

PNT X



Accelerate & Simplify PNT Testing

Spirent PNT X

Table of Contents

| | |
|--|----|
| PNT X Overview | 4 |
| PNT X Signal Generator | 4 |
| C50 X Host Controller | 4 |
| Infinite Scalability..... | 5 |
| GNSS Authorised Testing | 5 |
| GPS Authorised Testing..... | 5 |
| Galileo Authorised Testing | 5 |
| SimGEN Control Software | 6 |
| Ultimate Performance, Realism, Flexibility and Simplicity | 7 |
| Full GNSS Support..... | 7 |
| 2kHz System Iteration Rate | 7 |
| Remote Control - HIL | 7 |
| Secure by Design | 7 |
| Realistic Navigation Warfare (NAVWAR) Testing | 8 |
| Terrain Modelling..... | 8 |
| Jamming..... | 8 |
| Spoofing | 8 |
| I/Q Spatial Awareness..... | 9 |
| True PNT Testing | 9 |
| LEO PNT | 9 |
| Custom Waveform Definition | 9 |
| S-band..... | 9 |
| Inertial Sensors | 10 |
| Other Information | 10 |
| System Upgrades..... | 10 |
| System Calibration | 10 |
| Detailed Performance Specifications | 11 |
| GNSS Signals..... | 11 |
| System Performance..... | 12 |
| Performance in Multi-Chassis Configurations..... | 16 |
| Connectivity | 17 |
| Physical and Environmental Properties | 18 |
| Accreditation and Compliance..... | 18 |
| Related Brochures, Data Sheets and Specifications | 19 |
| Environmental Social & Governance (ESG) | 20 |
| For more information | 21 |

List of Tables

| | |
|---|----|
| Table 1: GNSS Signals Supported | 11 |
| Table 2: Performance Levels for PNT X..... | 12 |
| Table 3: Embedded Interference Option – Signal Performance..... | 13 |
| Table 4: Other Features..... | 15 |
| Table 5: Signal Generator Connectivity..... | 17 |
| Table 6: C50r SimGEN Host Connectivity..... | 17 |
| Table 7: Physical and Environmental Properties..... | 18 |
| Table 8: Safety and EMC Compliance | 18 |
| Table 9: Related Product References | 19 |

List of Figures

| | |
|--|----|
| Figure 1: PNT X Simulation System | 4 |
| Figure 2: SimGEN scenario running on the C50 X..... | 6 |
| Figure 3: SimGEN running a 3D scenario in White Sands with 2 interference transmitters | 8 |
| Figure 4: ESG Continual Improvement Process..... | 20 |

Spirent PNT X

PNT X Overview

Spirent PNT X is a revolutionary simulation system that addresses the increasing complexity of the PNT environment. This all-in-one solution generates all GNSS constellations, RF threats, and signals of opportunity available for comprehensive test coverage and high realism. In an era when compromising on PNT performance is not an option, PNT X delivers new patented capabilities, simplified software for configuring complex test scenarios, and critical simulation integrity to ensure trustworthy results.

PNT X is the 6th generation of Spirent’s GNSS and PNT simulators. It’s flexible software-defined hardware architecture comprises a signal generator and a dedicated C50 X host controller running Spirent’s SimGEN™ software (Figure 1).



Figure 1: PNT X Simulation System

PNT X Signal Generator

The PNT X signal generator can be configured with up to 10 SDR cards¹ generating up to 640 independent signals in total. Each SDR card comes with 64 channels enabled and is capable of supporting any number of licenced GNSS constellations within the same frequency band. The configuration of constellations and frequencies per SDR card is fixed for the duration of the scenario.

The PNT X signal generator has the following RF outputs:

- 2 combined RF outputs at the front panel for GNSS nominal power levels.
- 10 individual RF outputs (each of them connected to a SDR card) at the front panel for single channel applications².
- 2 combined RF outputs at the rear panel for high power levels (50 dBs above nominal).

By means of an output block, the SDR cards are linked to the combined RF outputs. By default, this combination is achieved by allocating up to 5 SDR cards behind RF1 and up to 5 SDR cards behind RF2. For single antenna applications, all 10 SDR cards can be combined into a single RF output on the front pannel connecting the loopback cable provided with the signal generator. The inherent flexibility of the hardware architecture also allows for an optional arrangement of SDR cards with up to 8 behind RF1 and up to 2 behind RF2. Applications for this configuration include dual-frequency embedded interference or GNSS + LEO³.

C50 X Host Controller

The signal generator is controlled by a dedicated, rack-mountable C50 X host controller, which is a Spirent proprietary design, multi-processor/core system, configured with a mixed Operating System (OS) environment (Debian 11 Linux and Windows® 10 LTSC IOT 2021 [Virtualisation Only]). This combination of processing power and dual OS provides the perfect platform to enable PNT X new bench-mark performance levels, and to support Spirent’s SimGEN scenario definition and simulation control software application.

PNT X integrates a diverse technology stack that leverages the right technology for every application. The C50 X incorporates the industry-proven purpose-designed FPGA-based SDR architecture used for GNSS signal generation as well as a NVIDIA® GPU.

¹ A “SDR card” consists of a digital signal generator and an RF upconverter.

² Please, contact Spirent for multichannel applications

³ Default configuration of L-band + S-band systems is also 8:2 (up to 8 SDR cards for L-band and up to 2 for S-band).

The GPU is leveraged in a targeted manner for specific software applications such as real-time 3D multipath calculations, I/Q spatial awareness and generating Xona signals. Optionally, a second GPU can be accommodated in the host controller⁴.

Infinite Scalability

Each PNT X solution offers the flexibility of scalable signal generation, allowing for seamless control of multiple signal generators within a unified system orchestrated by a single SimGEN scenario⁵. This configuration is suitable for applications requiring more than 2 combined RF outputs or the simulation of a high number of independent signals.

Spirent provides rack solutions tailored to accommodate PNT X systems and all associated ancillaries, including a signal distribution unit and a multi-chassis combiner unit.

Contact Spirent to discuss and customize your requirements for optimal performance and functionality.

GNSS Authorised Testing⁶

GPS Authorised Testing

PNT X supports GPS authorised testing via a range of additional options.

- Selective Availability/Anti-Spoofing (SA/A-S) simulation. The applicable package is SimSAAS (for authorised customers in USA) or SimCLASS (for authorised non-US customers).
- MNSA M-Code requires the SimMNSA option which is available for US authorised users only.
- AES M-Code requires the SimMCODE option – US customers can purchase directly from Spirent subject to approval by US authorities; non-US customers can only purchase SimMCODE software via Foreign Military Sales (FMS) program.
- SDS-M-Code requires the SimMCODE and SDS-M-Code via data server option⁷ – US customers can purchase directly from Spirent subject to approval by US authorities; non-US customers can only purchase SDS software via Foreign Military Sales (FMS) program.

In all cases, the options are available for authorised users only.

Further detail is given in [Detailed Performance Specifications](#).

Galileo Authorised Testing

Galileo FOC authorised testing can be supported with the Public Regulated Signal (PRS) at E1 and E6 and the encrypted part of the Commercial Service (CS) at E6. Full PRS requires the PRS[WARE] upgrade option. Full CS requires the SimCS upgrade option, (which also enables Safety-of-Life at E5). Both PRS[WARE] and SimCS provide the required full PRN data for the respective signals they support (non-authorised users are only supplied with 'dummy' data for these signals).

In all cases, the options are available for authorised users only.

Order processing for the "PRS[WARE]" solution is entirely managed by LZE GmbH of Erlangen, Germany, with Munich-based Fraunhofer IIS having complete responsibility for the current and future development, fulfilment and support of PRS[WARE] operating on the Spirent PNT X and future Spirent GNSS test solutions.

Fraunhofer IIS is the sole owner of PRS[WARE] software/firmware, therefore, all issues and questions relating to PRS and PRS[WARE] must be directed to Fraunhofer IIS.

Spirent cannot provide any support relating to PRS, please contact LZE and Fraunhofer IIS directly for all questions relating to the PRS capability and ordering.

LZE can be contacted as follows:

LZE GmbH, Tel: +49 9131 92894-85, contact@prs-ware.de

⁴ A second GPU is required to run simultaneously 2 GPU software applications.

⁵ Performance of PNT X in multi-chassis configurations can vary depending on several factors. Please refer to the Performance in Multi-Chassis Configurations section for more information.

⁶ Please see relevant datasheets for the authorized testing products.

⁷ SDS-M-Code via data server option is not a customer in-field upgrade.

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SimGEN Control Software

SimGEN is recognized as the most comprehensive GNSS and PNT simulation software, continuously evolving over 40 years in close alignment with the GNSS industry and authorities. Renowned for its unmatched capability and performance for scenario definition, execution and data management, SimGEN also features cutting-edge 3D scenario support alongside its rich feature set.

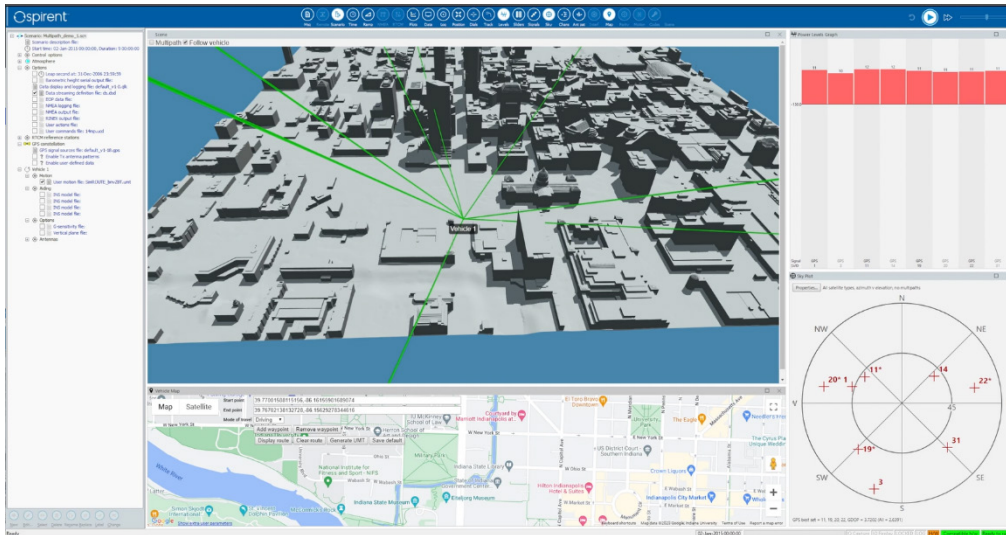


Figure 2: SimGEN scenario running on the C50 X

Precise Signal Definition

- Fully automatic and propagated generation of satellite orbital data, ephemerides and almanac, as well as capability to closely align simulated signals to live-sky (see MS3121).
- Multiple mechanisms for applying declared and undeclared errors and modifications to navigation data, satellite clocks and orbits.
- Independent satellite signal power, pseudorange⁸, modulation and code control.
- DGPS corrections.
- Leap-second and week roll-over event testing.

Advanced Simulation of Signal Impairments and Threats

- Terrain modelling features for real-time obscuration and multipath calculations based on a 3D scene.
- Simulation of ionospheric and tropospheric effects, including ionospheric scintillation.
- Coherent and non-coherent interference and noise modelling.
- Multi-copy constellations and spoofing capabilities.

Configurable Vehicle and Antenna Models

- In-built customisable dynamics models for aircraft, spacecraft, LEO satellites, marine vessels and land vehicles.
- Reception and satellite transmit antenna gain, phase and polarisation pattern control.
- Application of antenna lever arm effects – including fast-spinning vehicles.
- Consideration of clock g-sensitivity.

Real-Time and Post-Processing Tools

- Data logging and streaming of signal, time, control, vehicle and trajectory data over a variety of interfaces.
- In-built gRPC schema to support external applications written in different programming languages (e.g., Python, C++, Java).

⁸ Including the ability to simulate pseudorange ramps for RAIM testing.

Ultimate Performance, Realism, Flexibility and Simplicity

PNT X is Spirent's sixth generation PNT simulation system. This pioneering test platform has been designed to protect systems in the harshest RF environments. It simplifies comprehensive testing, delivering deterministic results from mission-critical scenarios. With unrivaled flexibility and the highest fidelity, PNT X brings together more signals from more sources under one platform, reducing lab footprint while maintaining optimal results.

Signal performance specification is met under ALL operating conditions, including the full range of ultra-high dynamics.

Full GNSS Support

Whether testing multi-frequency or multi-constellation receivers, PNT X offers the most comprehensive GNSS test solution, including global and regional systems, open and secure signals, with up-to-date ICDs. All open GNSS signals can be upconverted to RF or recorded into I/Q files for software receiver testing by means of SimIQ Capture (see MS3108).

PNT X can generate up to 4 embedded multipath channels per satellite signal source. These multipath channels are delayed and attenuated copies of the primary channel and are applied to the first 16 channels of each SDR radio card⁹. The delay and attenuation of each path is user-specified. This includes real-time modification of the individual embedded multipath channels in terms of power level (up to -60 dB) and code delay (up to 4000 m) through a remote interface.

2kHz System Iteration Rate

Due to its standard 2 kHz update rate, PNT X faithfully reproduces true motion for high-dynamics vehicles in RF. This capability is particularly important in cases where rapid acceleration and high-jerk dynamics are essential characteristics of the vehicle under test, such as missiles, space shuttles and drones. A faster update rate also reduces latency for HIL test environments (2 ms in all scenario configurations) - enabling trajectory and motion data from third-party hardware and software systems to be processed faster and more precisely.

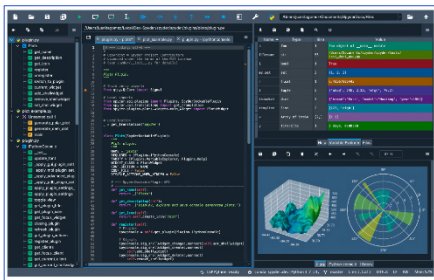
Enhanced Spinning Model: PNT X features an optional mode for fast spinning vehicles that increases the update rate to 100 kHz along the spinning axis to account for high pseudorange variations due to the angular dynamics at a given level arm distance^{10,11}.

Remote Control - HIL

Either via Ethernet, GPIB or SCRAMNet, PNT X can be remotely accessed and controlled via SimREMOTE (see MS3015)¹². SimREMOTE includes a comprehensive suite of commands for:

- Simulation control: such as selecting scenarios, start/stop and run-time control.
- Signal modification: finite manipulation of signal phase, delay and Doppler plus enabling/disabling of codes/data.
- Trajectory delivery: 6DOF trajectory delivery in real-time or from a file up to 2000Hz update rate.

gRPC: In addition, a gRPC schema is provided to automatically generate idiomatic clients for SimGEN service in a variety of languages and platforms, including C++, Java and Python.



Spyder: SimGEN installation also comes by default with Spyder, an open-source Python development environment. Combined with pre-loaded gRPC schema, users can now write their own scripts, applications and software add-ons in order to schedule tests, control the scenario execution and manage simulation data.

- Post-process SimGEN logging data using Python libraries.
- Accelerate the development of simulation software tools.
- Define self-explanatory test flows and share results with Jupiter Notebooks.

Secure by Design

PNT X has been designed with security at the front of mind. Consequently, it addresses general CAT I and CAT II STIG requirements as well as some CAT III vulnerabilities such as secure boot capabilities. The system is equipped with a TPM 2.0 (ISO/IEC 11889) chip on the motherboard, ensuring futureproofing for more demanding implementations of the STIG compliance.

PNT X can be also equipped with an optional self-encrypting FIPS-compliant SSD for users who need an extra layer of protection to their data at rest. In that case, for each C50 X a passphrase must be entered and validated before the controller boots to unlock the drive via terminal access.

⁹ Embedded multipath is a SimGEN default feature independent from other multipath solutions such as 3D or statistical models. This feature is compatible with SimIQ, allowing the generation of RF from 32 primary channels + 48 multipath channels + I/Q.

¹⁰ In this mode of operation, each SDR card can generate up to 8 channels.

¹¹ Compatible with all open GNSS signals. Please, contact Spirent for information related to authorised signal support.

¹² SimREMOTE implementation in PNT X is backwards compatible with all Spirent portfolio SimREMOTE scripts and applications.

Spirent PNT X

Realistic Navigation Warfare (NAVWAR) Testing

PNT X stands out as the ultimate PNT simulation platform, offering state-of-the-art simulation technology and intuitive controls for seamless evaluation of NAVWAR scenarios. Via SimGEN, users can replicate complex threat scenarios with high precision, either using embedded controls for signal definition or with user-supplied I/Q data.

Terrain Modelling

PNT X offers a unique approach to simulating real-time multipath and obscuration effects based on an embedded synthetic environment and an advanced GNSS propagation model. This model relies on a 3D scene, which is used to generate the multipath and obscuration signature relative to the location of the receiver's antenna¹³. The intuitive 3D visualization not only simplifies the configuration of complex settings but also facilitates the inclusion of elements like jammers, spoofers, and repeaters, providing a comprehensive and user-friendly solution for advanced scenario modelling.

This 3D realism is applicable to any signals generated within the system, including all GNSS constellations and frequencies, jamming, spoofing, LEO and I/Q-defined transmitters.

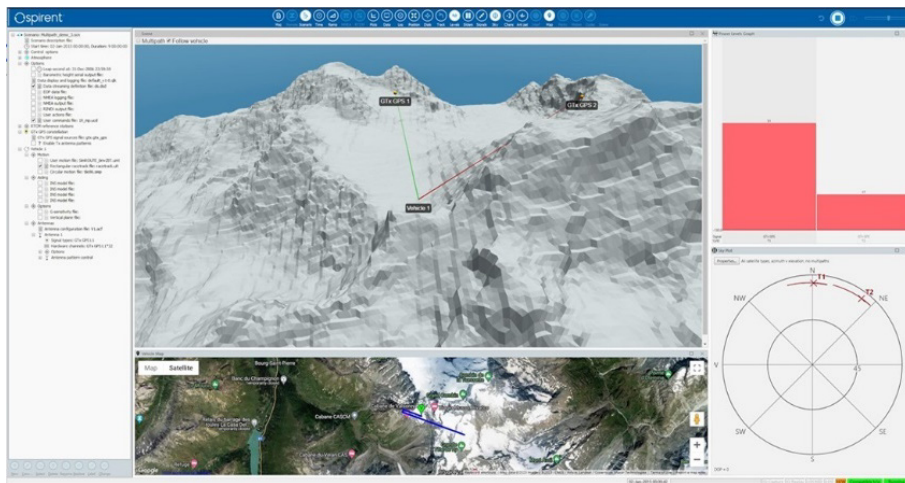


Figure 3: SimGEN running a 3D scenario in White Sands with 2 interference transmitters

Statistical Multipath: In addition to the 3D multipath capabilities, SimGEN supports different models for multipath signals that can be applied to 1 or more echoes of the LoS. They range from basic statistical (sinusoidal multipath and fifth-order polynomial and Legendre multipath) and offset models (range, power or doppler offset) to more complex simulation models to represent the ground reflections (including range and angle of arrival computations), signal reflections from building surfaces in an urban environment (vertical plane) or the use of predefined echoes that change depending on the vehicle's motion (reflection pattern and land mobile multipath).

Jamming

The embedded interference option allows users to natively generate L-band interference alongside GNSS signals. A wide range of signal types and options is supported, including CW, FM, AM, PM, wideband AWGN, BPSK, CW pulses, chirp and matched spectrum (see Table 3 for further information on the signal types supported and the definition parameters).

SimIQ Replay Interference: PNT X allows the generation of high-power custom waveform interference from user supplied I/Q files, alongside standard SimGEN GNSS signals, using the 2RF interference-capable architecture. Via this feature key, SimGEN allows the definition of transmitters objects that can be associated with the replayed I/Q file, using I/Q Spatial Awareness for enhanced realism (see MS3108).

External Interference Simulator: PNT X can be also combined with Spirent's external interference simulator, the GSS7765, to offer a comprehensive solution for testing satellite navigation equipment in the presence of intentional or unintentional RF interference. The GSS7765 offers a very broad range of interfering signal options, which may be used to represent a varied array of threat sources. The interference signals available include Continuous Wave (CW), AM and FM (pulsed signals also available). The interference simulator also supports noise generation with variable bandwidth. The seamless integration with PNT X offers full support for SimGEN scenarios and control over the interference signal content and dynamics (see MS3055).

Spoofing

With PNT X users can evaluate the spoofing risks associated with safety and liability-critical systems. The optional spoofing feature covers cases such as meaconing, code/carrier attacks, navigation data attacks, application-level spoofing and multi-method

¹³ 3D visualisation and obscuration effects are part of SimGEN baseline package. Real-time multipath generation based on a 3D model is an optional feature that uses an internal GPU to calculate these effects in real-time.

attacks. It can simulate up to 4 independent spoofers in a given scenario, allowing user definition of the following parameters for each spoofer:

- Number of transmitters (up to 64) and their dynamics.
- Power level model.
- False vehicle position (spoofed position).
- Spoofing signal content selection, including navigation data and errors.
- Independent and uncorrelated noise patterns with a fixed 90 MHz (3 dB bandwidth) noise source to simulate the unique wideband thermal noise of each transmitter¹⁴.

The resulting spoofer RF signal is automatically calculated by SimGEN based on user scenario settings, with the correct spoofer signal arrival angle and content. Spoofing is supported on the four GNSS constellations (GPS, GLONASS, Galileo, BeiDou), QZSS and IRNSS^{15,16}, provided that the appropriate constellation feature licence keys are present on PNT X.

I/Q Spatial Awareness

I/Q spatial awareness is an optional software feature of PNT X that introduces a newly-patented method for modelling I/Q-based signals. After the definition of transmitter objects for the I/Q files in SimGEN scenario, I/Q spatial awareness applies the corresponding attenuation to power levels, Doppler offsets and signal delays based on the distance from the I/Q-based transmitter to the antenna. This capability superimposes the realism of receiver antenna dynamics into I/Q data, making I/Q a valid alternative for high-dynamic spoofing and interference scenarios.

True PNT Testing

The PNT industry is transitioning from its traditional reliance on GNSS L-band-only applications to adopting a more expansive approach that incorporates a broader spectrum of signals. This evolution is driven by the need for enhanced accuracy, reliability, and resilience as well as new PNT applications such as lunar navigation. For this reason, PNT X moves beyond GNSS and L-band to support the generation of alternative PNT signals alongside traditional GNSS from a single chassis, reducing the system complexity and cost, and providing an all-in-one solution for these applications.

LEO PNT

PNT X incorporates native ultra-accurate LEO satellite dynamic models¹⁷, considering user-defined parameters such as atmospheric drag, satellite mass, and surface area. These models provide precise trajectories in LEO, applicable to vehicles under test, as an extension to SimGEN native spacecraft model, and full constellations with hundreds of satellites. Created in partnership with spaceborne receiver developer SpacePNT, the PNT X embedded LEO library provides real-time orbital information within SimGEN.

SimXona: SimXona enables the native generation of Xona Pulsar demonstration and production signals. The real-time generation of Xona orbits and signal content allow for its definition in conjunction with GNSS using a single SimGEN scenario (see MS3120).

Custom Waveform Definition

PNT X is built upon a flexible hardware architecture that allows the generation of user-defined RF signals. Custom waveforms, noise, interference or non-current ICD SIS can be easily generated at RF using the flexible signal simulation feature or directly injected using I/Q files.

FLEX: The flexible signal simulation comprises built-in and user-configurable control and set-up of non-current SIS ICD PRN codes, navigation data content, navigation data rate, chipping rate, edge shaping, and modulation types, as shown in Table 4. A single PNT X can accommodate up to 16 FLEX signal transmitters or SVs¹⁸, each comprising a primary and secondary code.

SimIQ Replay: SimIQ Replay allows the generation of user-defined RF signals from I/Q. With this optional feature, PNT X can generate RF from up to 3 simultaneous L-band or S-band I/Q files, allowing sample rates up to 60 Msps and up to 16-bit bitdepth. This feature is also compatible with I/Q spatial awareness (see MS3108).

S-band

Introducing new internal SDR cards specifically designed for S-band signals. Native S-band RF generation is now possible for regional GNSS constellations, LEO and novel PNT applications. This solution is compatible with SimIQ Replay, supporting static and dynamic I/Q-based transmitters enhanced with Spatial Awareness and terrain modelling.

S-band signals are generated using a separate RF output on the PNT X, allowing a maximum of 2 SDR cards per signal generator.

¹⁴ Single noise pattern per SDR card.

¹⁵ GPS: L1, L2, L5. BD: B1i, B2i, B2a, B1c, B3i, B2b. GAL: E1, E5, E6. GLO: F1, F2, C1, C2, C3. QZSS: L1, L2, L5, L6. IRNSS: L1, L5, S.

¹⁶ Authorised users should contact Spirent for information related to spoofing support with SimMCOE and SimMNSA.

¹⁷ Feature key required.

¹⁸ Up to 2 FLEX-capable SDR cards per signal generator with 8 FLEX signal transmitters each. Contact Spirent for tailored configurations.

Spirent PNT X

Inertial Sensors

Via SimINERTIAL™, PNT X provides full support for a wide variety of data interfaces, formats and sensors, including accelerometers, gyroscopes, magnetometers, compasses and barometers.

Coupled with Spirent's PNT X, and powered by SimGEN, Spirent's inertial simulation tools provide real-time emulation of raw measurements that can be fed into filters within the positioning engine.

Spirent's inertial simulation tools enable users of embedded GPS/inertial systems (EGIs), individually coupled GNSS/INS systems (IGIs) or standalone IMUs to simulate coherent GNSS and sensor measurements to evaluate the positioning algorithms. Modelling physical sensors using accurate error parameters in our simulation environment enables users to tune integrations and algorithms prior to deployment.

For further information, see MS3030.

Other Information

System Upgrades

The software-defined architecture of PNT X facilitates in-field upgrades to meet customer evolving needs. These include:

- Integration with another PNT X signal generator for multi-output applications.
- Addition of SDR cards to increase the maximum number of signals generated.
- Enabling software features such as 3D multipath, spoofing or I/Q Spatial Awareness.
- Adding constellation feature keys to enables other GNSS signal types.

See Table 9 for additional upgrade options. Please, contact Spirent to discuss your requirements.

System Calibration

PNT X is calibrated to the ISO/IEC 17025 standard at the time of purchase. Calibration is not affected by storage of up to 180 days prior to its initial receipt. The following recalibration of PNT X shall be based on when the product is put into service and first used. The recommended calibration interval is 12 months. Annual recalibration must be carried out at a Spirent facility or accredited laboratory to maintain this accreditation

The installation of additional purchased radio cards or performing calibrations outside of a Spirent authorized ISO/IEC17025 accredited laboratory will invalidate this accredited calibration. This includes customer use of the Auto Calibration Utility (where installed) and certain upgrade procedures¹⁹.

¹⁹ Contact Spirent local representative for more information on system recalibration and how to renew the annual accreditation.

Detailed Performance Specifications

GNSS Signals

Table 1: GNSS Signals Supported

| System | Carrier | Signal | Message Type | Level ²⁰ | Notes |
|-------------------------------------|---------|--|--------------|---------------------|---|
| GPS | L1 | C/A | Legacy | -130.0 dBm | Support for Y code requires SimCLASS/SimSAAS Option |
| | | P | Legacy | -133.0 dBm | |
| | | L1c Pilot code | CNAV-2 | -128.25 dBm | |
| | | L1c Data code | CNAV-2 | -133.0 dBm | |
| | | M Noise | - | -128.5 dBm | |
| | L2 | L2c or C/A | CNAV | -136.0 dBm | |
| | | P | Legacy | -136.0 dBm | |
| | | M Noise | - | -132.5 dBm | AES-M requires SimMCODE M requires SimMCODE and SDS-M via data server options MNSA requires SimMNSA |
| | L5 | I, Q | CNAV | -127.9 dBm | |
| | Galileo | E1 | E1-A | G/NAV | -125.5 dBm |
| E1-A PRS Noise | | | - | -125.5 dBm | |
| E1-B, E1-C (50/50 power sharing) | | | I/NAV | -128.0 dBm | OS Galileo – Excludes SOL support FOC Galileo – Includes SOL support |
| E6 | | E6-A | G/NAV | -125.5 dBm | PRS Galileo – Requires 3 rd party PRS[WARE] product |
| | | E6-A PRS Noise | - | -125.5 dBm | |
| | | E6-B, E6C (50/50 power sharing) | HAS | -128.0 dBm | |
| E5ab | | E5a(I+Q) and E5b(I+Q) (50/50 power sharing) | F/NAV, I/NAV | -122.0 dBm | OS Galileo – Supported FOC Galileo – Supported |
| GLONASS | F1 | C/A | Public | -131 dBm | |
| | | P | - | -131 dBm | |
| | F2 | C/A | Public | -137 dBm | |
| | | P | - | -137 dBm | |
| | L1 | CDMA | L1OC | -128.5 dBm | |
| | L2 | CDMA | L2OCp | -128.5 dBm | |
| | L3 | CDMA | L3OC | -128.5 dBm | |

²⁰ Nominal power levels as defined by Spirent. Via SimGEN, the user can adjust nominal power levels to meet individual ICD conditions.

Spirent PNT X

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|--------|----|------------------|--------------------------|---------------------------|---|
| BeiDou | B1 | B1I | D1, D2 | -133 dBm | D2 does not include differential corrections or Iono grid |
| | B1 | B1C | B-CNAV1 | -130 dBm | |
| | B2 | B2I | D1, D2 | -133 dBm | |
| | B2 | B2A | B-CNAV2 | -127 dBm | |
| | B2 | B2B | B-CNAV3, PPP-B2b_I | -130 dBm | |
| | B3 | B3I | D1, D2 | -133 dBm | |
| QZSS | L1 | C/A, C/B | QZ-Legacy | -128.5 dBm | |
| | | S | SLAS | -131 dBm | |
| | | L1c Data + Pilot | QZ-CNAV-2 | -127 dBm | |
| | L2 | L2c | QZ-CNAV | -130 dBm | |
| | L5 | I + Q | QZ-CNAV | -124.9 dBm | |
| | | S | | -127 dBm | |
| | L6 | D+E | CLAS, CLAS-E (MADOCA) | -126.82 dBm ²¹ | |
| IRNSS | L1 | SPS | L1 | -130 dBm | |
| | L5 | SPS | L5/S | -130 dBm | |
| | S | SPS | L5/S | -130 dBm | |
| SBAS | L1 | C/A | Data | -130 dBm | |
| | L5 | L5-I | DFMC Data | -127.9 dBm | |

System Performance

Table 2: Performance Levels for PNT X

| Parameter | Detail | Value | Foot note |
|-----------------------------|---|----------------------------------|-----------|
| RF Signal Level | Carrier Level Control | Maximum | +20 dB 22 |
| | | Minimum | -40 dB 23 |
| | Resolution | 0.1 dB | |
| | Linearity +20 dB to -30 dB -30.1 dB to -40 dB | <0.10 dB | |
| | | <0.20 dB | |
| | Absolute Accuracy | ±0.5 dB 24 | |
| | Run to Run Repeatability | ±0.1 dB | |
| Individual Output Mode | Nominal Signal Level | +71 dB | |
| Configurable Iteration Rate | Supported SimGEN Simulation Iteration Rates (SIR) | 10, 100, 250, 500, 1000, 2000 Hz | 25 |
| | Hardware update rate | 1000, 2000 Hz | |
| | Bulk logging update rate | 250 Hz | |
| | Relative Velocity | 120,000 m/s | 26 |

²¹ Default power level setting is for Block II satellites.

²² The maximum signal level of +20dB is available for all channels in the SDR card. The recommended power envelope is +20dB per channel for up to 16 channels and +17dB per channel for up to 32 channels.

²³ The control range extends to -50 dB, but performance is unspecified below -40 dB. Operation below -20 dB is primarily to support antenna pattern and multipath functionality.

²⁴ RSS at 21±5°C, +20 to -30 dB. ±1.5 dB 3-sigma all conditions.

²⁵ At 2000 Hz, limitations to the total channel count and number of constellations/frequencies apply.

²⁶ For 6-DOF data externally supplied via SimREMOTE or from data file.

| | | | |
|--------------------------|---|------------------------------------|--------|
| Limit of Signal Dynamics | Relative Acceleration | 192,600 m/s ² | 27 |
| | Relative Jerk | 890,400 m/s ³ | |
| | Angular Rates (at 1.5 m lever arm) (indicative) (at 0.05 m lever arm) | >15 π rad/s >60 π rad/s | |
| Signal Accuracy | Pseudorange Accuracy | 0.3 mm RMS | 28 |
| | Pseudorange Bias | 0 mm RMS | 29 |
| | Delta-range Accuracy | < \pm 1.0 mm RMS | |
| | Inter Frequency Alignment | < \pm 230ps (\pm 69mm) | 30 |
| | 1PPS to RF Alignment | < \pm 2 ns | 31 |
| Spectral Purity | Harmonics | < -40 dBc | |
| | In-band Spurious | < -182 dBW | 32, 33 |
| | Phase Noise (single sideband) | < 0.005 Rad RMS | 34 |
| Signal Stability | Internal 10.00 MHz OCX Oscillator (after warm up) | \pm 5 x 10-10 per day | |
| Embedded Multipath | Fixed path-length delay per path | 0 to 1245 m | |
| | Resolution (approximately) | 2.5 m | |
| HIL | System Latency | 2 ms | 35 |

Table 3: Embedded Interference Option – Signal Performance

| Parameter | Detail | Value | Footnote |
|--------------------------|-----------------------------|--------------|----------|
| Frequency bands | L1 | 1.57542 GHz | |
| | L2 | 1.2276 GHz | |
| | L5 | 1.17645 GHz | |
| | L6 | 1.27875 GHz | |
| Carrier frequency offset | Independent for each source | | 36 |
| | Range | \pm 25 MHz | |
| | Resolution | 0.5 kHz | |

²⁷ When operating at \geq 250 Hz SIR.

²⁸ For signal acceleration < 450 m/s², jerk < 500 m/s³, 1000 Hz SIR.

²⁹ Single radio card – supporting up to 32 channels. When the same signal is generated across multiple radio cards the inter radio card bias uncertainty is \pm 230ps (\pm 69mm).

³⁰ PRN code alignment between frequency band.

³¹ Between any RF carrier at the output port(s). Applicable for both single and multi-output systems.

³² For relative velocities <50,000 m/s.

³³ In-Band Spurious Bandwidths (relative to centre frequency unless otherwise stated):

GPS: L1 \pm 20.5 MHz, L2 \pm 20.5 MHz, L5 \pm 20.5 MHz

Galileo: E1 \pm 20 MHz, E6 \pm 20 MHz, E5a \pm 25.5 MHz, E5b \pm 25.5 MHz

GLONASS: (relative to channel frequency 0) L1 \pm 20 MHz, L2 \pm 20 MHz

BeiDou: B1/B2 \pm 20.5 MHz

³⁴ Value is typical, integrated over a 1 Hz to 10 kHz bandwidth. Worst case < 0.01 rad RMS.

³⁵ System latency is 4xSIR. At 2 kHz, system latency is 2ms.

³⁶ In addition to Doppler caused by vehicle motion. Applies to all signal types.

Spirent PNT X

| Parameter | Detail | Value | Footnote |
|---------------|--------------------------------------|----------------------------|----------|
| Signal Purity | Unmodulated in-band spurious | ≤ -60 dBm | |
| | Modulated in-band spurious | < 40 dBc | |
| BPSK | Narrowband main lobe width | 0.1023 MHz | |
| | Broadband main lobe width | 20.46 MHz | |
| CW Pulse | Pulse width | 1 to 10000 μ s | |
| | Pulse repetition interval range | 50 to 10000 μ s | |
| | Pulse repetition interval resolution | 50 μ s | |
| | Rise time (10% to 90%) | 100 ns (max) | |
| | On/Off ratio | 30 dB | |
| AWGN | 3 dB Variable Bandwidth | From 0.1 to 90 MHz | 37 |
| | Bandwidth Resolution | 0.01 MHz | |
| | Bandwidth accuracy | $\pm 5\%$ | |
| FM CW | FM deviation | ± 15 MHz | |
| | FM rate | 0.005 to 10 kHz | |
| | FM rate step size | 0.005 kHz | |
| | Modulating Waveform | Triangular, sine, chirp | |
| Chirp | Deviation | ± 0.01 to ± 15 MHz | |
| | Sweep Rate | ± 0.005 to 50 kHz | |
| | Modulation Type | Sawtooth | |
| AM | Modulation depth | 10 to 90% | |
| | Modulation depth step size | 10% | |
| | AM rate | 0.5 to 10 kHz | |
| | Modulating Waveform | Sinusoidal | |
| PM | Modulation deviation | ± 0 to ± 5 rad | |
| | PM rate | 0.5 to 10 kHz | |
| | Modulating Waveform | Sinusoidal | |

³⁷ Number of channels per SDR card is limited to 32 for 90 MHz AWGN signal generation.

| Parameter | Detail | Value | Footnote |
|-----------------|---|----------------|----------|
| Comb | Waveforms | CW, FM, AM, PM | |
| | Tone waveform frequency offset resolution | 0.5 kHz | |
| RF Signal Level | Single signal | -47 dBm (max) | 38 |
| | Multiple signals | -72 dBm (max) | 39 |
| | Minimum level per signal | -117 dBm | |
| | Linearity, per signal, >-97 dBm | <0.1 dB | |
| | Linearity: per signal, > -107 dBm | <0.2 dB | |
| | Linearity: per signal, > -117 dBm | <0.5 dB | |

Table 4: Other Features

| Parameter | Detail | Value | Foot note |
|--------------------|---------------------------------------|---|-----------|
| Terrain Modelling | 3D Maps | San Francisco, Tokyo, Paris, London, White Sands, Shanghai, Fort Huachuca, Cape Pendleton, Cape Canaveral, Fort Moore | 40 |
| 3D Multipath | Max. Simulation Iteration Rates (SIR) | 100 Hz | |
| | No. of Multipath per LoS | 1-8 | 41 |
| | 3D Format Supported | DTED (0,2) for a DTM (Digital Terrain Model). GeoTiff + ESRI shapefile, for any 3D building environment. | |
| FLEX | Carriers | L1,L2,L5,E1,E542,E6,B1,B2,QZL1 | |
| | Codes | Two or three user-definable signals per SV | |
| | Code Assignment | +I, -I, +Q, -Q | |
| | Code Definition | User-definable memory codes (primary and secondary for each Flex signal) | |
| | Base Chip Rate | 1.023 | |
| | Chip Rate Multiplier | 1, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10 | |
| | BOC Rates Multiplier | Integer multiple of Base Chip Rate | |
| | Nominal Signal Level | -123 to -133 | |
| | Nav Message | Standard for constellation | |
| LEO Orbital Models | Max. number of satellites | 500 | |

³⁸ Single signal per SDR card (CW, FM, PM, Chirp), -49dBm (BPSK, pulsed CW), -53dBm (AM), -60dBm (AWGN).

³⁹ Per signal, up to 16 signals of AWGN on the same radio card – other signal types can be up to 3dB higher.

⁴⁰ The approximated size of each 3D map is 100 sqkm.

⁴¹ User can define the number of multipath signals per LoS.

⁴² Galileo E5 AltBOC signal structure is not supported.

Spirent PNT X

Performance in Multi-Chassis Configurations

There is a practical limit to how much data can be reliably processed by the simulation engine at the designated simulation iteration rate. There are many factors that can influence the processing capacity of the simulation system, but in practical terms the main sources are:

1. The total number of active SDR cards (influenced by the number of antenna outputs in the configuration and the selected signal types).
2. The total number of satellite signals (channel density).
3. The volume of data logging enabled.

The variety of permutations from these contributing factors is extremely difficult to fully characterise. Instead, Spirent provides guidance based on previously explored cases in order to set a reasonable expectation of the performance that can be achieved. For a system with a capability of 256 channels or greater:

- The simulation iteration rate is recommended to be 100Hz.
- SimGEN “truth” data logging capability, during real-time scenario run, should be limited to bulk logging in binary format or data-streaming UDP or nav data binary dump.
- If high rate bulked log data is required, then two scenario runs can be employed. The first run in turbo mode to bulk log the data and the second run in real time without logging data.

If these operating criteria present a challenge to the intended test application, and for systems of more than 256 channels, Spirent is pleased to discuss the challenges of each user case and to determine whether an alternative system architecture might be suitable in those circumstances, via a Tailored Solution.

Connectivity

Table 5: Signal Generator Connectivity

| Port | Type | Parameter |
|-----------------------------|-------------|---|
| Main RF Port | Output | N-type coax female, 50 Ω , VSWR <1.2:1 AC coupled ± 50 V DC, maximum reverse RF 30 dBm |
| High Level RF Port | Output | N-type coax female, 50 Ω , VSWR <1.2:1 AC coupled ± 50 V DC, maximum reverse RF 30 dBm |
| Individual RF Ports | Output | N-type coax female, 50 Ω , VSWR <1.2:1 AC coupled ± 50 V DC, maximum reverse RF 30 dBm |
| Auxiliary RF | Input | N-type coax female, 50 Ω , VSWR <1.4:1 0.5 to 2 GHz, Insertion Loss 14.5 dB typical |
| External Frequency Standard | Input | BNC coax socket, 50 Ω -5 to +10 dBm at 1 MHz, 5 MHz, 10 MHz |
| Internal Frequency Standard | Output | BNC coax socket, 50 Ω 10.00 MHz at +5 dBm nominal |
| 1PPS IN | Input | BNC coax socket, 50 Ω , TTL level compatible |
| 1PPS OUT | Output | BNC coax socket, 50 Ω , TTL level compatible |
| Trigger IN | Input | BNC coax socket, 50 Ω , TTL level compatible |
| PCI Express | Private Bus | Cabled PCIe |

Table 6: C50r SimGEN Host Connectivity

| Interface | Type | Parameter |
|-------------------|-------------|---|
| PCI Express | Private Bus | Cabled PCIe |
| USB | I/O | Maximum of 4 spare ports for general file access |
| Ethernet | I/O | RJ-45 Ethernet interface standard. Used for general network access and available for remote control ⁴³ |
| Optional GPIB | I/O | Available for remote control and GSS7765 control |
| Optional ScramNET | I/O | Available for remote control |

⁴³ The SimREMOTE and SimPORT ethernet ports support up to 10 Gbps.

Spirent PNT X

Physical and Environmental Properties

Table 7: Physical and Environmental Properties

| Part | Parameter | Value |
|------------------------|--|--|
| PNT X Signal Generator | Dimensions (H x W x D) (19" 4U chassis) | 177 x 482 x 665.8 mm 6.97 x 18.98 x 26.21" |
| | Typical Weight | <30 kg (66 lb) (configuration dependent) |
| | Electrical Power | 100-240 V 10A Max 50 to 60 Hz |
| C50 X Host Controller | Dimensions (H x W x D) (19" 4U chassis) | 177 x 486.8 x 638.6 mm 6.97 x 19.17 x 25.14" |
| | Weight (excl. peripherals) | <20.7 kg (45.6 lb) |
| | Electrical Power | 100-240 V 9A Max 50 to 60 Hz |
| Common | Operating Environment | +10 to +40°C (50 to 104°F) (40-90% RH, non-condensing) |
| | Storage Environment | -40 to +60°C (-90 to 140°F) (20-90% RH, non-condensing) |
| | System Mean Time Between (component) Failure (MTBF) | 2,562,327 hours (per Bellcore 6) |

Accreditation and Compliance

Table 8: Safety and EMC Compliance

| Compliance | Applicable Standard |
|------------|--|
| Safety | Low Voltage Directive (LVD) 2014/35/EC IEC 62368-1:2014 (Second Edition) Audio/video, information and communication technology equipment. Safety requirements |
| EMC | EMC Directive 2014/30/EC EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use. EMC requirements. General requirements |
| MET | MET Certification. Listing number E113897; MET Project Number 109752 UL 62368-1/CAN C22.2 CSA 62368-1, Second Edition: Audio/video, information and communication technology equipment. Safety requirements |

Related Brochures, Data Sheets and Specifications

Table 9: Related Product References

| Related Product | Description | Data Sheet / Specification |
|-----------------|--|----------------------------|
| SimGEN | GNSS Software Suite | MS3008 |
| GBAS | GSS4150 VHF Data Broadcast Simulator for GBAS Product Specification | MS3014 |
| SimREMOTE | Simulator Remote Control Additional Options | MS3015 |
| SimINERTIAL | Inertial Sensor Emulation Option | MS3030 |
| GSS7765 | External Interference Generator | MS3055 |
| SimBARO | Barometric Pressure Emulation Option | MS3056 |
| SimROUTE | Road-Matched Trajectory generation Tool | MS3073 |
| SimSENSOR | MEMS Sensor Simulation Option | MS3086 |
| SimSAFE | Vulnerability Test Tool | MS3092 |
| Sim3D | Real-time Multipath Simulation Software based on a Synthetic Environment | MS3105 |
| SimIQ | I/Q Data Generation and Replay Software Tool | MS3108 |
| SimOSNMA | Galileo Open Service Navigation Message Authentication Testing | MS3111 |
| PNT Automation | Test Orchestration and Automation Platform | MS3119 |
| SimXona | Xona Pulsar™ Signal Generation | MS3120 |
| Standpoint | Live-sky Synchronisation Solution | MS3121 |
| SimCLASS | GPS SA/A-S Upgrade Option (Non-USA) | MS9020 |
| SimCS | Galileo FOC Upgrade Option | MS9043 |
| SimMNSA | MNSA M-code Upgrade Option | MS9018 |
| SimMCODE | AES M-Code Upgrade Option | MS9048 |
| SDS-M-Code | SDS-M-Code via server Upgrade to SimMCODE | |
| SimSAAS | GPS SA/A-S Upgrade Option (USA only) | SF1001 |

Spirent PNT X

Environmental Social & Governance (ESG)

Spirent's Positioning Technology Business Unit has been committed to ESG good practice and improvement since achieving ISO14001:2015 Environmental Management System certification in 2004.

We take ESG seriously across all aspects of our business from Sustainable Buildings, Sustainable Product Design to Sustainable Supply Chain, Manufacturing and Shipping/Exports

Our approach is to follow a Continual Improvement process in respect of ESG:

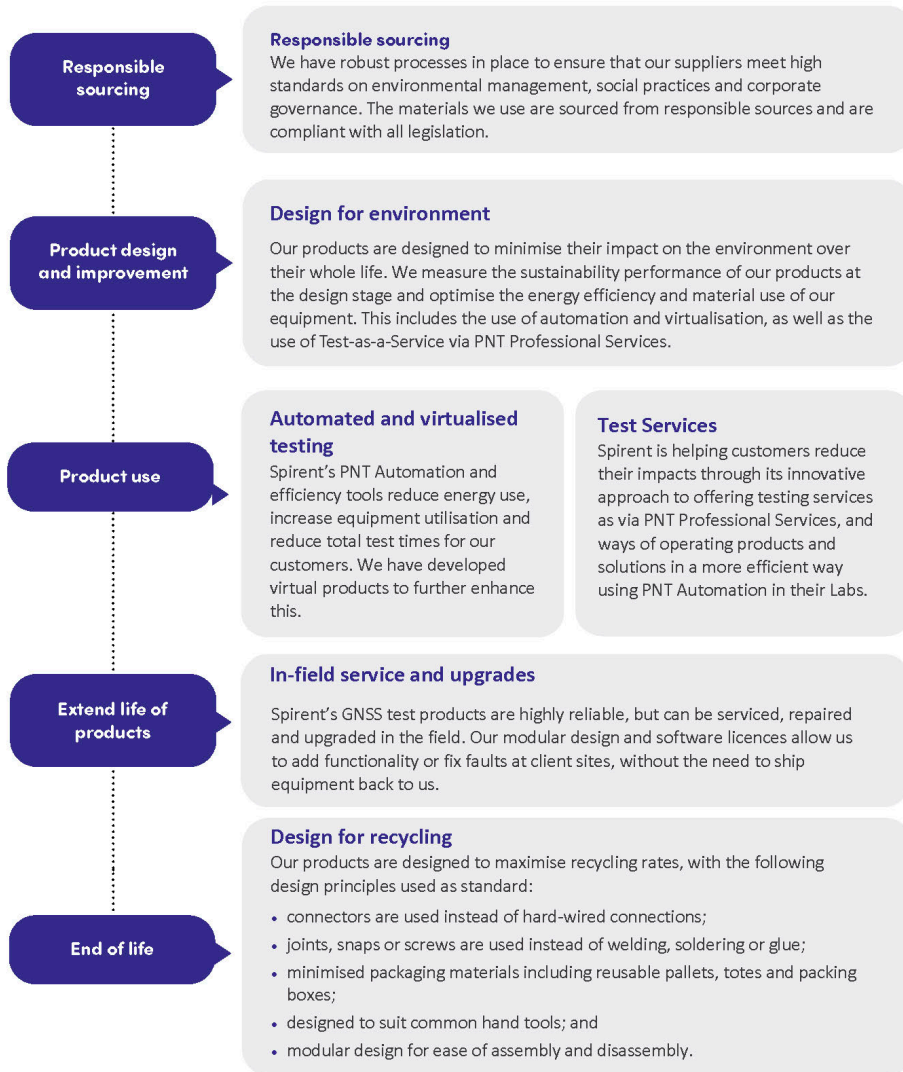


Figure 4: ESG Continual Improvement Process

Many of Spirent's Test Solutions rely on physical test equipment used in situ by our customers. We are working to reduce the lifecycle impacts of our products and the environments they are used in through a range of ways:

- Designing for environment and end of life, including compliance with all legal requirements;
- Reducing the size, weight, noise and power use of our products;
- Virtualisation and the development of Test-as-a-Service via PNT Professional Services;
- Improving utilisation and automation
- In-field servicing and upgrades.

We use formal sustainability metrics in the product development process.

For more specific information on how EGS applies to our PNT Test Solutions, please contact your Spirent representative.

For more information visit, <https://corporate.spirent.com/sustainability>

For more information

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Environmental Social & Governance (ESG)

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ESG is a priority for Spirent across all aspects of our business, from sustainable buildings and sustainable product design to sustainable supply chain, manufacturing and shipping/export processes. As is best practice, we follow a continuous improvement process in respect of ESG.

Many of Spirent's test solutions rely on physical test equipment used in situ by our customers. We are working to reduce the lifecycle impacts of our products, and the environments in which they are used, in a number of ways:

- Designing for environment and end of life, including compliance with all legal requirements;
- Reducing the size, weight, noise and power use of our products;
- Visualization and the development of Test-as-a-Service via PNT Professional Services;
- Improving utilization and automation; and
- In-field servicing and upgrades.

We use formal sustainability metrics in the product development process.

For more specific information on how ESG applies to our PNT test solutions, please contact your Spirent representative. For more information on Spirent initiatives, visit <https://corporate.spirent.com/sustainability>.

About Spirent Positioning Technology

Spirent enables innovation and development in the GNSS (global navigation satellite system) and additional PNT (positioning, navigation and timing) technologies that are increasingly influencing our lives.

Our clients promise superior performance to their customers. By providing comprehensive and tailored test and assurance solutions, Spirent assures that our clients fulfill that promise.

Why Spirent?

Over five decades Spirent has brought unrivaled power, control and precision to positioning, navigation and timing technology. Spirent is trusted by the leading developers across all segments to consult and deliver on innovative solutions, using the highest quality dedicated hardware and the most flexible and intuitive software on the market.

Spirent delivers

- Ground-breaking features proven to perform
- Flexible and customizable SDR technology for future-proofed test capabilities
- World-leading innovation, redefining industry expectations
- First-to-market with new signals and ICDs
- Signals built from first principles – giving the reliable and precise truth data you need
- Unrivaled investment in customer-focused R&D
- A global customer support network with established experts



About Spirent Communications

Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks. We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled. For more information visit: www.spirent.com

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