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OEM Lodestar Integration Guide

Document Revision History

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01. 1st Issue		AZC	Preliminary Version	MXC	27-06-14

1. Introduction

1.1. Scope, purpose and rationale

This document is intended to be used by third parties who wish to integrate Lodestar AAINS into their systems. The document covers physical, electrical and operational details of the system and its interfaces. The document should be considered as a summary of relevant information and rather than acting as the primary source, this document will reference the main Lodestar documentation, quoting some information where appropriate. With this in mind, the main Lodestar documentation referenced in section 2 should be referred to for the most up-to-date information.

2. References

1. SDS Lodestar Command and Control Language.doc
2. SDS Lodestar Messages.doc
3. Lodestar Datasheet
4. Lodestar Hardware Manual
5. SPRINT User Manual

3. Physical Details

Lodestar is available in a variety of different hardware variants:

- Surface housing
- Subsea housing (1,000m, 3,000m, 5,000m depth rating)
- OEM system

3.1. Interfaces

Lodestar provides 5x RS232/485 I/O ports and an Ethernet port for TCP IP data. It also provides 4x trigger inputs/outputs. A wide range of output messages can be configured on any port at rates up to 100Hz.

3.2. Power

The standard lodestar is fitted with a small battery that allows the unit to continue running during short (up to 2 hours) power drop-outs. It is assumed that this is not a requirement for the OEM unit so the battery will be removed. This simplifies the power specification as the battery can significantly increase the current draw of the unit while charging.
The standard Lodestar design includes dual (internal) power supplies to allow the unit to operate at 24V or 48V. In order to reduce the size of the power PCB it may be possible to remove some of this circuitry and operate at one voltage only.
Without the battery the operating power consumption of the unit is as follows:

Voltage	Current	Power
24V	740mA	17.8W
48V	360mA	17.3W

Table 1. Power consumption

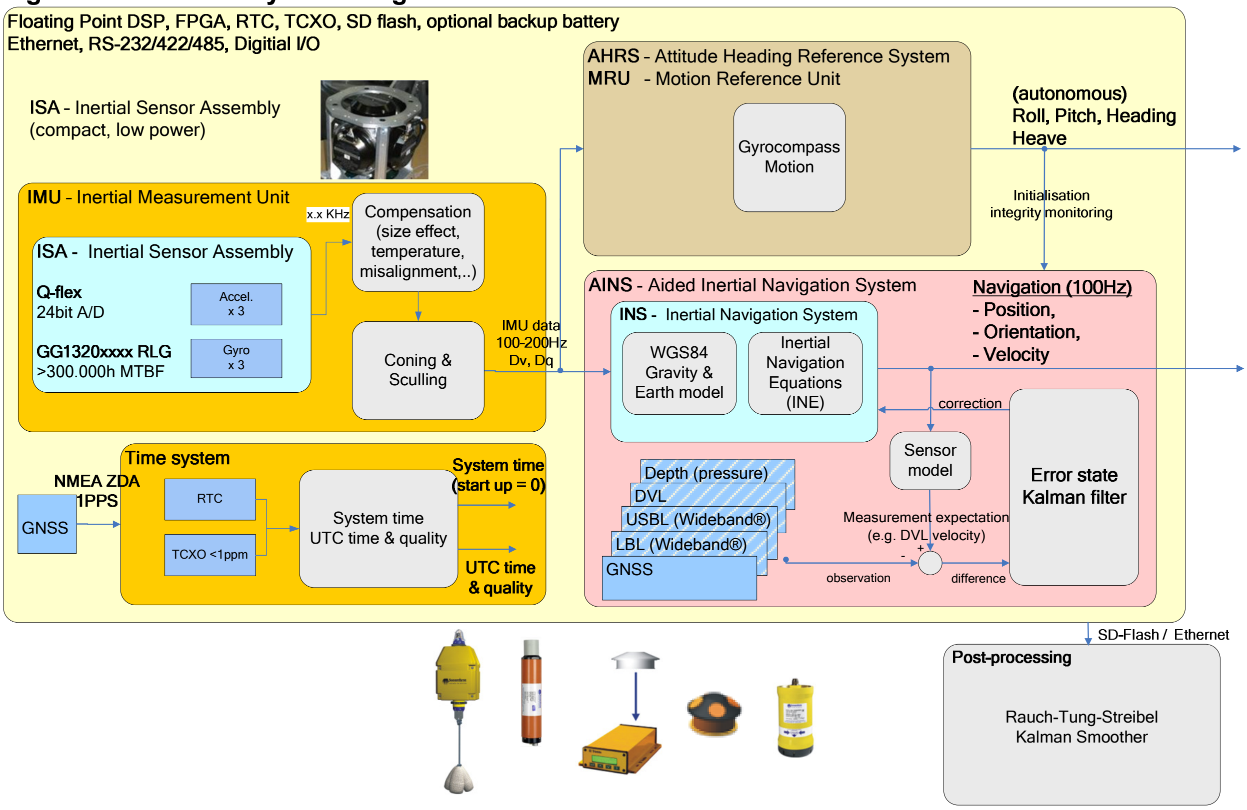
The power input on the lodestar is protected against reverse polarity and over voltage up to 100V. Input voltages higher than this will cause damage to occur.

3.3. Shock Vibration & Temperature

Operating Temperature: -10°C to +55°C
Shock Rating (Operational): 22 g, 11 ms half sine
Note: testing will be required to confirm these figures the new hardware designs.

4. System Overview

Figure 1 - Lodestar System Diagram



Lodestar was released to the market in 2007 as a premium quality, survey grade, Attitude and Heading Reference System (AHRS) for surface and subsea applications. Using identical hardware, Lodestar Acoustically Aided INS (AAINS) was released in 2010 for use primarily on surface Dynamically Positioned (DP) drilling vessels and subsea vehicles (ROV's and AUV's).

Adding a DVL to Lodestar AAINS provides an extremely practical dead-reckoning capability to an accuracy of on the order of a few meters of position drift per hour. Lodestar accepts and reduces the noise of Ultra-Short Baseline (USBL) positioning and can dramatically improve the operational efficiency of Long Baseline (LBL) by making use of sparser arrays of seabed transponder. INS also significantly reduces dynamic pressure depth error from e.g. wave motion, when used for subsea applications.

Lodestar makes use of three ring laser gyroscopes that measure the angular rate and three accelerometers that measure the specific force of a moving platform. The highest quality dual use (commercial and military) field proven sensors have been selected for use due to their performance, low mean time between failure (MTBF) and ease of export (ITAR-free). These sensors have highly stable error characteristics and are insensitive to temperature variation making them ideally suited to subsea applications

4.1. AHRS

Lodestar runs two algorithms in parallel at all times, the Attitude Heading Reference System (AHRS) and the Inertial Navigation System. The AHRS is a gyrocompass and a Motion Reference – it provides heading, pitch, roll and heave outputs based purely on data from the inertial sensors plus some basic aiding data: Latitude and (optionally) velocity.

Latitude can be entered and stored via the Command & Control (C&C) interface or updated automatically by feeding GPS or USBL data into Lodestar. Note: only coarse latitude aiding (up to 100km of latitude error) is required when the AHRS is used only for seeding the INS, as is typical for AUV use.

The AHRS provides an initial orientation for the INS algorithm, which removes the need for an 'alignment' procedure for the INS. After this initialisation, the AHRS and INS algorithms are completely independent. The AHRS algorithm requires 5 minutes to settle to a reasonable accuracy after power-on, before the INS will initialise. There is no restriction on vehicle dynamics during this period.

Where possible it is recommended that heading, pitch and roll information is obtained from the INS algorithm rather than the AHRS as the INS solution is more accurate than the AHRS. The AHRS will initialise the INS and can subsequently be used as a coarse quality check of the INS attitude. This means that it aiding of the AHRS is not critical to the navigation solution or vehicle operation.

4.2. Acoustically Aided Inertial Navigation System (AAINS)

The INS sensor outputs are combined mathematically to compute the position, velocity and attitude of the vehicle. The output is extremely low noise and very accurate in the short term but slowly degrades over time. Therefore it is necessary to seamlessly aid the INS with complimentary acoustic positioning and other aiding sources.

Acoustic Aiding with Sonardyne's latest Sixth Generation (6G®) vessel-based transceivers and subsea beacons maximise the benefits of the system by providing the most precise and reliable acoustic aiding input.

Various aiding options are available, including:

- USBL
- DVL
- Pressure / Depth
- Zero Velocity (ZUPT)
- LBL
- GPS

4.2.1. USBL Aiding

The vessel-mounted USBL transceiver determines the range and bearing to an acoustic beacon fitted to the subsea vehicle. Using vessel DGPS for position and VRU/MRU/AHRS for vessel motion compensation, an absolute position for the vehicle mounted beacon is calculated by the USBL system. This position is transmitted to the vehicle and fed into Lodestar as an absolute positioning aiding input. Additionally, the USBL system is synchronised to Coordinated Universal Time (UTC) to provide an accurate timestamp. Whilst the use of Sonardyne USBL provides a tighter acoustic / inertial integration and the best possible USBL positioning performance, Lodestar can accept position aiding from any USBL system that uses correct time-stamped positions in an industry standard telegram. Although Lodestar improves USBL system precision and short term accuracy, it will not resolve any inherent systematic errors that are present. Users must therefore make sure the USBL system they are using is correctly calibrated and recommended operating practices are observed, for example, using regular sound velocity profiles.

4.2.2. ZUPT (Zero Velocity) Aiding

In certain operational situations the subsea vehicle may be static (e.g. during average position fixes). In these situations, particularly if there is risk of loss of other aiding, it is beneficial to be able to aid the INS with 'zero velocity' updates to estimate inertial sensor errors.

4.2.3. Vehicle-Mounted Sensor Aiding

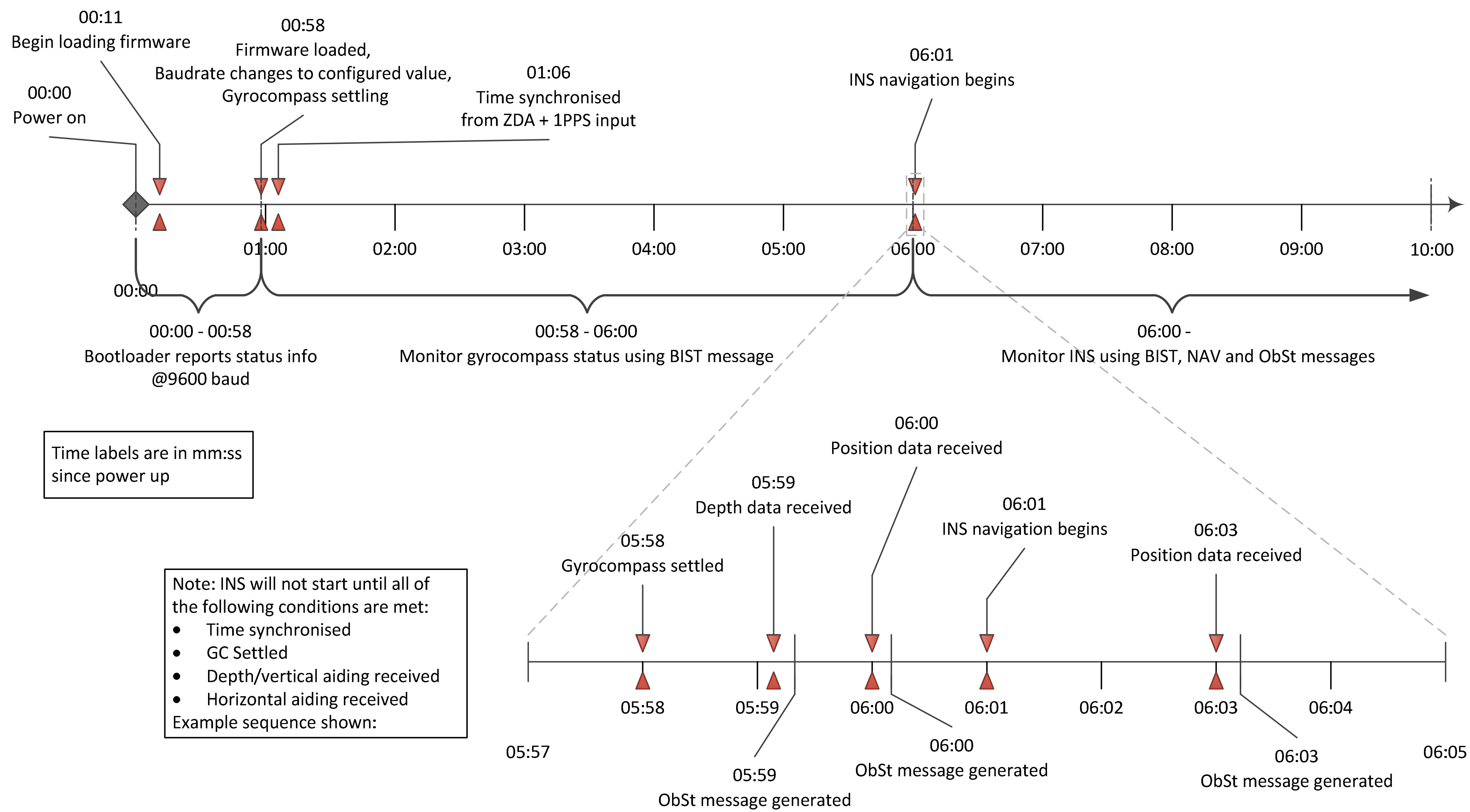
Lodestar has the ability to use vehicle-mounted aiding sensors such as Doppler velocity logs (DVL) and pressure/depth sensors. The use of these sensors provides further benefits for subsea navigation such as the ability to provide precise and continuous navigation output even if external acoustic positioning is lost for periods of time. Lodestar does not need to be physically co-located with the Doppler Velocity Log or integrated into the same housing. Only 'coarse' mounting angles for the DVL are needed from the user. Fine misalignments are then calculated in the field using a calibration routine. This approach allows for more flexible mounting configurations to be considered.

Table 4-1 – SPRINT INS Aiding Options

Aiding Source	Aiding Type	Aiding Considerations

	Position Aiding (Horizontal)	Velocity Aiding	Depth Aiding (Vertical)	Time Sync Required?	Can be used to Initialise INS?
USBL	✓	×	×	✓	✓
GPS	✓	×	×	✓	✓
LBL	✓	×	×	×	×
DVL	×	✓	×	×	×
Zero Velocity	×	✓	×	×	×
Pressure Depth	×	×	✓	×	×

4.3. Start-up Sequence



5. Integration details

5.1. Multiplex Protocol

When sending data to and from Lodestar, it is important that both Lodestar and the external system know what data is being sent and it is also important to be able to send multiple message types over the same physical link. For this reason Lodestar makes use of a ‘multiplex protocol’ to wrap messages into packets with message type identifiers and unique start and end sequences. Details of the multiplex protocol can be found in the messages documentation[2].

5.2. Time synchronisation

The Lodestar must be time synchronised to UTC time. This can be achieved by providing a 1PPS signal and ZDA message from a GPS receiver. If the serial communication link has known, very stable latency then it is possible to use ZDA only, but 1PPS is recommended if possible.

5.2.1. Inputs

The ZDA message should conform to the NMEA 0183 standard. The message can be received on any channel or over Ethernet. The baudrate is user configurable. Often, the GNSS PPP solution is calculated on a PC, however ZDA messages generated by a PC are rarely of any use for time synchronisation, so it is important that the ZDA message is generated by the GPS receiver and is associated with a 1PPS (if 1PPS is used).

The 1PPS signal should be a 5V pulse with >1ms duration. The signal can be fed to any of the trigger inputs. It is important to determine with certainty whether the GNSS receiver transmits the ZDA message before or after the associated 1PPS pulse. This information must be entered into the lodestar (see below for details of commands.)

The INS will not start until the system has been time synchronised and the INS will stop running if more than 30 minutes elapses between time sync updates (i.e. no ZDA/1PPS received for >30mins)

5.2.2. Commands

The Lodestar time system is configured using the following commands (see Command & Control documentation[1] for full details):

`IN <port> MSG + ZDA`
This tells Lodestar to accept ZDA messages on the selected UART [0-4] or IP port.

`TSYS SOURCE <ZDA|ZDA_1PPS|NONE>`
This sets the external UTC time source to use.

`TSYS ZDA <port>`
This sets the port number for the ZDA input. (This is the UART number [0-4] or IP port)

`TSYS PPS <port|NONE>`
This sets the 1PPS trigger input port where port is trigger ports numbered 1-4.

`TSYS PPSMODE <BEFORE|TOA|AFTER >`
This defines whether the ZDA arrives BEFORE or AFTER its associated 1PPS pulse.
TOA should be used if the UTC time in the ZDA message is the time of transmission of the first byte of the message.

`TSYS ZDALATENCY <d.d>`
This sets the latency in seconds for ZDA time of arrival and only used when TSYS SOURCE is set to ZDA.

`TSYS RST`
This resets the time system.

5.2.3. Monitoring

The time system can be monitored by interpreting the following output messages (see messages documentation[2] for details):

PSONTMS
PSONTRG
TMS

5.3. USBL Aiding

A remote, vessel mounted USBL system can be used to measure the absolute position of a transponder on the vehicle. A USBL position can be used to initialise the INS. Note: remote USBL aiding is often referred to as ‘Subsea USBL’ or ‘SUSBL’ in other documentation. This is to avoid confusion with (local) USBL aiding used on DP-INS vessels.

It is important to accurately measure the lever arm between the Lodestar and the transponder on the vehicle and enter it into Lodestar (see section 5.3.2). The transponder must be securely fixed to the vehicle and must not move during operation.

5.3.1. Inputs

The position of the transponder should be fed into Lodestar in the form of UTC time stamped SSB or GGA messages using world-frame co-ordinates (see messages documentation[2] for details).

As long as the UTC timestamp is accurate, position fixes can be sent to Lodestar with some latency. The default maximum latency is 2 seconds but this can be extended. Please contact Sonardyne for more information.

When using the multiplex protocol, USBL GGA messages must have SID set to 4.

5.3.2. Commands

The following commands are used to configure USBL aiding (see Command & Control documentation[1] for full details):

```
IN <port> MSG + SUSBL
```

This tells Lodestar to accept SSB and USBL GGA messages on the selected UART [0-4] or IP port.

```
SUSBL LA <d.d> <d.d> <d.d>
```

This sets the lever arms in metres, forward starboard and down from the CRP to the transponder.

```
INS USE + SUSBL
```

This configures Lodestar to use remote USBL aiding

```
SUSBL TPDR <1|0> [<d>]
```

If enabled, Lodestar will only use USBL fixes with the specified transponder number (using ‘station ID’ field in GGA message). Non-matching data will be logged but not used.

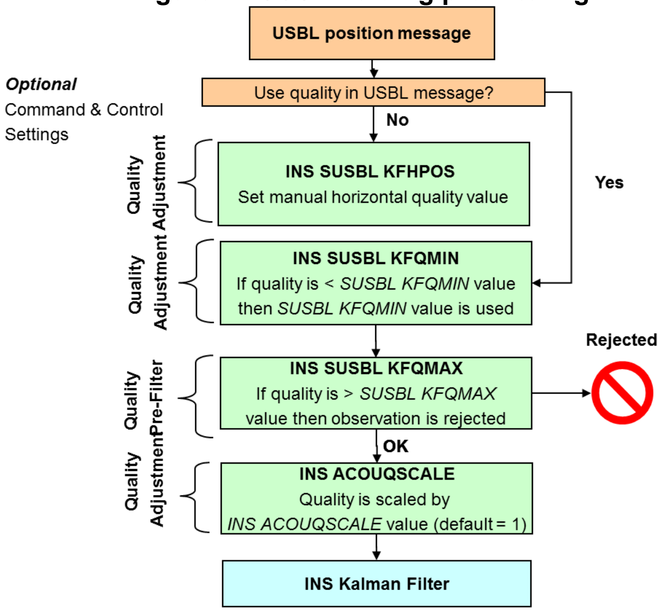
```
INS KFACOUQSCALE <d.d>
```

This command will set the Kalman Filter Acoustic Horizontal Scale to scale the error estimate reported in USBL messages.

```
INS SUSBL KFHPOS <d.d [m]>
INS SUSBL KFQMIN <d.d> <d>
INS SUSBL KFQMAX <d.d> <d>
INS SUSBL KFVPOS <d.d [m]>
```

The function of these commands is described in Figure 2.

Figure 2 - SUSBL aiding pre-filtering



5.3.3. Monitoring

For every USBL message received by the Lodestar, an ObStUSBL output message is generated which contains information on whether the update was accepted or rejected by the INS and any reasons for rejection if applicable. See messages documentation[2] for details.

5.4. LBL Aiding

Lodestar can use range measurements to seabed beacons with known locations to aid the INS.

Note: LBL cannot be used to initialise the INS – an absolute position must first be received from USBL or GPS.

Due to its DVL-inertial dead-reckoning capability, the INS can manage with less than the 4 or 5 beacons traditionally required for acoustic LBL tracking, hence the term ‘Sparse’ LBL.
Please consider the following features and operational guidelines for sparse LBL:

a. The minimum number of beacons at one site is two. Use of three beacons will support loss of acoustics to any single beacon and INS integrity if there is an error with aiding from any single beacon. For this reason the recommended number of beacons for a sparse array is three.
b. In specific scenarios with favourable vehicle dynamics / trajectory the INS can be aided with range observations from just a single beacon. Additional operational guidelines should be considered – contact Sonardyne for advice.
c. The INS can be actively aided by up to 6 beacons but can record LBL aiding observations for up to 10 beacons for analysis and post processing.
d. Acoustic update rate to each beacon should be faster than 10 seconds – this is primarily for screening of observations prior to INS use.
e. Pressure depth provided to the INS and beacon depths should be consistent. Relative depth errors will cause error in INS positioning if line of sight is not horizontal.
f. Sound velocity must be correct. Make regular updates if change is expected (> 0.5m/s).
g. LBL (range) aiding must be used in conjunction with DVL aiding, particularly in very sparse arrays. Contact Sonardyne for specific guidance if DVL is not available.
h. Make sure placement of LBL aiding beacons provides adequate acoustic line of sight and good geometry to the LBL transceiver during planned operations.
i. It is important to accurately measure the lever arm between the Lodestar and the transceiver on the vehicle and enter it into Lodestar (see section 5.3.2). The transponder must be securely fixed to the vehicle and must not move during operation.

5.4.1. Inputs

Range measurements can be made using an AvTrak 6 transceiver. The data provided by the AvTrak 6 must then be packaged into a PSONLOBS message and sent to Lodestar along with a PSONLVR and PSONLBLBCN message. Full details of these messages can be found in the messages documentation[2].

- The PSONLVR message contains details of the lever arm between the CRP and the LBL transceiver.
- The PSONLBLBCN message contains details of the position and configuration of the beacon being ranged to.
- The PSONLOBS message contains details of the range observation to the beacon. **Error! Reference source not found.** shows how to populate the PSONLOBS message.

When using multiple beacons, ranges can be obtained from each beacon individually, using the 'MR' command, or from up to four beacons simultaneously using the 'MSR' command. The process for making use of the ranges is similar in both cases.

The AvTrak 6 should be configured to append the following diagnostic information to range responses:

- Cross correlation (XC)
- Signal to Noise Ratio (SNR)
- Signal level (DBV)

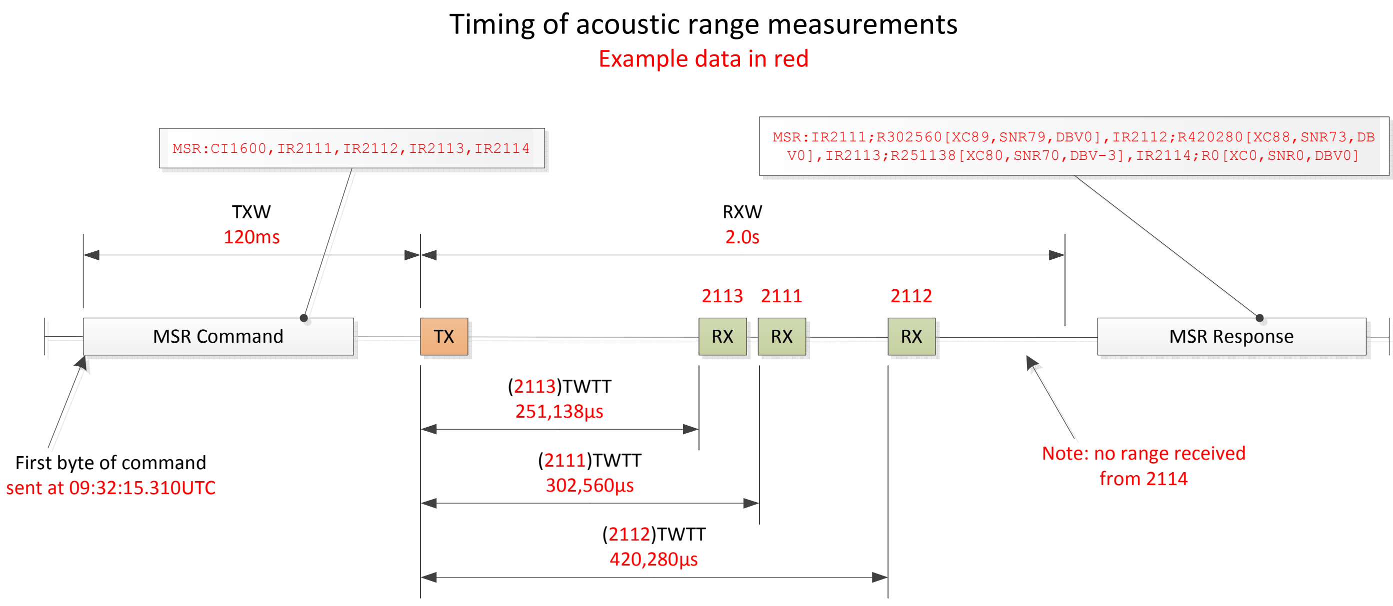
The command to enable this is:

```
DIAG:XC,SNR,DBV
```

Full details of the acoustic commands are available in the 6G command language documentation.

It is important to ensure that the time of validity for a range measurement is calculated correctly and accurately. Figure 3 shows how to calculate the TOV for ranges received using the MSR command, but the process is the same for the MR command.

Figure 3 - Timing of Acoustic Range Measurements



Time of validity of range measurement (TOV)

TOV = t_{cmd} + TXW + 0.5 * TWTT

t_{cmd} = Time of first byte of command (09:32:15.310UTC)
TXW = Transmit wait period (120ms)

Beacon	TWTT (µs)	Time of validity (UTC)
2111	302,560	09:32:15.581
2112	420,280	09:32:15.640
2113	251,138	09:32:15.556
2114	-	-

The Transmit Wait (TXW) period is the delay between receiving the first byte of the command and sending the acoustic signal. The Receive Wait (RXW) is the timeout period, i.e. the amount of time the transceiver will wait to receive a range reply from a beacon. The response message will be transmitted from the AvTrak serial port either after all ranges have been received, or after the RXW period has expired.

The TXW and RXW are user configurable. The TXW must be long enough for the AvTrak to receive the entire command message at the configured baudrate. A minimum of 120ms is recommended. The RXW should be as short as possible based on the maximum range expected in operation, in order to avoid long waits if a range is missed.

The user must not send a MR or MSR command until the previous range reply has been received.

Note: The AvTrak 6 has a watchdog timer that causes the device to be unresponsive for a short period, about once every 17 minutes. This means that it is possible that the device could occasionally fail to return a range reply. For this reason it is recommended that the user implement a timeout for range replies in order to avoid waiting indefinitely for the AvTrak to reply before sending the next range command.

PSONLVR and PSONLBLBCN messages must be received by the Lodestar at least once every 180 seconds, or LBL observations will be rejected. It is recommended that the user send a PSONLVR and PSONLBLBCN message with every PSONLOBS message.

5.4.2. Commands

The following Lodestar commands are used to configure LBL aiding (see Command & Control documentation[1] for full details):

```
IN <port> MSG + PSONLBLBCN
```

This tells Lodestar to accept PSONLBLBCN, PSONLVR and PSONLOBS messages on the selected UART [0-4] or IP port.

```
INS USE + LBL
```

This configures Lodestar to use LBL aiding

```
LBL SIGNAL <min SNR> <max SNR rel LPF> <min SL> <max SL rel LPF> <tau>
LBL RANGE <min> <max> <max range rate> <max error>
```

These commands configure the LBL pre-filtering

5.4.3. Monitoring

For every PSONLOBS message received by the Lodestar, an ObStLBL output message is generated which contains information on whether the update was accepted or rejected by the INS and any reasons for rejection if applicable. See messages documentation[2] for details.

5.5. DVL Aiding

A DVL provides accurate 3D measurements of velocity with respect to the seabed. The INS uses this information to perform 'dead-reckoning' between absolute position observations.

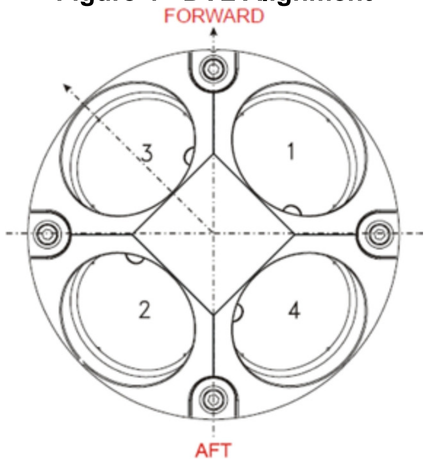
5.5.1. Triggering

The DVL can be configured to be free running (i.e. providing a constant stream of observations), or triggered. Lodestar can provide a trigger pulse for the DVL from any of its trigger ports. See commands below for configuration details.

5.5.2. Mounting

The mounting angles of the DVL used on the vehicle can be accurately calculated using post-processing software (see DVL Calibration, below). Therefore a variety of mounting angles can be supported but the default DVL configuration will assume the DVL is mounted with the transducers facing towards the seabed and the alignment mark (also referred to as navigational groove) aligned to the forward direction of the vehicle reference frame.

Figure 4 - DVL Alignment



5.5.3. DVL Calibration Procedure

By collecting a set of data containing various dynamics, the precise mounting angles of the DVL with respect to Lodestar can be calculated. The logged data is processed offline using supplied software and the misalignments are then configured in the Lodestar.

The exact sequence of manoeuvres to be carried out during calibration will be discussed as it will be dependent on vehicle and operational constraints.

Note: Accurate GPS aiding could result in very good DVL calibration in shallow water.

5.5.4. Inputs

DVL data should be fed into Lodestar from the DVL in the form of binary PD0 or PD4/5 messages (PD4 recommended). See messages documentation[2] for details.

5.5.5. Commands

The following commands are used to configure DVL aiding (see Command & Control documentation[1] for full details):

`IN <port> MSG + DVL`

This tells Lodestar to accept PD0 and PD4/5 messages on the selected UART [0-4] or IP port.

`DVL LA <d.d> <d.d> <d.d>`

This sets the lever arms in metres, forward starboard and down from the CRP to the DVL.

`DVL MA <d.d> <d.d> <d.d>`

This sets the mounting angles (degrees) of the DVL.

`INS USE + DVL`
This configures Lodestar to use DVL aiding

`DVL TRIG <port>` (This is the TRIG number [1-4], or ‘none’)
This sets the trigger output port for the DVL. Its parameters preconfigured – they can be changed subsequently if required by using the TRIG commands.

If a DVL TRIG port command is sent the default TRIG port settings are:

```
TRIG <port> ACTIVE 1
TRIG <port> WIDTH 10.0000
TRIG <port> PERIOD 500.000
TRIG <port> START 20.0000
TRIG <port> INPUT 0
TRIG <port> FILTER 0
TRIG <port> NRZ 1
TRIG <port> LINK NONE
```

`DVL OPFORMAT <ASCII|BINARY>`
This sets the DVL output data format input to the Lodestar to be either HEX-ASCII or BINARY.

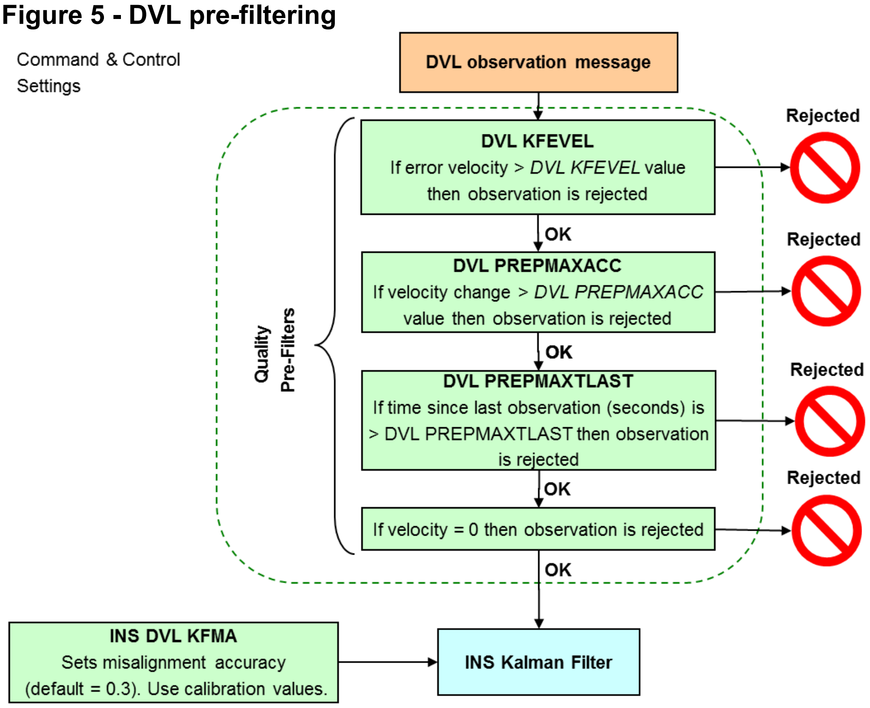
`DVL LATENCY <d.d>`
This sets the latency of the DVL in seconds. Values allowed are -0.1 <= d <= 2.0.

`DVL SFERROR <d.d>`
This sets the scale factor error of the DVL.

```
DVL PREPMAXTLAST <d.d>
DVL PREPMAXACC <d.d>
DVL KFEVEL <d.d>
```

These commands configure the pre-filtering of DVL data, as shown in Figure 5.

Figure 5 - DVL pre-filtering



5.5.6. Monitoring

For every DVL message received by the Lodestar, an ObStDVL output message is generated which contains information on whether the update was accepted or rejected by the INS and any reasons for rejection if applicable. See messages documentation[2] for details. Note that as the output rate of the DVL is usually quite high, so the rate of ObStDVL messages from Lodestar will be correspondingly high.

5.6. GPS Aiding

Lodestar can use position data from GPS for aiding. Even if it is not being used for aiding, GPS data should still be sent to the Lodestar for logging, as it can be very useful in post-processing and performance analysis. If the vehicle surfaces for a brief period to obtain a GPS position fix then this fix can be used to constrain the INS drift before and after the fix in post-processing. GPS data is also required for time synchronisation (see section 5.2) and AHRS aiding (see section 0)

5.6.1. Inputs

GPS position data should be fed into Lodestar using the NMEA 0183 standard 'GGA' message.

5.6.2. Commands

The following commands are used to configure GPS aiding (see Command & Control documentation[1] for full details):

`IN <port> MSG + GPS`
This tells Lodestar to accept GPS messages on the selected UART [0-4] or IP port.

`GPS LA <d.d> <d.d> <d.d>`
This sets the lever arms in metres, forward starboard and down from the CRP to the GPS antenna.

`GPS QUALITY <d> <d>`
This sets the minimum and maximum quality level to be accepted by the INS. The quality value is reported in the GGA string after latitude and longitude.

`INS USE + GPS`
This configures Lodestar to use GPS aiding

`INS GPS USEVERTICAL <1|0>`
This configures Lodestar to use 3D GPS aiding. This can be useful to correct for tidal changes during long periods at the surface.

`INS GPS KFQMAX <d.d> <1|0>`
If enabled, this sets the maximum HDOP value to be accepted by the INS. The HDOP is reported in the GGA string after the number of satellites.

5.6.3. Monitoring

For every GGA message received by the Lodestar, an ObStGPSPos output message is generated which contains information on whether the update was accepted or rejected by the INS and any reasons for rejection if applicable. See messages documentation[2] for details.

5.7. Pressure (depth) Aiding

Lodestar supports either pressure or depth aiding input to determine the depth of the INS. There are several factors that should be considered during the planning phase.

5.7.1. Pressure to Depth Conversion

In the case of a pressure aiding input the Lodestar performs a simple pressure to depth (metres) conversion. The pressure to depth conversion scale factors are provided below:

Pascal to Metres: 0.00009938710
PSI to Pascals: 6894.757293168361

If there is a requirement for a different pressure to depth conversion calculation to be used, the operator can either:

- Convert the pressure sensor data to metres using the required conversion and pass this to the Lodestar as a depth (m) aiding message. (recommended)
- Apply a pressure depth offset to the system at operating depth so the INS depth is consistent with the intended depth datum.

- Convert the INS depth output from the system to another datum using the provided conversion calculations.

5.7.2. Surface Pressure
Most pressure sensors will measure ambient air pressure at the surface. This is the equivalent of approximately 10 metres of water depth. Lodestar allows the operator to measure the surface pressure on deck and remove it from any subsequent depth calculation. Depending on project requirements surface pressure may be removed as described above or the INS depth could also include surface pressure – this should be decided at the planning strange.

5.7.3. LBL References
Whichever method or configuration of pressure depth is used, the INS depth should always be consistent and relatively accurate to any LBL reference depths.

5.7.4. Inputs
Pressure can be fed into Lodestar from a depth sensor using any of the following formats:

- Paroscientific Digiquartz message format, referred to in the messages documentation as PRDDIGIQ[KPA/M/PSI]
- Valeport Midas SVX2 message format (PRDSVX2DBAR)
- Tritech Winson (WINSON)
- Keller pressure sensor (PRDKELLBAR)

Depth in metres can be fed into lodestar using the PRDSONDEPM message

See messages documentation[2] for full details.

5.7.5. Commands
The following commands are used to configure depth aiding (see Command & Control documentation[1] for full details):

`IN <port> MSG + <msgname>`
This tells Lodestar to accept the desired message on the selected UART [0-4] or IP port.

`PRESS LA <d.d> <d.d> <d.d>`
This sets the lever arms in metres, forward starboard and down from the CRP to the pressure sensor.

`PRESS OFFSET <d.d>`
This sets the offset in metres. The offset is subtracted from the measured pressure for all types of pressure input.

`INS USE + PRESS`
This configures Lodestar to use depth aiding

5.7.6. Monitoring
For every pressure/depth message received by the Lodestar, an ObStPDepth output message is generated which contains information on whether the update was accepted or rejected by the INS and any reasons for rejection if applicable. See messages documentation[2] for details.

5.8. Zero Velocity Update (ZUPT)
If the vehicle is known to be completely static, e.g. resting on the seabed, then a zero velocity update can be sent to the INS which will prevent the solution from drifting.

5.8.1. Commands
To initiate a zero velocity update, send the following command sequence to Lodestar:

```
INS USE - DVL
INS USE + ZUPT
```

To end a zero velocity update, send the following command to Lodestar:

```
INS USE – ZUPT
INS USE + DVL
```
(if applicable)

Note that DVL aiding must be disabled during a ZUPT.

See Command & Control documentation[1] for full details

`ZUPT MAXVEL <d.d>`
This sets the maximum velocity (m/s).

5.8.2. Monitoring
The INS may reject zero velocity updates (especially if the vehicle is not completely static). The system will output ObStZUPT messages regularly while in ZUPT mode. This message contains information on whether the update was accepted or rejected by the INS. See messages documentation[2] for details.

5.9. Sound Velocity
Sound velocity is used for compensating DVL observations.

5.9.1. Inputs
Sound velocity can be fed into Lodestar in the following ways:
- From a Valeport sound velocity sensor using the 'VALEPORT' message format
- From any source using the 'PSONSS' message format
- From any source using the `INS XSV` command
- Calculated from the DVL temperature sensor and `INS XSAL` (salinity) command

See messages[2] and commands[1] documentation for details.

5.9.2. Commands
The following commands are used to configure depth aiding (see Command & Control documentation[1] for full details):

`SVS TYPE <VALEPORT|PSONSS|MANUAL|AUTO|NONE>`
This defines the type of Sound Speed sensor used.

Type AUTO computes the sound velocity using the Chen & Millero equation. It gets the temperature from the DVL, pressure from the pressure sensor and salinity from the `INS XSAL` command.
Type MANUAL allows the user to set the sound velocity using the `INS XSV` command.

`INS XSV <d.d>`
This sets the sound speed, in metres per second

`INS XSAL <d.d>`
Sets current salinity of Sea-water. It is measured in parts per thousand (ppt) [‰].

5.10. System Outputs
The main output of the INS is the NAV message. The NAV message contains timestamped position and attitude data plus velocities, angular rates and accelerations. The full details of this message is described in the messages documentation[2].

There are a number of other output messages that the system can generate, depending on the user's requirements. For example:

SON2 – AHRS roll, pitch and heading.
TMS – Time system message, allows 3rd party system to translate between Lodestar system time and UTC time.

5.10.1. Quality Control / Monitoring
The NAVQual message accompanies every NAV message and contains the 3D error estimate for the navigation solution. The full details of this message are described in the messages documentation[2].

The system also generates a BIST (Built In Self Test) message every two seconds which contains a large amount of status information. It is important to monitor this message in order to ensure that the system is behaving as it is intended to. Some of the information included in the BIST is listed below, but the full detail is available in the messages documentation[2].

- Sensor health status
- Comms status/activity
- SD card status
- Hardware health status
- Aiding status
- AHRS status
- INS status

Every time Lodestar receives an aiding message, it will output an Observation Status (ObSt) message. These messages should be monitored to ensure that the system is working correctly and not rejecting data unnecessarily.

5.11. Switching between aiding sources

Lodestar supports changing aiding modes while the INS is active. To support seamless transition between aiding that may have systematic differences (e.g. USBL to LBL) the default configuration will artificially increate the INS position uncertainty during the transition.

5.12. Data Logging

A configuration file will be provided that will ensure that all required log data required for QC and Post Processing is output on the primary Lodestar connection and also on the on-board SD card. It is recommended that:

- The data be received from Lodestar is recorded in separate multiplexed binary log files, e.g. a file every 10 minutes
- Shall support the recording of IMU data without any loss
- Lodestar files are named using a forever growing “file number” (e.g. 000123) and “UTC date time” (e.g. 20101117_1707) followed by job specific name/comment e.g. “startOfRunline1”

6. PC Utility

The Lodestar PC utility software can be used for maintenance tasks such as firmware download and manual configuration. Please see Lodestar AHRS manual for further details.

7. Post Processing

The Janus post processing and QC software can be used with the recorded Lodestar data explained in section 5.12. The Janus software is explained further in manual “Janus Software Manual 8254”. Note that the Janus software is dongle controlled. A dongle is provided with each Lodestar to allow for DVL calibration, QC checks and plotting. A dongle upgrade is required for any re-processing of navigation.

8. Messages

The table below provides a summary of useful messages that are sent to and from the Lodestar. The MID column indicates what Message ID is used in the multiplex protocol. Please see the messages documentation[2] for full details of the messages and the multiplex protocol.

Name	Notes	MID
	Inputs to Lodestar	
Command	Command and Control	0
ZDA	For Time Synchronisation	61
GGA	For GPS Aiding (or USBL aiding if sent with SID 4)	64
PSIMSSB	(From USBL System) For USBL aiding	152
PRDDPT	For Pressure Depth aiding (PRessure Depth NMEA DPT metres)	147
PRDSONDEPM	For Pressure Depth aiding (PRessure Depth pSONDEP Metres)	145
PRDDIGIQM	For Pressure Depth aiding (PRessure Depth DIGIQuartz Metres)	144
PRDDIGIQPSI	For Pressure Depth aiding (PRessure Depth DIGIQuartz PSI)	158
PRDDIGIQKPA	For Pressure Depth aiding (PRessure Depth DIGIQuartz KPA)	159
SVS	For Sound Velocity compensation	143
PSONSS	For Sound Velocity compensation	146
PSONLBLUOBS	Output from a LBL system with ranging data	163
PSONLBLBCN	Output from a LBL system for a Transponder	160
PSONLVR	Output from a LBL system, for Lever Arms	161
PD0	DVL data	141
PD4/5	DVL data	140
	Outputs from Lodestar	
TMS	Time System State Data	208
PSONTRG	Trigger status	129
ObStSUSBL	Subsea USBL observation status message	174
ObStPDEPTH	Pressure depth observation status message	176
ObStSVS	Sound Velocity observation status message	177
ObStDVL	DVL Observation status message	178
ObStGpsPos	GPS Observation status	172
obStLBL	LBL Observation status	179
Nav	Navigation Data	213
NavQual	Navigation Quality Estimate Data	214
SON2	AHRS Attitude	120
BIST	Built-In Self Test	217

9. Command & Control

Full details of lodestar commands are available in the command and control documentation[1]. A summary of useful commands is listed below:

9.1. File New and File Save

Function	Mnemonic	Purpose
New	SYS LOAD FACTORY	Restore Lodestar to factory default settings
Save	SYS SAVE FLASH	Save current Lodestar settings to flash memory
Save	SYS LIST	List all Lodestar settings
Save	SYS NONDEFAULT LIST	List all non factory default Lodestar settings

9.2. Lodestar Configuration and Diagnostic

Function	Mnemonic	Purpose
Shutdown	SYS SHUTDOWN	Turns off the Lodestar
Reset	SYS RST	Reboot the system
	GC RST	Reset Gyrocompass (AHRS) algorithm.
Gyrocompass Latitude	GC LAT	Set Gyrocompass Latitude
Lever Arms	IMU LA	Sets Lever Arms (Must perform INS RST and GC RST if modified)
Mounting Angles	IMU MA	Sets Mounting Angles (Must perform INS RST and GC RST if modified)
Serial Traffic	SYS UART	Returns the serial traffic % on all serial UARTS

9.3. Lodestar Connection and Lodestar Port

Function	Mnemonic	Purpose
Current LS Port	PORT	Returns the Lodestar port currently in use
LS Port I/O	PORT n	Lists all OP, LOG or IN messages configured on the specified port.
Configuration	OP LIST	Lists all OP parameters
Set serial config	OP SER	Sets the baud rate, number of data bits, the parity and the number of stop bits
Sets baud rate	OP BAUD	Sets the baud rate
Sets data bits	OP DATA	Sets the number of data bits
Sets parity	OP PAR	Sets the parity
Sets stop bits	OP STOP	Sets the number of stop bits
Sets protocol	OP PROT	Set signalling protocol (232, 485 …)
Set multiplex	OP MULTIPLEX	Sets if port is to output in binary or ascii format
Sets Ethernet Port	OP NET	Sets up the protocol for a network port
Configuration	OP LIST	Reads LS port settings

9.4. USBL

Function	Mnemonic	Purpose
Lever Arms	SUSBL LA	Sets or reads the USBL transponder lever arms
Set Input	IN <PORT> MSG + PSIMSSB Or IN <PORT> MSG + SUSBL *(for USBL GGA)*	Set USBL Input (see note below). • For PSIMSSB send MID 152 SID 0 to Lodestar • For USBL GGA (SUSBL) send MID 64 SID 4 to Lodestar
Remove Input	IN <PORT> MSG - PSIMSSB Or IN <PORT> MSG –	Remove USBL Input

	SUSBL *(for USBL GGA)*	
Beacon ID Filter	SUSBL TPDR <on|off> [<tpdrNo>]	Enables and then sets the beacon ID filter for incoming PSIMSSB messages
Configuration	SUSBL LIST	Read USBL settings

Note: Lodestar currently supports only one instance of each aiding sensor type. Therefore when adding aiding sensor input on a specific port, ensure that any other instances of that aiding sensor input are removed from any other Lodestar ports.

9.5. GPS

Function	**Mnemonic**	**Purpose**
Lever Arms	GPS LA	Sets or reads the GPS transponder lever arms
Set Input	IN <PORT> MSG + GPS	Set GPS Input (see note below)
Remove Input	IN <PORT> MSG - GPS	Remove GPS Input
Quality Limits	GPS QUALITY	Set minimum and maximum acceptable GPS quality level
HDOP Limit	INS KFQMAX	Set maximum acceptable HDOP value
Configuration	GPS LIST	Read GPS Settings

Note: Lodestar currently supports only one instance of each aiding sensor type. Therefore when adding aiding sensor input on a specific port, ensure that any other instances of that aiding sensor input are removed from any other Lodestar ports.

9.6. ZUPT

Function	**Mnemonic**	**Purpose**
Max Velocity	ZUPT MAXVEL	Set the maximum velocity during ZUPT
Configuration	ZUPT LIST	Read ZUPT Settings

9.7. LBL

Function	**Mnemonic**	**Purpose**
Lever Arms	N/A	These are updated from PSONLVR message
Set Input	IN <PORT> MSG + PSONLBLBCN	Set LBL Input (see note below)
Remove Input	IN <PORT> MSG - PSONLBLBCN	Remove LBL Input
Configuration	LBL LIST	Read LBL settings
LBL Range Rejection	LBL RANGE	Sets LBL Range Rejection Settings

Note: Lodestar currently supports only one instance of each aiding sensor type. Therefore when adding aiding sensor input on a specific port, ensure that any other instances of that aiding sensor input are removed from any other Lodestar ports.

9.8. Pressure Depth

Function	**Mnemonic**	**Purpose**
Lever Arms	PRESS LA	Sets or reads the Pressure Depth lever arms (m)
Offset	PRESS OFFSET	Sets or reads Pressure Offset (in metres)
Set Input	IN <PORT> MSG + • PRDDPT • PRDSONDEPM • PRDDIGIQM • PRDDIGIQPSI • PRDDIGIQKPA	Set Press Input (one of the following): PRDDPT PRDSONDEPM PRDDIGIQM PRDDIGIQPSI PRDDIGIQKPA
Remove Input	IN <PORT> MSG - • PRDDPT • PRDSONDEPM • PRDDIGIQM	Remove Press Input (one of the following): PRDDPT PRDSONDEPM PRDDIGIQM

	• PRDDIGIQPSI • PRDDIGIQKPA	PRDDIGIQPSI PRDDIGIQKPA
Configuration	PRESS LIST	Reads LS Pressure Depth settings

Note: Lodestar currently supports only one instance of each aiding sensor type. Therefore when adding aiding sensor input on a specific port, ensure that any other instances of that aiding sensor input are removed from any other Lodestar ports.

9.9. DVL

Function	Mnemonic	Purpose
DVL Lever Arms	DVL LA	Sets or reads the DVL lever arms (m)
DVL Mounting Angles	DVL MA	Sets or reads the DVL mounting angles (degrees)
DVL Trigger Port	DVL TRIG	Sets the DVL trigger port output
DVL Latency	DVL LATENCY	Sets the latency for the DVL
DVL Scale Factor Error	DVL SFERROR	Sets the scale factor error for the DVL
Data Format	DVL OPFORMAT	Set DVL data format to hex-ASCII or binary
Set DVL Input	IN <PORT> MSG + DVL	Set DVL Input
Remove DVL Input	IN <PORT> MSG - DVL	Remove DVL Input
Configuration	DVL LIST	Reads LS DVL settings

Note: Lodestar currently supports only one instance of each aiding sensor type. Therefore when adding aiding sensor input on a specific port, ensure that any other instances of that aiding sensor input are removed from any other Lodestar ports.

9.10. Sound Velocity

Function	Mnemonic	Purpose
Lever Arms	SVS LA	Sets or reads the lever arms (m)
Manual Sound Speed	INS XSV	Sets or reads current manual sound speed
Salinity	INS XSAL	Sets or reads current Salinity of Sea Water
Type	SVS TYPE	Sets or reads type of pressure sensor (one of): • VALEPORT • PSONSS • MANUAL • AUTO • NONE Note that AUTO can only be used if a DVL and PRESS aiding sensor have been configured (they supply temperature and pressure/depth for the automatic sound velocity calculation)
Set Input	IN <PORT> MSG + SVS	Set SVS Input
Remove Input	IN <PORT> MSG - SVS	Remove SVS Input
Power from LS C1	SYS EXTPWR C1	Set external power (12v) on C1 Port
Configuration	SVS LIST	Reads LS Sound Velocity settings

Note: Lodestar currently supports only one instance of each aiding sensor type. Therefore when adding aiding sensor input on a specific port, ensure that any other instances of that aiding sensor input are removed from any other Lodestar ports.

9.11. INS

Function	Mnemonic	Purpose
Configuration	INS LIST	Reads LS INS settings
Aiding	INS USE	Sets or reads the aiding messages for the AINS, e.g. INS USE SUSBL DVL PRESS Or INS USE + DVL INS USE – PRESS Aiding inputs supported:

		• GPS • SUSBL • DVL • PRESS • ZUPT • LBL
Reset	INS RST	Reset the INS

9.12. Time Synchronisation

Function	Mnemonic	Purpose
Configuration	TSYS LIST	Reads LS Time System settings
Set Input	IN <PORT> MSG + ZDA	Set (ZDA) Input
Type	TSYS SOURCE	Sets or reads the external UTC source to use; one of: • ZDA • ZDA_1PPS • NONE
Set Input	TSYS ZDA	Sets or reads the port number for GPZDA input (should be the LS multiplexed port) Cannot be used with TSYS SOURCE NONE
1PPS PORT	TSYS PPS	Sets or reads the port number for 1 PPS Cannot be used with TSYS SOURCE NONE/GPZDA
ZDA Arrives	TSYS PPSMODE	Sets or reads the mode of GPZDA and its corresponding 1 PPS Cannot be used with TSYS SOURCE NONE/GPZDA
Latency	TSYS ZDALATENCY	Sets or reads GPZDA latency in seconds Cannot be used with TSYS SOURCE NONE/GPZDA_!PPS
Reset	TSYS RST	Resets the time system
Trigger Edge	TRIG <PORT> ACTIVE	Sets or reads if the trig pulse is active high or low

9.13. PC & Lodestar Port Outputs

Function	Mnemonic	Purpose
Output Configuration	OP LIST	Lists all output configuration
Set Output	OP <PORT> MSG + <MSG> [RP <rpIndex> SRC <dataSrc>]	Lists the messages and their numbers or sets the messages to be output
Remove Output	OP <PORT> MSG - <MSG>	Removes the output message