance of the SiRFDRive system can be evaluated by using the tool set provided and by comparing the results with known reference data. It should be noted that proper installation and use of this system will have a direct effect on the quality of results.

To properly evaluate the performance of a GPS DR system, it should be installed and tested on a moving vehicle or platform integration, and tested with one or more GPS-only systems for comparison. The moving vehicle may be substituted with a platform using a GPS simulator with DR sensor emulation. In either case all GPS receivers under test should be connected to the same signal source, either a common antenna or simulator output. The resulting navigation data must be able to be compared to a truth. This truth can be of a map matching type for a vehicle or a known path of travel from the simulator.

The most effective test would be in a vehicle travelling in a built-up urban area. This area would offer a change of velocities and turns, and also GPS satellite blockages. With more than one system involved in the test, some being 'GPS only', a good comparison can be made of the different systems and the value of GPS DR can easily be seen.

7.0 System operation

The GPS DR system must be configured with all of the common practices of a stand-alone GPS system with the addition of a source of wheel ticks and a heading rate gyro. Once properly connected and powered, the receiver will declare the DR sensors uncalibrated. At this time it will operate as a stand-alone GPS system. When the system starts to navigate using GPS measurements, calibration will begin. During calibration, (usually 2 to 4 seconds) the vehicle or platform must not be moving. It is during this period of no movement, that the gyro bias is determined. Since there is no movement, there cannot be any rate of turn and this resulting bias will then signify straight-line movement. Once movement begins and a turn is made followed by the straight-line movement again, the gyro scale factor can be determined. This scale factor is the vehicle turning rate versus voltage change of the gyro output. Wheel ticks are calibrated after travelling a distance sufficient for the GPS to accurately compute scale factors.

When the DR sensors are calibrated, the receiver will transition from GPS-only to 'combined mode'. In combined mode, the GPS will continuously calibrate the DR sensors while providing absolute position information. The DR sensors will provide proper heading and velocity information for the next position to be calculated. The gyro will be sampled at a 10 Hz rate, however the combined navigation will update and output position, velocity, and heading estimates at a rate of 1 Hz (once per second).

If the system is in combined mode, and the GPS experiences a blockage of satellite signals, it will automatically transition to DR-only mode until satellites are re-acquired. In DR-only mode the system will use the DR sensor information to estimate and output the next position. After satellites are re-acquired, the system will return to combined mode.

Note: DR navigation shall be available at start-up if position and heading are both 'Valid', and if the Speed = 0 for at least 1 second after the system has finished initializing.

The position and heading shall be considered 'Valid' if during the last operating session, DR Navigation was 'Valid', Velocity = 0 (so that position and heading were not changing), position, heading, and DR calibration data were preserved through the OFF/ON or RESET cycle. Or, the user supplies the last valid DR position and heading data.

If updated DR calibration is not available, the system will use the current default sensor parameter values. The subsequent DR navigation performance will depend on how well the default parameters match the true sensors.

8.0 Software and messaging description

The Jupiter 20 DR receiver supports all the necessary GPS navigation capabilities, with the addition of DR messaging. Much of the standard GPS messaging will be modified to include the factors of DR along with the addition of messaging specific to DR. The added DR specific messaging will perform functions such as configure DR navigation, set up calibration factors, monitor instrument readings, and query calibration factors when needed. Navman has added to the standard SiRFDRive message set with a proprietary NMEA DR status message as shown in Section 8.3.

The messages can be described as Data Reporting, Status Reporting or Control. The reporting messages can be classified as output messages and the control messages can be classified as input messages.

At start-up, the system will check the status of stored DR values. If any of the critical DR values (i.e. necessary for DR navigation) are invalid, the system will report the condition and DR navigation will become invalid until either GPS operation or user inputs provide the necessary DR navigation initialization data.

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Status Reporting:

Internal DR sub-system states are made available as outputs:

- DR Navigation Valid
- Position Valid
- Heading Valid
- DR Calibration Valid
- DR Data Valid

DR sub-system calibration values and status are made available as outputs:

- Gyro Scale Factor
- Gyro Scale Factor Error Standard Deviation
- Gyro Bias
- Gyro Bias Error Standard Deviation
- Gyro Calibration Valid
- Speed Scale Factor
- Speed Scale Factor Error Standard Deviation
- Speed Calibration Valid

8.1 SiRFDRive output messages

8.1.1 Message ID 0x29

Geodetic Navigation State Output Message – Output at all times. Refer to Jupiter 20 Binary Reference Manual (MN00031).

8.1.2 Message ID 0x30, Sub-ID 0x01

DR NAV Status Output Message – Output when enabled.

Byte No.	Field*	Details†
1	Message ID	–
2	Sub-ID	–
3	DR Navigation Valid	Bit 0: GPS only navigation required Bit 1: Speed not equal to zero at start-up Bit 2: DR position invalid Bit 3: DR heading invalid Bit 4: DR calibration invalid Bit 5: DR data invalid Bit 6: System has gone into cold-start Bit 7: Reserved
4 – 5	DR Data Valid	Bit 0: DR gyro sub-system not operational Bit 1: DR speed sub-system not operational Bit 2: DR measurement time < 80 ms Bit 3: Input serial DR message checksum invalid Bit 4: No DR data for > 2 seconds Bit 5: DR data timestamp did not advance Bit 6: DR data bytes all 0x00 or all 0xFF Bit 7: Composite wheel tick count jumped by more than 255 between successive DR messages Bit 8: Input gyro data bits (15) value of 0x0000 or 0x3FFF Bit 9: More than 10 DR messages in one second Bit 10: Delta time ≤ 0 Bit 11–15: Reserved
6.0 – 6.3	DR Calibration Valid	Bit 0: DR gyro bias calibration invalid Bit 1: DR gyro scale factor calibration invalid Bit 2: DR speed scale factor calibration invalid Bit 3: GPS calibration required but not ready

Byte No.	Field*	Details†
6.4 – 6.7	DR Gyro Bias Calibration Valid	Bit 0: DR data invalid Bit 1: Zero speed gyro bias calibration not updated Bit 2: Heading rate scale factor ≤-1 Bit 3: Reserved
7.0 – 7.3	DR Gyro Scale Factor Calibration Valid	Bit 0: DR heading invalid. Bit 1: DR data invalid. Bit 2: DR position invalid. Bit 3: Heading rate scale factor ≤-1
7.4 – 7.7	DR Speed Scale factor Calibration Valid	Bit 0: DR data invalid Bit 1: DR position invalid Bit 2: GPS velocity invalid for DR Bit 3: DR speed scale factor ≤-1
8.0 – 8.2	DR Navigation Valid Across Reset	Bit 0: DR navigation invalid Bit 1: Speed > 0.01 m/s Bit 2: Reserved
8.3 – 8.7	DR Position Valid	Bit 0: Speed not equal to zero at start-up Bit 1: Valid GPS position is required and GPS position invalid Bit 2: System has gone into cold-start Bit 3: DR data invalid Bit 4: Reserved
9.0 – 9.7	DR Heading Valid	Bit 0: Speed not equal to zero at start-up Bit 1: Valid GPS position is required and GPS position invalid Bit 2: Valid GPS speed is required and GPS speed invalid Bit 3: GPS did not update heading Bit 4: Delta GPS time ≤0 and ≥2 Bit 5: System has gone into cold-start Bit 6: DR data invalid Bit 7: Reserved
10.0 – 10.3	DR Gyro Sub-system Operational	Bit 0: High persistent turn rate Bit 1: Low persistent turn rate Bit 2: Gyro turn rate residual is too large Bit 3: Reserved
10.4 – 10.7	DR Speed Sub-system Operational	Bit 0: DR speed data = 0 when GPS speed not equal to zero Bit 1: DR speed data not equal to zero when GPS speed = 0 Bit 2: DR speed residual is too large Bit 3: Reserved
11.0 – 11.3	DR Navigation State Integration Ran	Bit 0: Update mode ≠ KF Bit 1: EHPE >50 Bit 2: No previous GPS KF update Bit 3: GPS EHPE , DR EHPE
11.4 – 11.7	Zero Speed Gyro Bias Calibration was Updated	Bit 0: GPS speed >0.001 Bit 1: Zero speed during cycle Bit 2: Zero speed previous Bit 3: Reserved
12.0 – 12.3	DR Gyro Bias and Scale Factor Calibration was Updated	Bit 0: DR data invalid Bit 1: DR position invalid Bit 2: GPS velocity invalid for DR Bit 3: GPS did not update heading
12.4 – 12.6	DR Speed Calibration was Updated	Bit 0: DR data invalid Bit 1: DR position invalid Bit 2: GPS velocity invalid for DR
12.7	DR Updated the Navigation State	Bit 0: DR navigation invalid

Byte No.	Field*	Details†
13.0 – 13.7	GPS Updated Position	Bit 0: Update mode ≠ KF Bit 1: EHPE > 50 Bit 2: No previous GPS KF update Bit 3: GPS EHPE < DR EHPE Bit 4: DR EHPE < 50 Bit 5: Less than 4 satellites Bit 6: Zero satellites Bit 7: DR navigation only required
14.0 – 14.7	GPS Updated Heading	Bit 0: Update mode ≠ KF Bit 1: GPS speed ≤ 5.0 m/s Bit 2: Less than 4 satellites. Bit 3: Horizontal velocity variance > 1.0 $(m/s)^2$ Bit 4: GPS heading error ≥ DR heading error Bit 5: GPS KF not updated Bit 6: Initial speed transient incomplete Bit 7: Reserved
15.0 – 15.3	GPS Position Valid for DR	Bit 0: Less than 4 satellites Bit 1: EHPE > 30 Bit 2: GPS KF not updated Bit 3: Reserved
15.4 – 15.7	GPS Velocity Valid for DR	Bit 0: GPS position invalid for DR Bit 1: EHVE > 3 Bit 2: GPS speed < 2 m/s Bit 3: GPS did not update the heading
16 – 17	Reserved	–

** The bit map of the field variable reports the status. If all the bits in the bit map are zero, then the status of the variable = Valid. Otherwise, if any of the bits in the bit map are set (i.e. = 1), then the status of the variable = Not Valid, and the individual bits give the reason why.*

† The individual bits are referenced by their offset from the start of the bit map, starting with offset 0 for the LSB of the least-significant byte.

8.1.3 Message ID 0x30; Sub-ID 0x02

DR NAV State Output Message – Output when enabled.

Byte No.	Field	Range	Resolution
1	Message ID	–	–
2	Sub-ID	–	–
3 – 4	DR Speed	0 to 655 m/s	0.01
5 – 6	DR Speed Error	0 to 655 m/s	0.0001
7 – 8	DR Speed Scale Factor*	-1 to 3	0.0001
9 – 10	DR Speed Scale Factor Error	0 to 3	0.0001
11 – 12	DR Heading Rate	-300 to 300 °/s	0.01
13 – 14	DR Heading Rate Error	0 to 300 °/s	0.01
15 – 16	DR Gyro Bias	-300 to 300 °/s	0.01
17 – 18	DR Gyro Bias Error	0 to 300 °/s	0.01
19 – 20	DR Gyro Scale Factor*	-1 to 3	0.0001
21 – 22	DR Gyro Scale Factor Error	0 to 3	0.0001
23 – 26	Total DR Position Error	0 to 6,000,000 m	0.01
27 – 28	Total DR Heading Error	0 to 180°	0.01

Byte No.	Field	Range	Resolution
29	DR Nav Mode Control	Bit 0 = 1: GPS only Nav required, no DR Nav allowed Bit 1 = 1: OK to do DR Nav with default or SRAM calibration Bit 2 = 1: DR Nav Ok if using current GPS calibration Bit 3 = 1: DR only Nav	
30	DR Direction	0 = Forward 1 = Reverse Boolean	–
31 – 32	DR Heading	0 to 360°/s	0.01
** Scale Factor is defined: True = Measured/(1 + Scale Factor)*			

8.1.4 Message ID 0x30; Sub-ID 0x03

NAV Sub-systems Data Output Message – Output when enabled.

Byte No.	Field	Range	Resolution
1	Message ID	–	–
2	Sub-ID	–	–
3 – 4	GPS Heading Rate	-300 to 300°/s	0.01
5 – 6	GPS Heading Rate Error	0 to 300°/s	0.01
7 – 8	GPS Heading (True)	0 to 360°	0.01
9 – 10	GPS Heading Error	0 to 180°	0.01
11 – 12	GPS Speed	0 to 655 m/s	0.01
13 – 14	GPS Speed Error	0 to 655 m/s	0.01
15 – 18	GPS Position Error	0 to 6,000,000 m	0.01
19 – 20	DR Heading Rate	-300 to 300°/s	0.01
21 – 22	DR Heading Rate Error	0 to 300°/s	0.01
23 – 24	DR Heading (True)	0 to 360°	0.01
25 – 26	DR Heading Error	0 to 180°	0.01
27 – 28	DR Speed	0 to 655 m/s	0.01
29 – 30	DR Speed Error	0 to 655 m/s	0.01
31 – 34	DR Position Error	0 to 6,000,000 m	0.01
35 – 36	Reserved	–	–

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8.1.5 Message ID 0x30; Sub-ID 0x08

DR Data Block Output Message – Output when enabled.

Byte No.	Field	Range	Resolution
1	Message ID	–	–
2	Sub-ID	–	–
3	Measurement Type	0 = Wheel tick + gyro (Boolean)	–
4	Valid Measurements in Block	1 – 10	1
5 – 6	Back-up Flags	0 = True, 1 = False (Boolean)	–
7 + (n-1)	Time Tag	–	1
11 + (n-1)	DR Speed	0 to 655 m/s	0.01
13 + (n-1)	Gyro Heading Rate	0 to 360 °/s	0.01

8.1.6 Message ID 0x30, Sub-ID 0x06

Gyro Factory Calibration Response Output Message – Output after successful completion of each calibration stage.

Byte No.	Field	Details
1	Message ID	–
2	Sub-ID	–
3	Gyro Factory Calibration Progress*	Bit 0: Gyro bias calibration completed Bit 1: Gyro scale factor calibration completed Bit 2 – 7: Reserved†
4	Reserved	–

** The bit map of the field variable reports the status of each calibration stage. All pertinent bits must be set (i.e. = 1) to Valid before the calibration is considered successful.*

† The individual bits are referenced by their offset from the start of the bit map, starting with offset 0 for the LSB of the least-significant byte.

8.1.7 Message ID 0x30; Sub-ID 0x07

Stored (in Non-Volatile Memory) Gyro and Odometer Parameters – Output in response to a poll, or when updated by the system, or when updated via user input.

Byte No.	Field	Range	Resolution
1	Message ID	–	–
2	Sub-ID	–	–
3	Baseline Speed Scale Factor	1 to 255 ticks/m (default: 4)	1
4 – 5	Baseline Gyro Bias	2.0 to 3.0 V (default: 2.5)	0.0001
6 – 7	Baseline Gyro Scale Factor	1 to 65 mV/°/s (default: 22)	0.001

8.2 SiRFDRive Input Commands

8.2.1 Message ID 0xAC; Sub-ID 0x01

DR NAV Initialization Input message

Byte No.	Field	Range	Resolution
1	Message ID	–	–
2	Sub-ID	–	–
3 – 6	Latitude	-90 – 90°	10^{-7}
7 – 10	Longitude	-180 – 180°	10^{-7}
11 – 14	Altitude (from Ellipsoid)	-2,000 to 100,000 m	0.01
15 – 16	Heading (True)	0 to 360°	0.01
17 – 20	Clock Offset	25,000 to 146,000 Hz	–
21 – 24	Time of Week	0 to 604,800 s	0.01
25 – 26	Week Number	0 to 1023	–
27	Number of Channels	1 to 12	–
28	Reset Configuration	Bit 0: Data valid flag (hot start) Bit 1: Clear ephemeris (warm start) Bit 2: Clear memory (cold start) Bit 3: Factory reset Bit 4: Enable raw track data Bit 5: Enable debug data for SiRF binary Bit 6-7: Reserved	

8.2.2 Message ID 0xAC, Sub-ID 0x02

DR NAV Mode Control Input message

Byte No.	Field	Details
1	Message ID	–
2	Sub-ID	–
3	DR Navigation Mode Control	Bit settings are exclusive. Bit 0: GPS navigation only Bit 1: DR navigation OK (with stored or default calibration) Bit 2: DR navigation OK with current GPS calibration Bit 3: DR navigation only Bit 4 – 7: Reserved

8.2.3 Message ID 0xAC, Sub-ID 0x03

Gyro Factory Calibration Control Input message

Byte No.	Field	Details
1	Message ID	–
2	Sub-ID	–
3	Gyro Factory Calibration Control[*]	Bit 0: Start gyro bias calibration Bit 1: Start gyro scale factor calibration[†]

[*] The bit map of the field variable controls the gyro factory calibration stages. The Gyro Factory Calibration procedure calls for the Gyro Bias Calibration to be done first while the gyro is stationary, and the Gyro Scale Factor Calibration to be done next while the gyro rotates smoothly through 360°.

[†] The individual bits are referenced by their offset from the start of the bit map, starting with offset 0 for the LSB of the least-significant byte.

8.2.4 Message ID 0xAC; Sub-ID 0x04

DR Sensor's Parameters Input message

Byte No.	Field	Range	Resolution
1	Message ID	–	–
2	Sub-ID	–	–
3	Baseline Speed Scale Factor	1 to 255 ticks/m (default: 4)	1
4 – 5	Baseline Gyro Bias	2.0 to 3.0 V (default: 2.5)	0.0001
6 – 7	Baseline Gyro Scale Factor	1 to 65 mV/°/s (default: 22)	0.001

8.3 Navman proprietary NMEA DR status message

A proprietary NMEA message indicates the current status of DR. The message is in the following format:

$PTTK,DR,X,y.yy,Z[*CS]

Where **X** is the navigation mode:

X	Description
G	GPS-only navigation
D	DR-only navigation
C	Combined GPS/DR navigation

y.yy is the Expected Horizontal Position Error (EHPE) in metres, and **Z** is a validity flag:

Z	Description
A	valid
V	invalid

The default output rate of this message shall be 1 Hz. To change the output rate of this message, refer to it as message 7 in the Query/Rate Control ($PSRF103) input message.

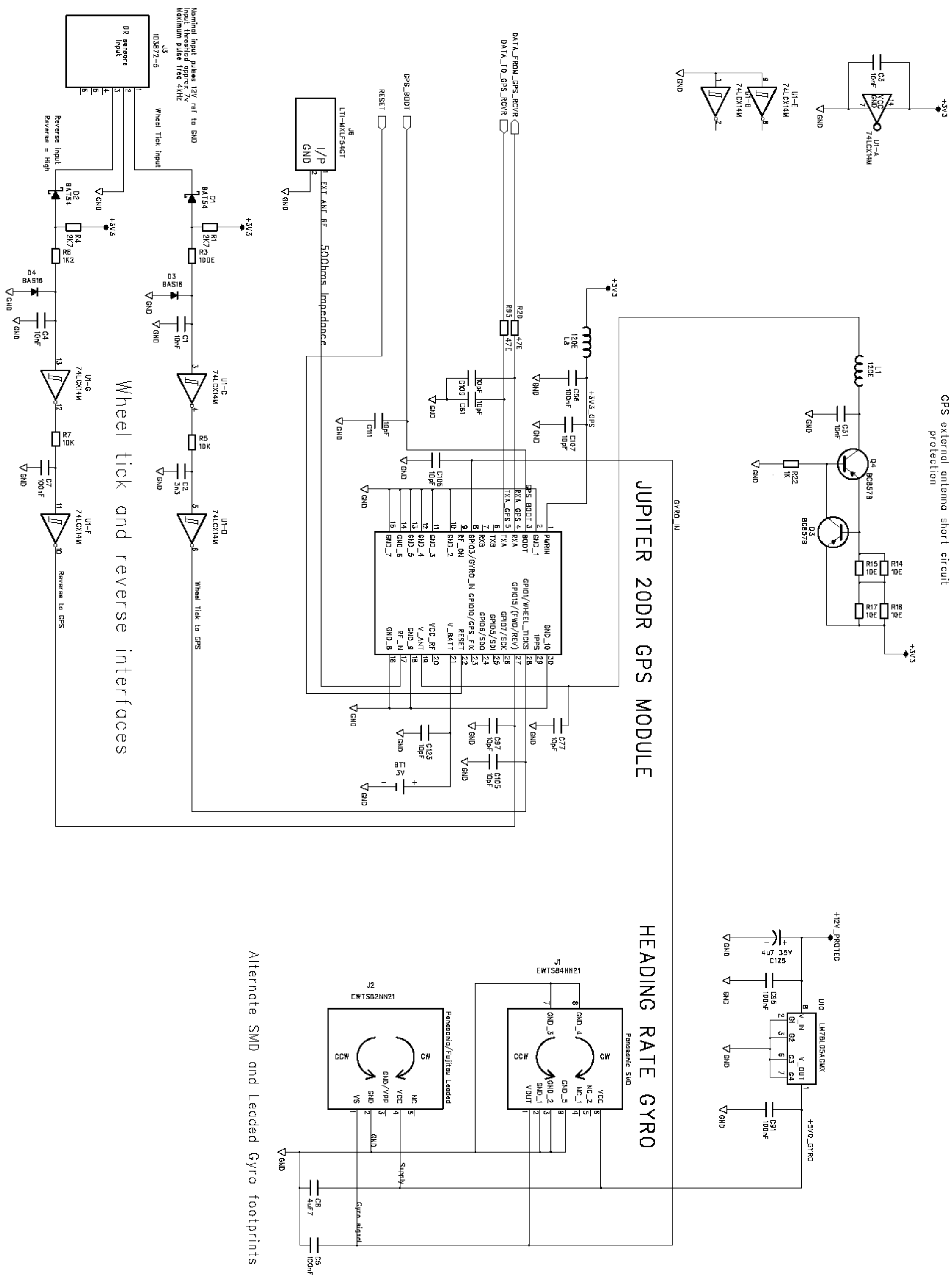
9.0 Summary of features

- The system will update the position, velocity, and heading estimates once per second (1Hz)
- The following navigation modes are user specific:
  - GPS only navigation
  - DR navigation using stored DR sensor calibration, i.e. OK to do DR-only at start-up
  - DR navigation using current GPS-based calibration, i.e. no DR navigation after start-up until after calibration by GPS
  - Combined navigation mode; the integration of GPS measurements and sensor information
- The user has the ability to initialize the DR navigation by entering the Position and Heading data at start-up
- The user has the ability to upload the DR sensor calibration values
- The system has the capability of eliminating the gross DR sensor errors by means of a factory calibration procedure
- The user has the ability to enter the new DR sensor parameters based on the following:
  - Gyro scale factor (mV/°/s)
  - wheel ticks per metre
- The system will compute and apply the true parameter values once GPS calibration

becomes available, regardless of the parameter values being used to determine the DR sensor operation at start-up (whether they are default values or user-entered)

- If a DR sensor has failed, and GPS calibration is available, the system will detect and identify the following DR sensor failures, and then switch to GPS-only navigation:
  - Gyro Sensor Failures:
  - High, Persistent Turn Rate
  - Low, Persistent Turn Rate
  - Gyro Turn Rate Residual is too large – Generally caused by discontinuities in heading rate data due to gyro or A/D failure
  - DR Speed Failures:
  - DR Speed data == 0 when GPS speed != 0
  - DR Speed data != 0 when GPS speed == 0
  - DR speed data residual too large – Generally caused by discontinuities in DR speed sensor output

Appendix A – Jupiter 20 DR reference design



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