PsiNav – Easy to Integrate High Precision Laser Guidance and Positioning Products

PsiNav is the suite of hardware and software products from Guidance Navigation Limited designed to provide the highest precision direction and position data which can be easily integrated into Automated Guided Vehicles (AGVs) and other mobile platform control applications. This range of complimentary products results from more than twenty years of development and delivery of unequalled precision navigation, positioning, and measuring systems and components to the AGV, marine transport and measurement industries worldwide.

Some key features of the PsiNav suite of products include:

- Measurement of range and bearing to yield unambiguous navigation data.
- Best in class bearing accuracy (better than 0.1 mrad).
- Uses low cost flat reflector tape for targeting.
- High frequency position update calculations performed enabling high vehicle speed operation. (30 msec response time).
- Choice of integrated single package scanner and navigational computer (LSi) or separate scanner and navigational computer (LSm) or stand-alone scanner (LS9) configurations to suit user requirements.
- Multi-scanner capability for LSm configuration option to reduce obscuration in low on vehicle mounting point applications.
- User selectable choice of industry standard serial communication interfaces. (RS422/RS232).
- USB and Ethernet connectivity is provided for easy firmware upgrade from a memory stick and data diagnostics acquisition respectively.
- Powerful integrated features which enable simple automated execution of essential but normally expensive set-up tasks such as site surveying.
- Comprehensive diagnostic data logging and report generation to simplify rapid site layout optimisation and blind-spot elimination.
- Easy to operate user friendly graphical interfaces of windows based configuration and diagnostic software.
- Additional FreeNav® option which provides an integrated safety sensor and target-less navigation capability to enable accurate operation in workspace areas where reflective target placement is sparse, impractical or impossible.
PsiNav Configuration Options

Guidance Navigation Limited offers PsiNav products in three hardware configurations.

Firstly there is an integrated scanner and navigation computer option known as LSi. This configuration is available in a single package combining the precision laser scanner and the navigation computer together. It is all housed within a light and tough ABS casing.

The second configuration option is for a stand-alone scanner (LS9) and navigation computer (PsiModule). This two component configuration is known as LSm.

The final configuration is for a stand-alone scanner (LS9 or LS10). This is for applications where Guidance Navigation’s algorithms and computation of the scanner output are not required. In such applications there are two product options, LS9 or LS10. LS9 provides standard RS422/232 serial output interface, whereas LS10 connects using a bespoke legacy serial protocol developed by Guidance for a specific customer in the very early days of laser scanner navigation.

LSi is intended for applications where a single package is desirable. LSm configuration offers advantages where the mounting position may benefit from a dual scanner system. The user can choose the integrated or modular configuration to best suit their vehicle layout requirements.

Design and Operating Principles

Automated guided vehicle navigation and the determination of exact position and direction of a mobile platform depends on knowing the vehicle or platform’s exact position in relation to an accurate map of its operating environment. This is an absolute requirement if your mobile platform is to function reliably and effectively. Therefore it is vital to have highly accurate position data that you can rely on. Through constant investment in development, and collaboration with the best academics in the field, Guidance Navigation Limited is committed to providing the most accurate and easy to operate guidance and positioning systems in the world. Our design principles are simple:

- Develop the most accurate, simplest and most reliable scanner system.

- Use sophisticated mathematical, Analog and Digital Signal Processing control and filtering algorithms to rapidly calculate the most accurate position and heading possible.

- Continue research and engineering to achieve continual improvement of the system’s capabilities.

Simplicity – The Key to Reliability

Guidance Navigation adopts the following approach to make our products both the most accurate and the most reliable in the world:

- Design a modulated laser scanner for greater accuracy and range.

- Construct a simple and robust system to maximise reliability.

- Use inexpensive flat reflectors that are easier, quicker, and cheaper to survey.

- Offer an integrated single package configuration (LSi) for most customer requirements, or a modular system (LSm) if customer needs call for a dual scanner configuration, or scanner only option (LS9) where no scanner data processing is needed.
The Choice of Laser Scanner Design Technologies

There are two major optical design technologies used in laser scanner systems for navigation and positioning:

- Pulsed – used by other laser scanner suppliers.

As we shall explain below, by using modulated lasers, Guidance Navigation scanners have the simplest design and the highest heading resolution and accuracy.

Modulated Laser Scanners (Guidance Navigation Limited)

Guidance Navigation scanners emit a continuous fan of modulated laser light. This produces an uninterrupted reflection once the beam strikes a target reflector which continues until the beam reaches the trailing edge of the target reflector. Then it gives an abrupt and easy to measure cessation of the reflection. This ensures that every target reflector gives an extremely accurate and consistent measurement on every scan.

Guidance Navigation scanners all use an infrared class 1 eye-safe laser, which is intrinsically safe for continuous use in environments where people are present and thus exposed to the laser radiation.

With our modulated laser and flat reflector system we achieve angular resolution of better than 0.1 mrad which is 0.006°. This is calculated and reported back to the main controller unit of the mobile platform it is fitted to at least every 30msecs. Hence very accurate heading and position control of even high speed vehicles can be achieved. (Guidance Navigation scanners are being used successfully in applications where mobile platforms are travelling at over 3 metres per second).

Pulsed Laser Scanners (Other Laser Scanner Suppliers)

Typically pulsed laser scanners emit bursts of laser light at a frequency of 14,400 Hz. This gives a maximum possible angular resolution of 3.5mrad which is 0.2° when the scanner revolves at 8 revolutions per second. To achieve workable data for navigation and accurate positioning the measured reflections received back from the targets then have to be compared to previous reflections to determine the centre of the reflective target. This is a more difficult, more ambiguous and hence less accurate, less repeatable and less reliable calculation method in comparison to Guidance Navigation’s modulated laser used with flat reflectors.

Simple Robust Reliable Scanner Design

Guidance Navigation scanners incorporate the following design concepts for increased service life and reliability:

- **Direct Motor Drive** – eliminates drift due to wear that is experienced by belt driven systems, resulting in greater reliability and longer operating life without the need for servicing. All slip rings have also been eliminated to ensure the extended life of reliable power and signal connections.
- **Simple Optics** – developed to minimise complex mirror systems. A vertical fan spreads the beam which increases the ability of the scanner to obtain the reflected signal reliably. This simple design means that Guidance Navigation scanner to scanner repeatability is extremely high.

Reflector Design

There are two main types of reflector design used in laser scanning for automated navigation and positioning:

- **Flat Reflectors** (preferred and recommended by Guidance Navigation)
- **Cylindrical Reflectors** (Required by other scanner manufacturers but still usable with Guidance Navigation scanners).
Flat Reflectors

Flat reflectors give an unrivalled level of accuracy because they provide an easy to measure unambiguous fixed point to survey by providing a very clear square wave trailing edge on the signal they reflect back to the scanner. This ensures that noise has less effect on measurement accuracy.

Flat reflectors are simple and inexpensive strips of retro-reflective tape. They can be installed on site in seconds. Unlike other scanners from other manufacturers, Guidance Navigation scanners do not require larger reflectors to be used for greater distances. Thus the same 50mm reflective strip targets can be used throughout the customer site.

Cylindrical Reflectors
(Required by Other Scanner Suppliers)

Cylindrical reflectors do not produce an easy to measure trailing edge, so more processing is required to calculate a fixed centre point for the reflector. In practice, this calculation can also be significantly affected by noise. They are more difficult to mount, more vulnerable to damage, and are more intrusive in the operating environment. Other manufacturer scanners also require different sized reflectors to be deployed for different distances throughout the layout.

Enhancing Navigation with Sophisticated Algorithms - The PsiNavigator Module

By using measured bearings from three reflectors and employing compensation for mobile platform speed, position and heading can be calculated by simple mathematical triangulation.

Guidance Navigation’s scanner systems selectively ignore reflection data from targets that are surplus to requirement for obtaining accurate navigation and positioning at any given location in the layout. This is achieved by measuring the distance of each reflector and only using the data from the reflectors that are best positioned to give high position accuracy in that particular part of the layout.

It might be thought that having more reflectors would improve accuracy but only three ideally located reflectors are required to obtain the best calculations. Extra reflectors do not add better data and would simply clutter and reduce the speed at which accurate position and heading information can be calculated.

Additionally our reflector association algorithms are used to simplify site reflector layout design and to disregard reflections that would give poor data. This technique eliminates stray reflections from damaged reflectors and other reflective surfaces. Additionally Guidance Navigation’s system does not require a site to be sub-classified into layers or areas and so simplifies installation and set-up.
Guidance Navigation Filter Algorithms

Once the system has selected the reflector data it will use, it still has to deal with unavoidable signal noise that is present. The control system of the application’s mobile platform requires current, highly accurate information about its position and heading, given only a sequence of observed bearing measurements from known reflectors, and speed from a wheel encoder.

Bearing measurement is extremely accurate but inevitably still includes error. Speed measurement can be degraded by noise factors such as wheel slip at any point in time, particularly when cornering or accelerating, and this is critical in calculating position when used in combination with bearing data. Dealing with these signal errors is where Guidance Navigation’s highly advanced correctional computation tools come into their own.

A specifically developed Guidance Navigation Kalman filter combines knowledge of noise levels and confidence levels of current inputs to update estimated position in a mathematically robust and highly accurate way.

This digital signal processing technique produces a very highly accurate calculation of x and y coordinate position and heading angle. It also caters for the sort of sensor performance degradation that occurs in any mechanical system such as encoder wear causing drift or reflectors being damaged.

The complex filtering and mathematical control algorithms discussed above are done by the navigating computer component of the PsiNav system known as the PsiModule. It assimilates the range and bearing inputs from the laser scanner along with inputs such as speed supplied to it by the host mobile platform controller. It then rapidly processes these inputs to provide position and bearing data to the mobile platform’s controller. Both the LSi and LSM configuration options of the PsiNav system are powered by the host platform’s own power system of 24V dc (+/- 2V) and power consumption is typically only 6.5W in the case of LSi. Communication between PsiNav and the vehicle control system is via industry standard protocols such as RS422/232 at user selectable baud rates and is electrically noise-free opto-isolated. Both LSi and LSM configurations have Ethernet interconnect capability. This enables remote connection to the units for diagnosis and performance monitoring.

System Diagnostics

A four-state flag protocol provides a user-friendly measure of the current navigation and position calculation performance of the system. The four states: Good; Normal; Uncertain and Lost are particularly useful during commissioning of the site layout and set-up.

System logs are automatically produced by the LSi or the PsiModule and can be downloaded using FTP via Ethernet. This enables rapid diagnostics of navigation, mobile platform sensors, or environment layout problems to be performed.

The PsiNav Software (PsiConsole)

The user interface software of the PsiNav suite is known as PsiConsole. It provides a graphical windows interface that is very easy to use and enables rapid reflector placement optimisation and work environment automatic surveying. The user simply drives the vehicle around the work area and the PsiConsole software automatically records calculations of the range and bearing of reflectors as the area is traversed. New reflectors can be added to improve coverage of the entire workspace and reduce blind spots and regions of poor navigation accuracy, which are clearly displayed on the screen in PsiConsole to indicate where extra reflectors should be employed. The site layout can be optimised very quickly and without the need for an expensive manual workspace survey. This flexibility enables workspace layouts to be changed at will without costly delays.
FreeNav® – Accurate Navigation in Untargeted Areas

In some parts of a customer’s process it may be impossible or impractical to install target reflectors. Examples of this could be the loading of road-going trucks, deep pallet stacking or long corridors where transient objects often block reflectors. In such an untargeted environment we cannot expect to achieve the positional accuracy at the speed needed for factory navigation that we can obtain in targeted areas. However, there are many untargeted applications where sufficient accuracy to perform the desired task at the desired speed may be required. To achieve this Guidance Navigation offers more sophisticated techniques and state of the art algorithms. Thus the Guidance Navigation system can operate in both targeted and untargeted environments and freely move between the two.

Transition from Targeted To Untargeted Areas

Consider the application below of loading a road-going truck as a typical example of the requirement for the mobile platform to be able to transition between a targeted and an untargeted area:

FreeNav® SLAM Algorithms

Utilising Simultaneous Localisation and Mapping (SLAM) advanced navigation algorithms Guidance Navigation offers the option of FreeNav®. This provides increased flexibility and scope of operation for automated mobile platform guidance. The algorithms developed jointly with Oxford University allow the system to build up a geometrically accurate map of a previously unknown environment, whilst at the same time enabling the mobile platform to keep track of its current position.

SLAM incorporates a number of advanced mathematical techniques to use the data that is provided by the standard safety scanner, which is fitted to the mobile platform for the primary function of preventing the vehicle from colliding with transient objects, to successfully navigate in untargeted areas. Guidance Navigation’s Free-Nav® algorithms achieve top class positional accuracy in even the most demanding environments. SLAM solves the age-old automated guidance ‘chicken and egg’ conundrum of needing a good map to be able to determine where the mobile platform is, but needing to know where the mobile platform is to build a good map. Maps are built up by measuring distances and directions of

obstacles iteration by iteration. However, if uncorrected the map becomes increasingly inaccurate and thus useless. SLAM compensates for this problem by comparing current sensor data with previous recent sensor data to build a map of the environment. This map is coordinated and referenced to the map of target reflectors in the targeted areas and so transition between two such areas is seamless. Continuing joint development with leading academics means that accuracy continues to improve as yet more sophisticated algorithms are produced. More and more applications without targets will be able to be achieved as this development continues.

Guidance Navigation Engineering Resource

All Guidance Navigation’s products have been market driven. That is to say they are the result of us designing and engineering a product to meet customer application requirements. Often products have been designed in partnership with customers to produce the best and fastest results. Our development engineers have many years of experience in automated vehicle guidance, embedded microcontroller, DSP, FPGA, laser optics, microwave radar, precision analog electronics, advanced software control algorithm and image processing design. Guidance Navigation Limited works closely with leading academic institutions such as Oxford University, Cambridge University and University College London (UCL). Over many years Guidance Navigation has commissioned and collaborated on PhD level research to forward technology with the above institutions. Many of our current senior management and development personnel started out with the company on such PhD collaborative projects.

This expertise has enabled us to produce optimal solutions for many applications. We recognise that our success depends on your success and our engineers work very closely with your design team to achieve this. Guidance, navigation and position measurement are our business, and our depth of engineering talent and accumulated expertise is available to you to help you produce new products with rapid time to market at minimal development cost. We have application experience and provide expert assistance in all areas of navigation and guidance implementation in applications such as automated warehousing, hazardous industrial environments, hospital transportation, operating theatre assistance, pharmaceutical research and production, automated stage and scenery, nuclear processing, automotive assembly, port automation, hazardous environment precision material thickness measurement, and many more.

As a consequence of our customisation capability, what started as special products have become available as standard product options. LSi and LS9 are available to IP65 enhanced environmental rating specification. In addition they can all be ordered as extended operating range higher power variants. We can offer specially designed products for usage in cold store, freezer, and cold climate outdoor applications.

In short, at Guidance Navigation Limited we are driven by our customers’ requirements. Our industry leading products and engineering expertise are focused to ensure your application succeeds.
### Whole Product Range Common Data Scanner

<table>
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<tr>
<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Ingress Protection</td>
<td>IP54 (standard) or IP65 (Extended)</td>
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<tr>
<td>Vibration Tolerance</td>
<td>To IEC 68</td>
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<tr>
<td>Laser Safety</td>
<td>Eye-safe to Class 1 EN 60825</td>
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<tr>
<td>EMC</td>
<td>EMC Directive 2004/108/EC; EN 61000-6-2; EN 61000-6-4</td>
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<tr>
<td>Reflector Range</td>
<td>1m – 50m (Extended range versions available)</td>
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<tr>
<td>Target Type</td>
<td>Flat, retro-reflective, uncoded</td>
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<td>Target Width</td>
<td>50mm</td>
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### LSi Specific Data

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<tr>
<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Dimensions</td>
<td>Height - 200mm; Body Ø – 125mm; Flange Ø – 167mm</td>
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<tr>
<td>Weight</td>
<td>1.83kg</td>
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<tr>
<td>Operating Temperature</td>
<td>0°C to 45°C</td>
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<tr>
<td>Construction</td>
<td>ABS</td>
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<tr>
<td>Communication Interfaces</td>
<td>RS422/232 (M2M); USB (firmware upgrade); Ethernet (diagnostics/setup)</td>
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<tr>
<td>Power Consumption</td>
<td>6.5W (excluding start up and USB connection)</td>
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<tr>
<td>Supply Voltage</td>
<td>22-26Vdc (100mV max ripple)</td>
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### LS9/LS10 Specific Data

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<th>Feature</th>
<th>Specification</th>
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<tr>
<td>Dimensions</td>
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<td>Weight</td>
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<td>Operating Temperature</td>
<td>-10°C to 55°C</td>
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<td>Construction</td>
<td>Powder coated machined aluminium</td>
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<td>Communication Interfaces</td>
<td>RS422 (LS9); Bespoke (CAT) serial interface (LS10)</td>
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<td>Power Consumption</td>
<td>14.4 W (typical excluding start up)</td>
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<td>Supply Voltage</td>
<td>22-26Vdc (100mV max ripple)</td>
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### PsiModule Data

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<th>Feature</th>
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<tbody>
<tr>
<td>Position/Heading Accuracy</td>
<td>Better than 4mm/ better than 0.1mrad (0.006°)</td>
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<td>Maximum L9 Scanners per module</td>
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<td>Maximum number of targets</td>
<td>65535</td>
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<tr>
<td>Dimensions</td>
<td>Height 167mm; width 150mm; depth 33mm</td>
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<td>Vibration Tolerance</td>
<td>To IEC 68</td>
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<td>Operating Temperature</td>
<td>0°C to 55°C</td>
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<td>Power Consumption</td>
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<td>Supply Voltage</td>
<td>22-26Vdc (max 100mVs ripple)</td>
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