DATASHEET

Spirent Federal Systems

Spirent PNT X

Accelerate & Simplify PNT Testing

Spirent PNT X

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Introduction

Spirent PNT X is a revolutionary simulation system that simplifies positioning, navigation, and timing (PNT) testing for rapid deployment of robust PNT systems. 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.

The most powerful, capable, and realistic NAVWAR test platform available today, PNT X features a flexible software-defined hardware architecture that consists of a signal generator and a dedicated C50 X host controller running Spirent's SimGEN™ software, the most comprehensive GNSS and PNT simulation tool trusted and verified by leading experts in the PNT industry (Figure 1).

Figure 1: PNT X Simulation System

PNT X integrates a diverse technology stack that leverages the right technology for every application. The Spirent C50 X host controller incorporates a proven, purpose-designed, FPGA-based software-defined radio (SDR) architecture used for GNSS signal generation as well as a NVIDIA® GPU. 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 controller[1].

[1] A second GPU is required to run simultaneously 2 GPU software applications.

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 Modeling

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 antenna[2]. 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 modeling.

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.

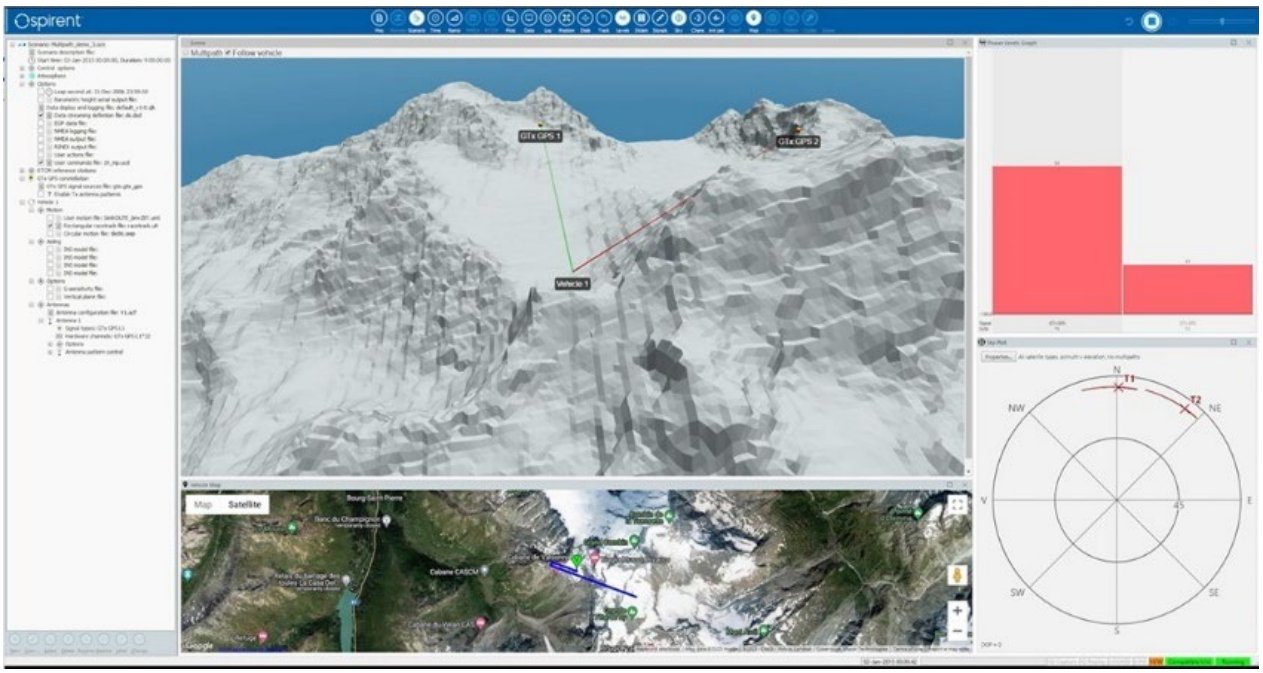

Figure 2: SimGEN running a 3D scenario in White Sands with 2 interference transmitters

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 line of sight (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).

[2] 3D visualization 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.

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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 also be 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 that 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 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 transmitter[3]

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[4,5], provided that the appropriate constellation feature license keys are present on PNT X.

[3] Up to 4 noise patterns per SDR card.
[4] 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.
[5] Authorized users should contact Spirent Federal for information related to spoofing support with SimMCODE and SimMNSA.

I/Q Spatial Awareness

I/Q spatial awareness is an optional software feature of PNT X that introduces a newly-patented method for modeling 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[6].

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 models[7], 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 SVs[8], 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 bit depth. This feature is also compatible with I/Q spatial awareness. (See MS3108.)

[6] This feature is currently not available for external real-time DUT trajectory input.
[7] Feature key required.
[8] Up to 2 FLEX-capable SDR cards per signal generator with 8 FLEX signal transmitters each. Contact Spirent Federal for tailored configurations.

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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 modeling.

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

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. Modeling 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.

Ultimate Performance, Realism, Flexibility, and Simplicity

PNT X is Spirent's 6th 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 card[9]. 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[10]: 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[11,12].

Remote Control - HIL

Either via Ethernet, GPIB or SCRAMNet, PNT X can be remotely accessed and controlled via SimREMOTE. (See MS3015.)[13] 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

[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] Access to this feature is restricted and can only be supplied under a UK Export License.
[11] In this mode of operation, each SDR card can generate up to 8 channels.
[12] Compatible with all open GNSS signals. Please contact Spirent Federal for information related to authorized signal support.
[13] SimREMOTE implementation in PNT X is backwards compatible with all Spirent portfolio SimREMOTE scripts and applications.

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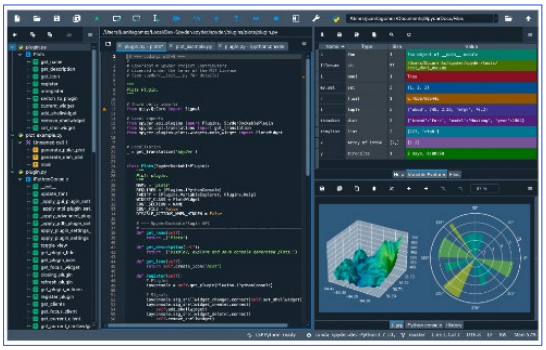
gRPC: In addition, a gRPC schema is provided to automatically generate idiomatic clients for SimGEN service in a variety of languages and platforms, including C++, Java, and Python.

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 future proofing for more demanding implementations of the STIG compliance.

PNT X can also be 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.

PNT X Overview

PNT X Signal Generator

The PNT X signal generator can be configured with up to 10 SDR cards[14] generating up to 640 independent signals in total. Each SDR card comes with 64 channels enabled and is capable of supporting any number of licensed 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 applications[15]
- 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 panel 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 + LEO[16].

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 [Virtualization 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.

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 scenario[17]. 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 Federal to discuss and customize your requirements for optimal performance and functionality.

[14] An "SDR card" consists of a digital signal generator and an RF upconverter.
[15] Please contact Spirent Federal for multichannel applications.
[16] 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).
[17] 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.

Encrypted Military Signals Testing[18]

PNT X supports GNSS-authorized testing of encrypted military signals for both GPS and Galileo.

GPS Authorized Testing

PNT X supports GPS-authorized testing via a range of additional options:

- Selective Availability/Anti-Spoofing (SA/A-S) simulation. The applicable package is SimSAAS (for authorized customers in USA) or SimCLASS (for authorized non-US customers).
- MNSA M-Code requires the SimMNSA option, which is available for US authorized users only.
- AES M-Code requires the SimMCODE option – US customers can purchase directly from Spirent Federal subject to approval by US authorities. Non-US customers can only purchase SimMCODE software via the Foreign Military Sales (FMS) program.
- SDS-M-Code requires the SimMCODE and SDS-M-Code via data server option[19] – US customers can purchase directly from Spirent Federal subject to approval by US authorities.

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

Further detail is given in the ***Detailed Performance Specifications*** section.

Galileo Authorized Testing

Galileo FOC-authorized 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-authorized users are only supplied with 'dummy' data for these signals).

In all cases, the options are available for authorized 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**

[18] Please see relevant datasheets for the authorized testing products.
[19] SDS-M-Code via data server option is not a customer in-field upgrade.

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.

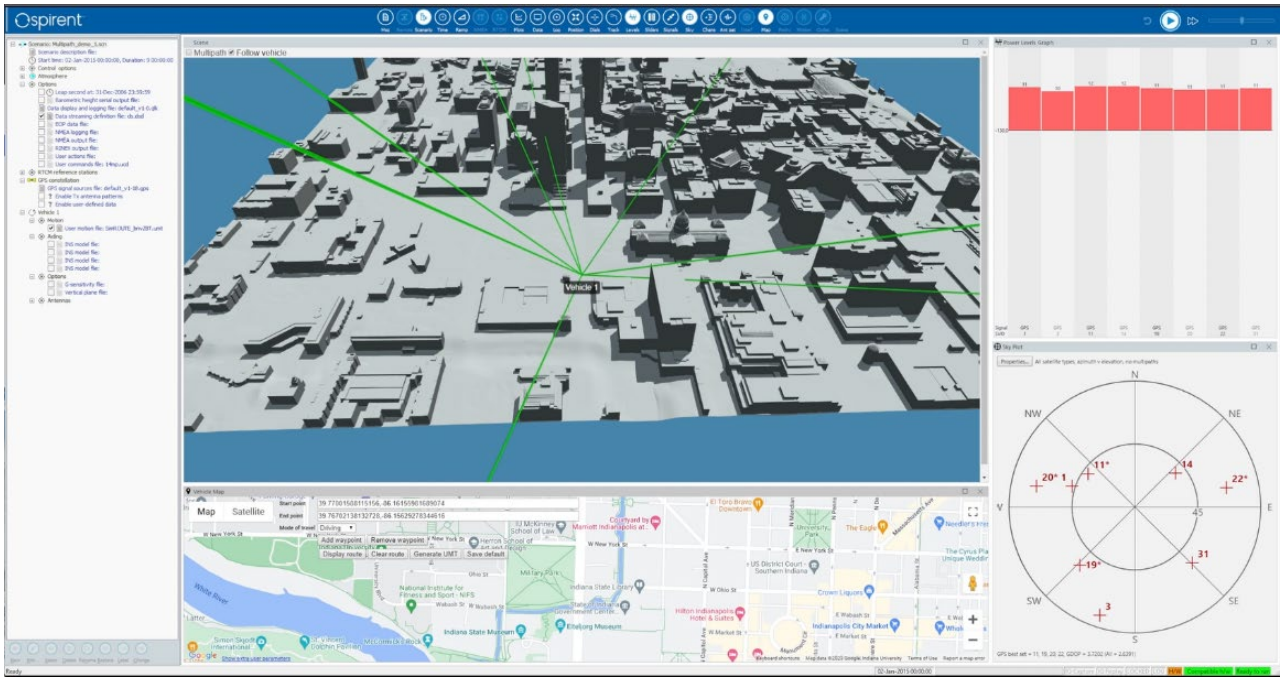


Figure 3: SimGEN scenario running on the C50 X

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, pseudorange[20], modulation and code control
- DGPS corrections
- Leap-second and week roll-over event testing

Advanced Simulation of Signal Impairments and Threats

- Terrain modeling 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 modeling
- Multi-copy constellations and spoofing capabilities

[20] Including the ability to simulate pseudorange ramps for RAIM testing.

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Configurable Vehicle and Antenna Models

- Built-in customizable dynamics models for aircraft, spacecraft, LEO satellites, marine vessels, and land vehicles
- Reception and satellite transmit antenna gain, phase, and polarization 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
- Built-in gRPC schema to support external applications written in different programming languages (for example, Python, C++, Java)

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 enable other GNSS signal types

See Table 9 for additional upgrade options. Please contact Spirent Federal 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 Federal facility or accredited laboratory to maintain this accreditation.

The installation of additional purchased radio cards or performing calibrations outside of a Spirent Federal authorized ISO/IEC17025 accredited laboratory will invalidate this accredited calibration. This includes customer use of the Auto Calibration Utility (where installed) and certain upgrade procedures[21].

[21] Contact Spirent Federal for more information on system recalibration and how to renew the annual accreditation.

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Detailed Performance Specifications

GNSS Signals

Table 1: GNSS Signals Supported

System	Carrier	Signal	Message Type	Level[22]	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	AES-M requires SimMCODE M requires SimMCODE and SDS-M via data server options MNSA requires SimMNSA
	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	PRS Galileo – Requires 3rd party PRS[WARE] product
		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 3rd 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

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

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	
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[23]	
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	

[23] Default power level setting is for Block II satellites.

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System Performance

Table 2: Performance Levels for PNT X

Parameter	Detail		Value	Foot note
RF Signal Level	Carrier Level Control	Maximum	+20 dB	24
		Minimum	-40 dB	25
		Resolution	0.1 dB	
		Linearity +20 dB to -30 dB -30.1 dB to -40 dB	<0.10 dB <0.20 dB	
	Absolute Accuracy Run to Run Repeatability		±0.5 dB ±0.1 dB	26
	Individual Output Mode	Nominal Signal Level	+71 dB	
Configurable Iteration Rate	Supported SimGEN Simulation Iteration Rates (SIR)		10, 100, 250, 500,1000, 2000 Hz	27
	Hardware update rate		1000, 2000 Hz	
	Bulk logging update rate		250 Hz	
Limit of Signal Dynamics	Relative Velocity		120,000 m/s	28
	Relative Acceleration		192,600 m/s^2	29
	Relative Jerk		890,400 m/s^3	
	Angular Rates (indicative)	(at 1.5 m lever arm) (at 0.05 m lever arm)	>15π rad/s >60π rad/s	
Signal Accuracy	Pseudorange Accuracy		0.3 mm RMS	30
	Pseudorange Bias		0 mm RMS	31
	Delta-range Accuracy		< ±1.0 mm RMS	
	Inter Frequency Alignment		< ±230ps (±69mm)	32
	1PPS to RF Alignment		< ±2 ns	33

[24] 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, +17dB per channel for up to 32 channels, and +15dB for up to 64 channels.
[25] 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.
[26] RSS at 21±5°C, +20 to -30 dB. ±1.5 dB 3-sigma all conditions.
[27] At 2000 Hz, limitations to the total channel count and number of constellations/frequencies apply.
[28] For 6-DOF data externally supplied via SimREMOTE or from data file.
[29] When operating at >=250 Hz SIR.
[30] For signal acceleration < 450 m/s^2, jerk < 500 m/s^3, 1000 Hz SIR.
[31] Single radio card – supporting up to 64 channels. When the same signal is generated across multiple radio cards the inter radio card bias uncertainty is +/-230ps (+/-69mm).
[32] PRN code alignment between frequency band.
[33] Between any RF carrier at the output port(s). Applicable for both single and multi-output systems.

Spectral Purity	Harmonics	< -40 dBc	
	In-band Spurious	< -182 dBW	34, 35
	Phase Noise (single sideband)	< 0.005 Rad RMS	36
Signal Stability	Internal 10.00 MHz OCX Oscillator (after warm up)	± 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	37

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		38
	Range	± 25 MHz	
	Resolution	0.5 kHz	
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 µs	
	Pulse repetition interval range	50 to 10000 µs	
	Pulse repetition interval resolution	50 µs	
	Rise time (10% to 90%)	100 ns (max)	

[34] For relative velocities <50,000 m/s.
[35] In-Band Spurious Bandwidths (relative to center frequency unless otherwise stated):
GPS: L1 ± 20.5 MHz, L2 ± 20.5 MHz, L5 ± 20.5 MHz
Galileo: E1 ± 20 MHz, E6 ± 20 MHz, E5a ± 25.5 MHz, E5b ± 25.5 MHz
GLONASS: (relative to channel frequency 0) L1 ± 20 MHz, L2 ± 20 MHz
BeiDou: B1/B2 ± 20.5 MHz
[36] Value is typical, integrated over a 1 Hz to 10 kHz bandwidth. Worst case < 0.01 rad RMS.
[37] System latency is 4xSIR. At 2 kHz, system latency is 2ms.
[38] In addition to Doppler caused by vehicle motion. Applies to all signal types.

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Parameter	Detail	Value	Footnote
	On/Off ratio	30 dB	
AWGN	3 dB **Variable** Bandwidth	From 0.1 to 90 MHz	39
	Bandwidth Resolution	0.01 MHz	
	Bandwidth accuracy	±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	
Comb	Waveforms	CW, FM, AM, PM	
	Tone waveform frequency offset resolution	0.5 kHz	
RF Signal Level	Single signal	-47 dBm (max)	40
	Multiple signals	-72 dBm (max)	41
	Minimum level per signal	-117 dBm	

[39] Number of channels per SDR card is limited to 32 for 90 MHz AWGN signal generation.
[40] Single signal per SDR card (CW, FM, PM, Chirp), -49dBm (BPSK, pulsed CW), -53dBm (AM), -60dBm (AWGN).
[41] Per signal, up to 16 signals of AWGN on the same radio card – other signal types can be up to 3dB higher.

Parameter	Detail	Value	Footnote
	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 Modeling	3D Maps	San Francisco, Tokyo, Paris, London, White Sands, Shanghai, Fort Huachuca, Cape Pendleton, Cape Canaveral, Fort Moore	42
3D Multipath	Max. Simulation Iteration Rates (SIR)	100 Hz	
	No. of Multipath per LoS	1-8	43
	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,E5,E6,B1,B2,QZL1	44
	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	

[42] The approximated size of each 3D map is 100 sqkm.
[43] User can define the number of multipath signals per LoS.
[44] Galileo E5 AltBOC signal structure is not supported.

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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 characterize. Instead, Spirent Federal 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 more:

- 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 Federal 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: C50 X 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[45]
Optional GPIB	I/O	Available for remote control and GSS7765 control
Optional ScramNET	I/O	Available for remote control

[45] The SimREMOTE and SimPORT Ethernet ports support up to 10 Gbps.

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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 61326-1:2021 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	Document #
SimGEN	GNSS Software Suite	MS3008
SimREMOTE	Simulator Remote Control Additional Options	MS3015
SimINERTIAL	Inertial Sensor Emulation Option	MS3030
GSS7765	External Interference Generator	MS3055
SimROUTE	Road-Matched Trajectory Generation Tool	MS3073
SimSENSOR	MEMS Sensor Simulation Option	MS3086
Spoofing Feature	Spoofing Scenario Solution	MKT00432AAA
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
SimXona	Xona Pulsar™ Signal Generation	MS3120
Standpoint	Live-sky Synchronization Solution	MS3121
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

For more information on these resources, contact Spirent Federal at **info@spirentfederal.com**.

Environmental Social & Governance (ESG)

Spirent's Positioning Technology Business Unit has been committed to ESG good practice and improvement since achieving ISO14001:2015 Environmental Managemental 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.

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;
- Virtualization 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 Federal representative.

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

For More Information

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Why Spirent?

Across five decades Spirent has brought unrivaled power, control and precision to positioning, navigation and timing (PNT) simulation. Spirent partners with the leading developers and integrators to consult and deliver on innovative solutions, using the highest quality hardware and the most flexible and intuitive software on the market.

Spirent delivers

- Simplified testing accelerates the innovation cycle and deployment of robust PNT systems
- Proven track record of being first-to-market with new signals and ICDs
- Unrivaled investment in customer-focused R&D
- World-leading expertise, redefining industry expectations
- Powerful, flexible and customizable SDR technology for future-proofed test capabilities
- Signals built from first principles — giving reliable and precise truth data

About Spirent Positioning Technology

Spirent enables innovation and development in the GNSS and additional PNT 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.

About Spirent Federal Systems

Spirent Federal Systems provides the world's leading PNT test solutions to the US Government and contractors to enable resilient PNT under any conditions and outpace evolving navigation warfare threats. As a US proxy company, Spirent Federal enhances Spirent's commercial offerings with classified and other sensitive military signal emulation capabilities.