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Technical Overview
IS-900 Motion Tracking System

Brief Introduction & Synopsis of the Operation of the IS-900

The InterSense IS-900 Motion Tracking System, commercially introduced in 1999, was developed in conjunction with a Navy SBIR program. To date, there are over 500 IS-900 systems in the field today with the majority of applications found in the military sector (flight simulators, weapon training systems, etc..), industry (oil & gas, automotive) and university research labs.

The system is a 6 degree of freedom motion (6-DOF) tracking system based on a hybrid technology of inertia and ultrasonic tracking. The position and orientation of the tracking stations are determined by the output of the accelerometers and gyros. Drift correction is accomplished in our advanced kalman filter by fusing the output of the inertial sensors with range measurements obtained from the ultrasonic components. The result is full 6-DOF data that is very smooth, precise, and free from jitter.

Advantages of the IS-900 technology include:

- Immune to metallic, acoustic, and optical interference
- Sensor design eliminates acoustic transmitter “line of sight” blockage
- Consistent accuracy over entire tracking volume
- Applications range in size from small cockpit simulators to large broadcast studios
- One-time system calibration performed during initial installation with accurate position mapping of acoustic transmitters
- Superior motion prediction algorithms
- Wireless tracking devices
- Integration of tracking devices into OEM applications

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System Components & Configuration

Figure 1 illustrates the configuration of the hybrid inertial-acoustic tracking system. The IS-900 hardware is made up of SoniStrips™, Tracked Devices or Stations, and the Processor Unit. The drawing illustrates the IS-900 being used to track two inertial/acoustic devices. The SoniStrip constellation transmits 40 kHz ultrasonic signals that are received by the tracked devices. The inertial component in the tracked station calculates orientation and position updates. The acoustic components prevent drift accumulation to provide full 6-DOF data sent out via an RS-232 connection.

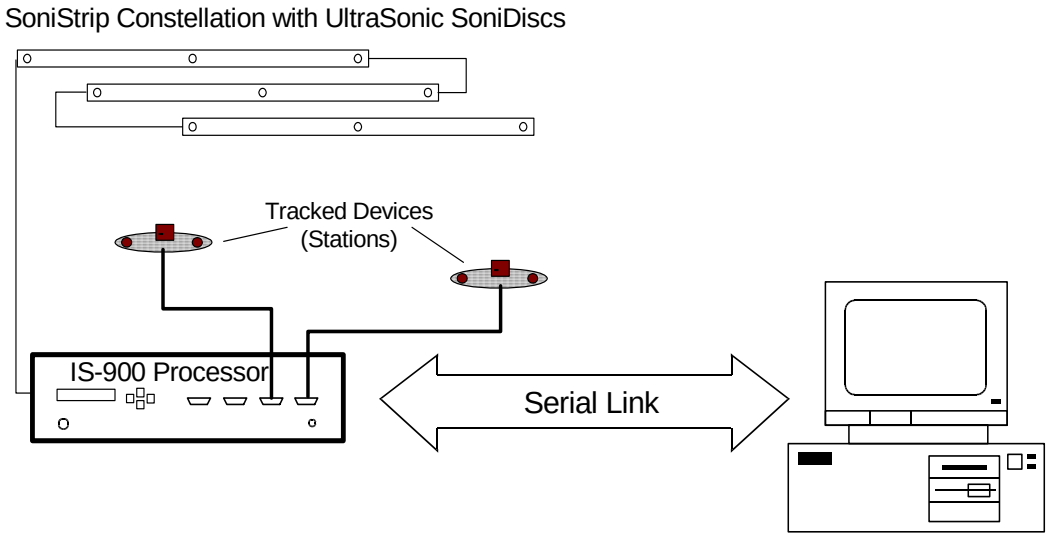

Figure 1 – IS-900 HW diagram

The IS-900 has expansion capability up to 4 tracked stations. Since each tracking station is pre-configured, your IS-900 automatically registers each station type and its physical connection to the IS-900 base processor upon power up. The IS-900 SoniStrips are designed for mounting above your tracked space in flexible configurations to allow use in a wide variety of large area tracked environments.

IS-900 Processor

The IS-900 Processor uses specialized firmware to control several independent microprocessors used throughout the system. Shown in Figure 2, the Processor has four front panel inputs for tracked stations, a front panel LCD status indicator, and four back panel SoniStrip hub connections (to support a total of 48 SoniDiscs). A SoniStrip Expansion hub can be added for additional SoniStrips

Figure 2 – IS-900 Processor

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SoniStrips™ and fixed SoniWing™ Constellation acoustic pulse transmitters

The SoniStrips and SoniWing shown in Figure 3 have ultrasonic SoniDisc transponders that receive addressed signals from the Base Processor Unit and transmit ultrasonic pulses in response. The acoustic transmission beam width for each SoniDisc is adjusted for wide-angle coverage (approx. 70-degree cone angle) to maximize the tracking area.

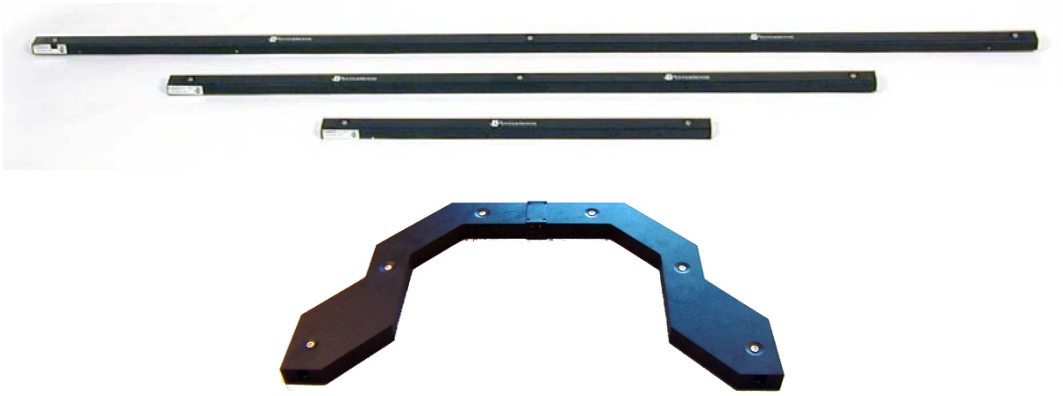

Figure 3 – IS-900 SoniStrips and SoniWing

The IS-900 uses an acoustic time-of-flight (TOF) ranging system to prevent position and orientation drift. For maximum accuracy and resolution, acoustic range measurements are made with unidirectional TOF measurements from the SoniStrip transmitters to the Tracked Stations. The SoniDiscs' acoustic pulses are detected by the microphones that are integrated into the Tracked Stations

First a command from the Processor triggers a SoniDisc transmitter in the SoniStrips to send a 40 kHz ultrasonic pulse. At the same time, separate timing counters are started in each of the Tracked Stations and then halted by the arrival of the unique acoustic pulse signature. Making use of the speed of sound (which is calculated from the measured ambient temperature), range measurements are obtained and used to compute position.

SoniStrip and SoniWing Mounting and Configuration

SoniStrips are normally mounted from the ceiling over the desired tracking workspace. To increase the flexibility of this system, the IS-900 has been designed with different sized SoniStrips for mounting in a variety of immersive environments (CAVE, ImmersaDesk, ReaCTor, PowerWall, HoloBench, CUBE, etc.). The user is able to position SoniStrips in most environments, including confined spaces such as virtual workbenches, automobiles, and cockpit simulators. Once installed, the user must calibrate the SoniStrip Constellation by measuring the Cartesian x, y, z coordinates of each SoniStrip and enter this information using the constellation Configuration Utility Program provided with the system. The process of calibration should be performed by a trained technical representative. InterSense provides installation and training upon request.

The SoniWing is a fixed constellation of ultrasonic SoniDiscs, which does not require special measurement or calibration. The exact locations of the SoniDiscs are factory calibrated by InterSense and included in the ISDEMO Constellation Configuration Utility Program provided with the system.

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Tracking Station Description

For InterSense motion tracking systems, a "**station**" is the tracked object or device, which by industry jargon is also called a **sensor**. An IS-900 tracks all stations in a 6-DOF mode, meaning each tracked device outputs an X, Y, Z position information along with a pitch, yaw and roll orientation information. In addition, the Wand and Stylus Tracking Stations output joystick and button information for use with the immersive environment software. Table 4 summarizes InterSense's IS-900 Tracking Stations.

Tracked Station	Function
MiniTrax Wand w/ Joystick Tracking Station	Five button with center push button joystick
MiniTrax Standard & High Accuracy Head Tracking Stations	Stereo glasses and Head Mounted Display (HMD) mounted
MiniTrax Hand Tracking Station	Right or left hand versions designed to mount on virtual reality interface gloves
Stylus Tracking Station	Two button

Table 4 – IS-900 Tracked Stations

Each tracked station uses InterSense's Station Protocol to combine raw data from the InertiaCube (angular & acceleration rates) with URM acoustic range data for transmission to IS-900 base processor. Station Protocol is data independent (i.e. it is a data bus architecture that can pass any data in the correct format back to the base processor), so it also passes the state information of the buttons and joystick to the IS-900 base processor.

InterSense currently provides three different types of tracked stations for use in immersive environments. All of these tracked stations use InterSense's advanced inertial MiniTrax technology combined with miniaturized digital acoustic position referencing components. These tracked stations include the MiniTrax 5-button wand with a center-click joystick, a standard MiniTrax Head Tracker and a High Accuracy MiniTrax Head Tracker.

In addition to InterSense's standard tracked stations, there are also new OEM devices being delivered with some IS-900 systems that integrate the IS-900 MiniTrax technology into custom 3rd party tracked stations. For example, the MiniTrax technology is successfully integrated into devices for multiple weapons systems and fire fighter training apparatus.

MiniTrax Head Tracker

The MiniTrax Head Tracker (Figure 5) is a lightweight, ergonomically designed tracking device for use on stereo glasses, head mounted displays and any item requiring tracking in the virtual environment. It is available in both a standard and high accuracy version

In the standard version, there are two miniature acoustic receiver microphones integrated into the MiniTrax Head Tracker. Each miniature receiver microphone has a reception cone angle approaching 180°. The microphones are positioned at a 45° angle pointing up and forward to optimize tracking in both ceiling (horizontal) and immersive screen (vertical) mounted SoniStrip Constellation configurations.

The high accuracy version has four acoustic receiver microphones with two positioned upward and two facing to the back of the device. The High Accuracy MiniTrax Head Tracker is ideal for applications requiring higher orientational accuracy, as required in augmented reality systems, for example.

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Figure 5 – MiniTrax Head Tracker on stereo glasses and the High Accuracy Head Tracker

MiniTrax Wand with Joystick

The MiniTrax Wand with center-click Joystick (Figure 6) is a tracked device that provides a simple and convenient way for the user to interact with virtual environments.

There are four miniature acoustic receiver microphones integrated into the MiniTrax Wand. During any given measurement cycle, only a pair of these microphones are active and listening for ultrasonic signals from the SoniDiscs that make up the position referencing constellation. Each miniature receiver microphone has a reception cone angle approaching 180°. With two pairs of microphones located on the top and bottom of the MiniTrax Wand, the wand will consistently track over a full 360° range of motion in all axes while under the active constellation array. The Wand will continue to track during brief (less than 1 minute) occlusion of one of the active pair microphones.

For interaction to the application, the wand has five buttons (four on top and one below) plus sixth button on the joystick and a four axis analog joystick that provides an easy "fly-through" navigation interface used in immersive virtual environments.

Figure 6 – MiniTrax Tracked Wand (wireless model shown)

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Wireless MiniTrax Modules

All MiniTrax tracked stations can be operated without cabling to the IS-900 processor by using the IS-900 Wireless Modules. The Wireless Modules have two components—a receiver component that plugs into the IS-900 Processor and a rechargeable, battery operated transmitter that is either integrated into the tracked station (IS-900 Wireless MiniTrax Wand—Figure 8), or connected to a small, body worn transmitter that plugs directly in to the MiniTrax Station (MiniTrax Head or Hand Tracked Stations—Figure 7). Photos of the IS-900 MiniTrax Wireless Modules are included here for reference.

Figure 7 – IS-900 Wireless MiniTrax Head Receiver, Head Tracker and Transmitter components (left to right)

Figure 8 – IS-900 MiniTrax Wireless Wand and Receiver components

Applications

Due to the flexible configuration, the IS-900 is used in numerous applications. The following is a brief summary of the most common. Please contact us for more information on each application.

Immersive Environments (CAVEs, Powerwalls, etc…)

- Seismic analysis and well planning on oil & gas fields
- Virtual automotive design and analysis

Military Simulator Programs

- Fixed Wing and Rotary Flight Simulators
- Weapon Training Systems (i.e. Stinger Missile)
- Homeland Defence
- Tank Simulators

Also used in systems with Head Mounted Displays, Camera Tracking for Virtual Sets, Welding Simulators, Fire Fighter Training, Augmented Reality

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Technical Information

- Max serial rate: 115.2 kbaud
- Genlock options: NTSC, PAL, TTL
- Latency: 4 ms (without prediction)
- Interface: RS-232 or Ethernet
- Protocol: Industry Standard, SDK available
- Wireless option for tracking devices operating at a spread spectrum 2.4 GHz

Device specifications

	Wand	Hand Tracker	Head Tracker	High Accuracy Head Tracker
Resolution (RMS)				
Position (X/Y/Z)	0.75 mm	0.75 mm	0.75 mm	0.75 mm
Angular (P/R/Y)	0.05˚	0.05˚	0.05˚	0.05˚
Wireless Position	1.5 mm	1.5 mm	1.5 mm	1.5 mm
Wireless Angular	0.10˚	0.10˚	0.10˚	0.10˚
Static Accuracy				
Position	2.0 – 3.0 mm	2.0 – 3.0 mm	2.0 – 3.0 mm	2.0 – 3.0 mm
Angular (P/R, Y)	0.25˚, 0.50˚	0.25˚, 0.50˚	0.25˚, 0.50˚	0.25˚, 0.25˚
Wireless Position	3.0 – 5.0 mm	3.0 – 5.0 mm	3.0 – 5.0 mm	3.0 – 5.0 mm
Wireless Angular	0.50˚, 1.00˚	0.50˚, 1.00˚	0.50˚, 1.00˚	0.50˚, 0.50˚
Size (WxLxH)	10.0 x 17.0 x 5.5 cm	10.0 x 8.0 x 4.4 cm	9.4 x 2.7 x 2.7 cm	20.5 x 3.0 x 2.7 cm
Weight	140g wired 220g (wireless)	44g	23g	38g

General specifications

- Base processor dimensions: 16.75 x 12 x 3.5 in (425.45 x 304.8 x 88.9 mm)
- Rack mounting options are available
- Standard cable length of tracking devices is 40 ft (13.3m)
- Maximum distance between base processor and the end of the SoniStrip daisy chain is 15 meters.
- Maximum cable length between tracking device and base processor is 15 meters.
- The distance between the tracking devices and the SoniStrip array should not exceed 4 meters.
- SDK available for Windows, Linux, IRIX, MAC platforms

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OEM and Custom IS-900 Configurations

Building on the standard interfaces and serial processor of the IS-900 system provides system integrators and OEM customers a broader range of options in deploying customized tracking configurations.

Custom Tracked Devices

The IS-900 MiniTrax devices use a standard communication interface to receive and transmit data from local auxiliary items such as the the buttons and joystick found in the IS-900 Tracked Wand. This interface is known as the Inter-IC (I^2C) Bus.

The I^2C bus is an industry standard interface developed by Philips nearly 20 years ago to establish a simple 2-wire communication standard between a variety of IC's and interface devices. The MiniTrax circuit board includes a 4-pin header for interfacing auxiliary digital and analog signals such as buttons and potentiometers into the tracker. Using this interface, OEM's and systems integrators can embed the IS-900 tracking sensors into their own 3D interaction devices, and pass all the data from their custom controls through the tracking system interface, taking advantage of the tracker's wireless link, if desired. The I^2C implementation allows up to 4 bytes of auxiliary data for input and output, simultaneously, from the MiniTrax board per cycle. By alternating input and output cycles, it would be possible, for example, to simultaneously read control signals from a variety of buttons and potentiometers and write feedback data to various indicators, LEDs, buzzers, or tactile displays.

Designers have the choice of using InterSense's existing 23 x 23 mm button/joystick board directly or as a reference design. It supports six digital I/O connections and two 12-bit analog inputs, or can be used as a development platform for implementing custom processor boards using the same processor and existing sample code.

Examples in Figure 9 custom tracked devices recently built by InterSense in cooperation with partners include the NVIS SX Virtual Binoculars & HMD, and the wireless Stinger missile trainer in cooperation with partners AEgis & EER.

Figure 9 - MiniTrax Tracked Virtual Binoculars, HMD, and Wireless Stinger Missile

Ultrasonic SoniDisc Configuration Options

As covered above in this document, standard IS-900 systems use an ultrasonic constellation consisting of 2 or 3 discrete transmitters (SoniDiscs) conveniently packaged in aluminum "SoniStrips" in both 4 and 6 foot lengths (two beacons in a 2 foot length). A typical system ships with six SoniStrips, which may be mounted either above or around an immersive display. With the standard SoniStrips, tracking areas covering up to 140 m^2 are possible.

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For additional flexibility, each SoniDisc can be discretely mounted in the tracking environment and provide a programmable volume control to support longer range applications. As shown in Figure 10, the Discrete SoniDisc can be mounted individually in a small, shielded enclosure

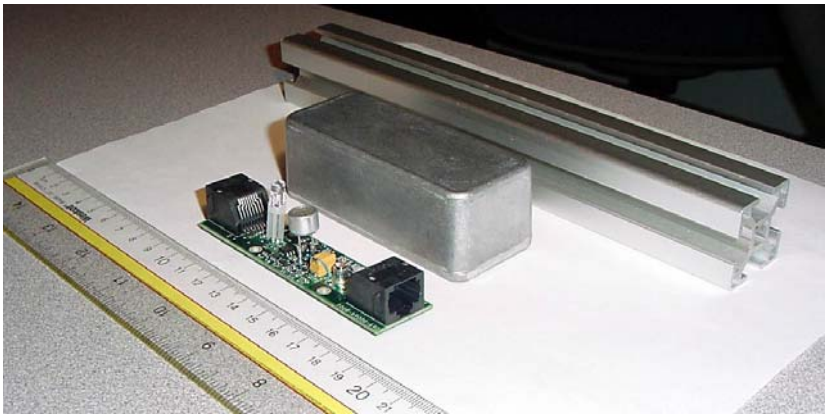

Figure 10 - Discrete SoniDisc mounting options

Tracking systems are being installed in a wide variety of environments including large spaces for studio, museum and entertainment applications down to small cockpit or desktop environments for flight simulators, design workstations or virtual training applications.

While the SoniStrip array addresses most standard immersive display applications, a modular approach to the ultrasonic array is desired to cover a larger range of tracking applications. With a typical installation of SoniStrips in a large room environment, the SoniStrips are mounted in a grid pattern on the ceiling, spaced roughly 1 meter apart. Once installed, the full array is measured with an optical sighting tool ("Total Station") to determine the exact location of each beacon. These measured coordinates are downloaded into the IS-900 processor to establish a tracking constellation reference for the environment.

For smaller installations, a fixed, factory calibrated beacon configuration provides a quick and simple way to set-up the tracking volume without the need for surveying. Shown in Figure 11, two fixed constellation configurations are now part of the standard IS-900 systems—the SoniWing, which uses six transmitters to track volumes up to 1.5 x 1.5 x 2 meters, and the SoniFrame, which supports nine ultrasonic transmitters for tracking volumes up to 2.5 x 2.5 x 3 meters.

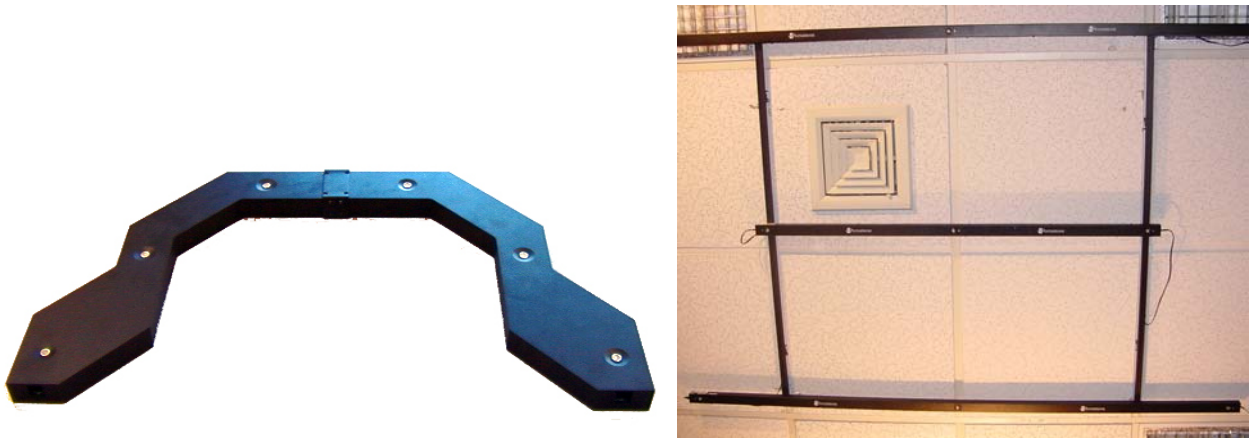

Figure 10 - SoniWing and SoniFrame mounted on ceiling

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In certain OEM or custom installations, the SoniDiscs are installed in specific positions. For these applications, each SoniDisc is mounted individually in its own package that can be interconnected with standard Ethernet CAT5 cabling. The transducer elements may be remotely mounted up to 15 cm from the SoniDisc electronics to provide very unobtrusive transmitter reference points for visually sensitive applications (like in a six-sided CAVE®).

Examples in Figure 11 show individual SoniDiscs embedded into the screen bezel for a welding simulator application and along the base of a SimuSphere™ 360 degree display dome for a Link Simulation & Training flight simulator.

Figure 11 – Discrete SoniDiscs installed in welding simulator screen bezel and at base of Link's SimuSphere™ Flight Simulator

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