Defying Gravity: Part 2

Space tech solutions enabling confidence from design through orbit

KEYSIGHT

Introduction

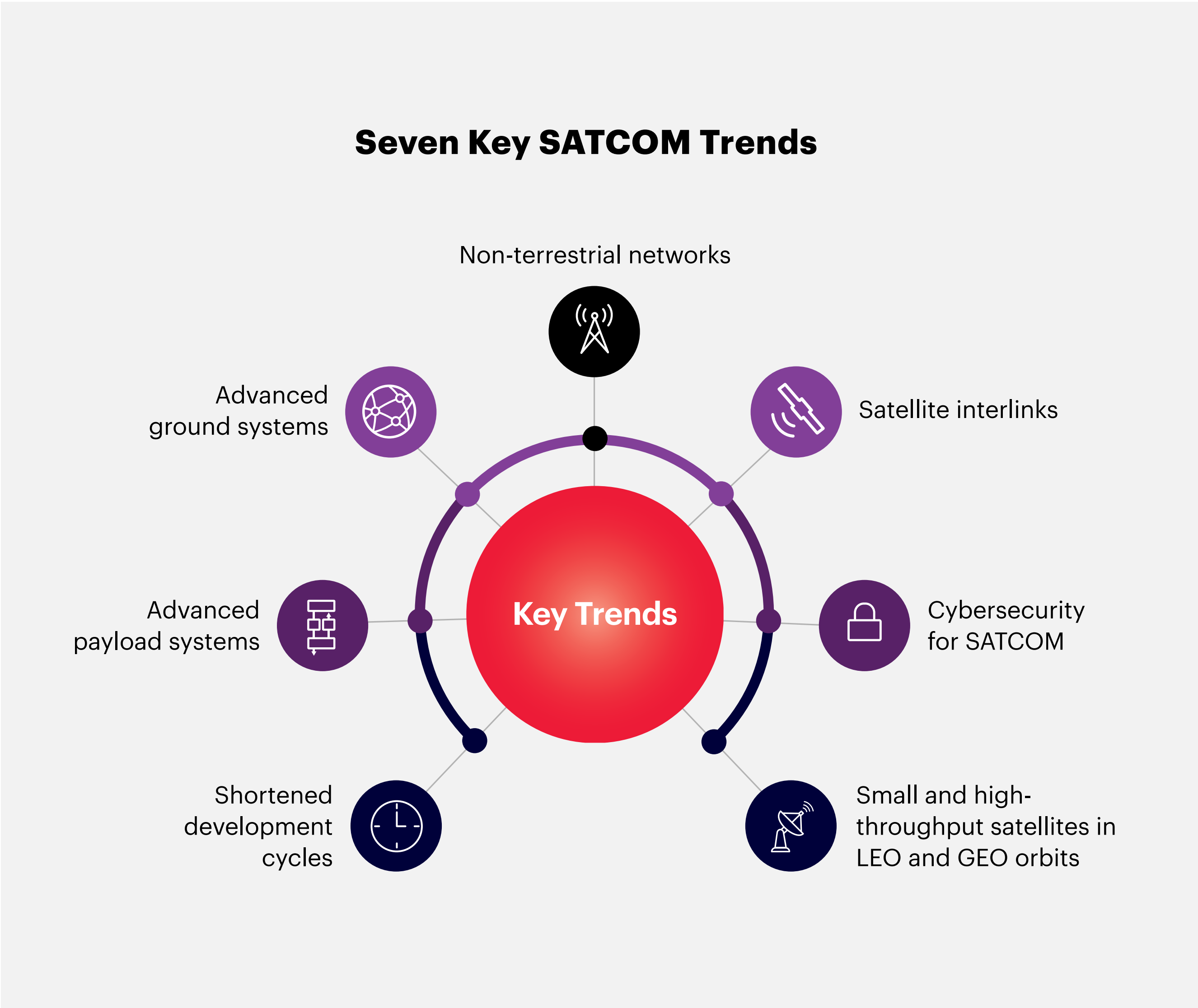
In our landmark report, *Defying Gravity: Challenges, opportunities, and innovations in the space tech industry*, Keysight and Coleman Parkes Research surveyed current trends and key challenges and opportunities in the space tech industry. The survey provided a broad overview of the space tech industry, the driving issues for decision-makers, and where the industry is headed in the near future.

This report, *Defying Gravity, Part 2: Space tech solutions enabling confidence from design through orbit* looks more closely at seven key trends that stood out as having the highest potential for development right now. We designed this eBook so that you can easily navigate to the topics that concern you most and find the solutions that best fit your needs.

Each article in this eBook focuses on a top trend and examines:

- the technical challenges related to the trend
- key test issues you're likely to face
- Keysight's test solutions
- potential use cases

The actionable insights provided in the report will help engineers understand and overcome the technical hurdles facing them as they design for space. We hope this resource will serve as a roadmap as you develop your strategy for success in space tech.



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TREND 1

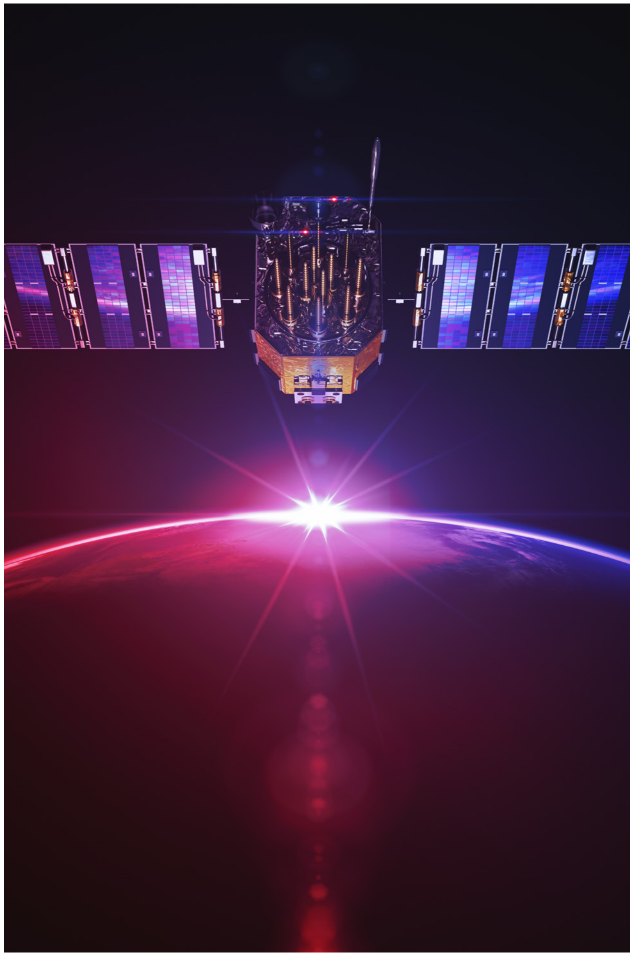
Shortened Development Cycles

The Challenges of Accelerated Development

Shortened development cycles consistently appeared as the top current trend in the satellite industry in our Defying Gravity report. Forty-three percent of surveyed space tech decision-makers cite it as the leading challenge in the industry.

The commercialization of space has changed the nature of space missions. Companies like SpaceX, Blue Origin, and Rocket Lab have developed reusable rockets and spacecraft that make space ventures more accessible and affordable.

Space technology is evolving rapidly, as are commercial and scientific opportunities in both the private and public sectors. With opportunities come challenges. To capitalize on the future of satellites, private and public sector players must accelerate development significantly while ensuring flawless performance. It is a daunting mission, but it is possible if you have efficient and accurate testing methods tailored to the demands of space technology.



Budgets and timelines are shrinking

With competition from commercial and government sectors, all space tech industry participants face increasing pressure to release projects faster, with the same resources. At the same time, budgets are tight, and the pressure on costs is high. Established manufacturers must accelerate or risk losing business to agile start-ups while monitoring operational and capital expenses. Start-ups need to balance their technological ambitions against limited capital resources.

Regulatory requirements are tightening

As the SATCOM industry matures, regulators are justifiably stepping up their oversight with more stringent regulatory requirements for safety, licensing spectrum allocation, export control, and environmental protection. Qualification and acceptance tests add to the workload.

Advanced space technology is complex

The technology used in space exploration is highly complex, comprising a convergence of cellular and satellite networks and, increasingly, 5G non-terrestrial networks (NTN). Furthermore, technology is continually advancing to maintain pace. For example, engineers must consider mmWave frequencies, multiple antennas, complex modulation, beam steering, and sophisticated algorithms when designing RF systems for SATCOM. Rough estimates, figures, formulas on spreadsheets, and internal or custom tools are insufficient. The number of systems involved across the upstream, midstream, and downstream of the space development value chain is ever-increasing. Moreover, interoperability is a crucial requirement for the majority of these systems. As the US Department of Defense Digital Engineering Strategy emphasizes, to sustain the pace of innovation while assuring optimal performance, the space technology industry must adopt digital, automated design and testing processes.

Zero tolerance for error

Satellites represent significant investments by multiple parties — the rocket company, payload owner, and customers benefiting from the service provided. Flawless performance requires built-in support from day one, as no one can hear your cries for help from space.

Satellite missions operate with a unique set of link budget obstacles. These include Doppler shifts, atmospheric distortion, latency, extreme temperature fluctuations, and high signal absorption. Overcoming these obstacles demands high output powers from the satellite, driving onboard amplifiers into non-linear distortion — all heightened by the unforgiving nature of space. Extra care is necessary in every stage of the design, manufacturing, and deployment process to ensure that a satellite works the first time, every time.

Rethinking testing

Until recently, space tech engineering practices used radiation-hardened, space-proven components that would remain in service for as long as 10 to 15 years to minimize risk. Testing was stringent and manual, taking a significant amount of time and effort, sometimes taking months. Manual testing is not feasible for launching state-of-the-art technologies at a futuristic pace.

The Need for Speed Meets Space-Ready Test Solutions

Developers must assemble an integrated toolbox for modeling complex systems, emulating the real-world environment in space, and automating design and testing across the life cycle to accelerate development and time to market.

Keysight offers an end-to-end suite of tools, including hardware, software, and services, to enable SATCOM companies to meet the heightened expectations of shortened timelines, cost control, and elevated quality assurance. Our scalable, flexible, and customizable solutions encompass the entire workflow — design, simulation, test, validation, and software. Use Keysight SATCOM solutions to help maintain measurement consistency across various cycles, shortening your path from concept to deployment in space tech.

One environment for system architecture, design, and verification

RF system design for SATCOM requires more than math-based modeling. The Keysight PathWave System Design software brings teams multi-domain modeling and simulation in one collaborative design environment for complex SATCOM RF systems. Backed by decades of Keysight measurement science in RF instrumentation, PathWave System Design offers the most advanced prototyping and design platform for complex RF systems with faster simulation speed, near-circuit fidelity, libraries for radar, electronic warfare, satellite, 5G, and Wi-Fi®, along with enterprise integration with numerous partners.

System-level modeling is one of the most effective methods to shorten development cycles. By allocating more time to simulation, designers can proactively uncover potential design issues before committing to hardware prototypes. With the Keysight W4815B PathWave satellite bundle, engineers and designers can access a cohesive set of resources and tools specifically tailored to their application domain. The PathWave System Design ecosystem can expedite design cycles, enhance performance, and attain accurate project results.

Satellite and aerospace channel emulation toolset

For today's complex communications systems, a failure in a communication link can be life-critical. Ensuring that space-borne equipment operates flawlessly is essential. That is why it is crucial to emulate various phenomena that may affect a radio device in its real-world environment.

The Keysight S8825A satellite and aerospace channel emulation toolset provides the foundation for covering the most advanced test requirements. The solution provides satellite link emulation to any signal that passes through it, providing realistic delay, Doppler, and fading effects. Testing in a controlled laboratory environment using a vast range of use case scenarios provides wireless communications systems developers with a reliable and cost-effective solution for testing air-to-air and air-to-ground communication links.

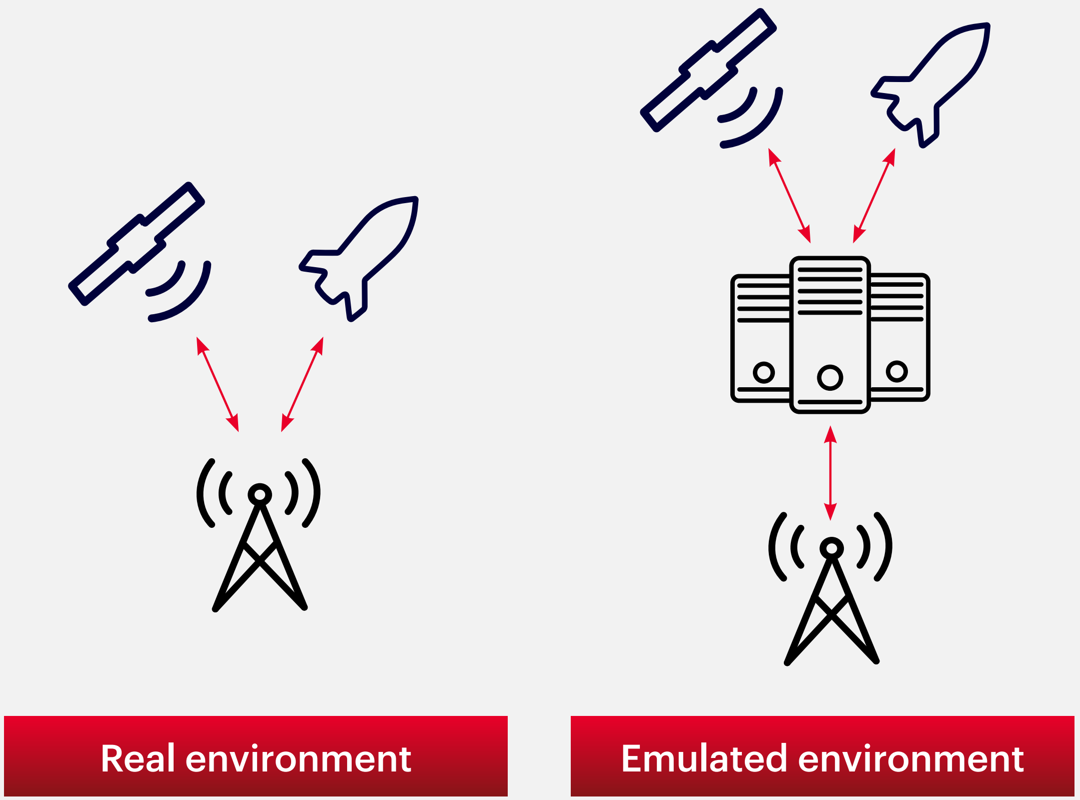


Figure 1. Bring real-world radio channel conditions into the lab with the S8825A satellite and aerospace channel emulation toolset

Network digital twin ecosystem

The use of models in engineering is not new. Today's computing power enables engineers to build complex models that can interact with one another in an entirely digital environment. These digital models can be detailed and accurate using digital twins that are interchangeable with the physical version.

When your innovation is operating at 1,200 miles or more above the Earth, testing in a real-world environment is extremely difficult and expensive. That is why system models, simulation, and digital twins are essential tools for space tech engineers. A network digital twin can study the behavior of its physical counterpart under a diverse set of operating conditions, including cyberattacks, in a low-cost and zero-risk environment.

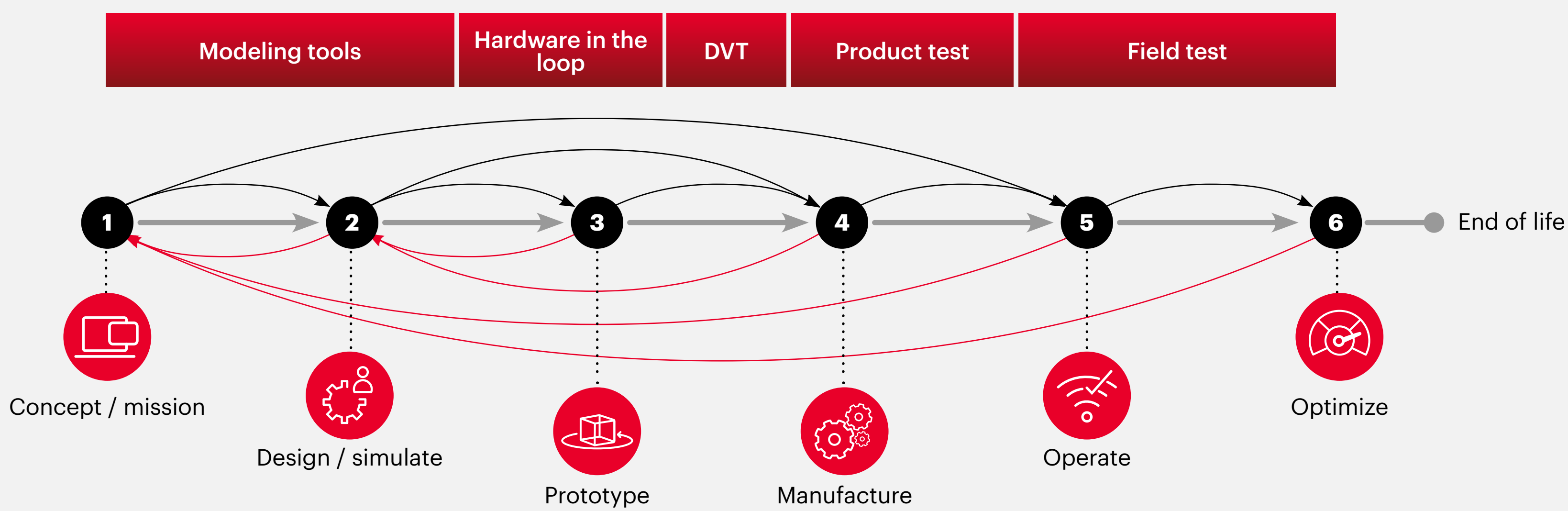


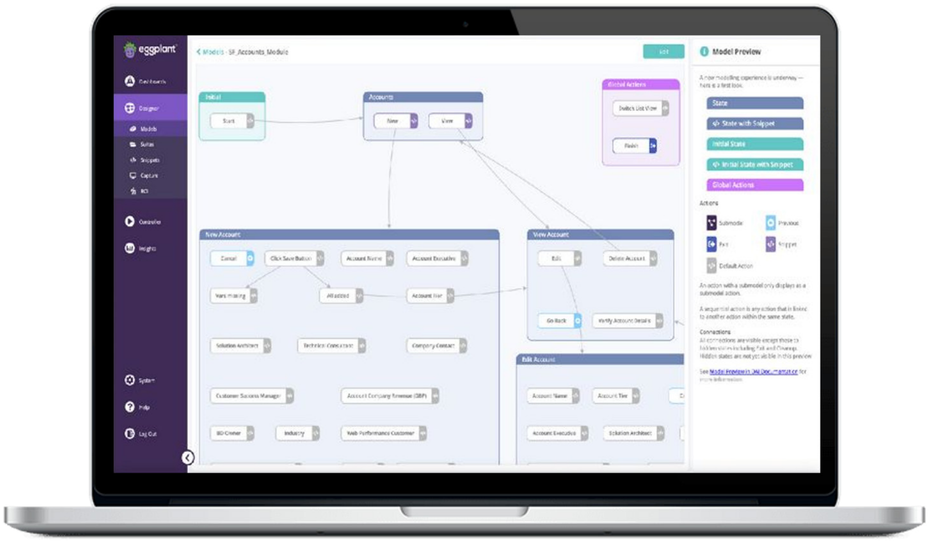
Figure 2. Processes and data through a simple product life cycle

Given the complexity of SATCOM technologies and the extremes of the space environment, creating a digital twin that accurately represents the topology, configuration, and traffic of an existing physical SATCOM network can be challenging.

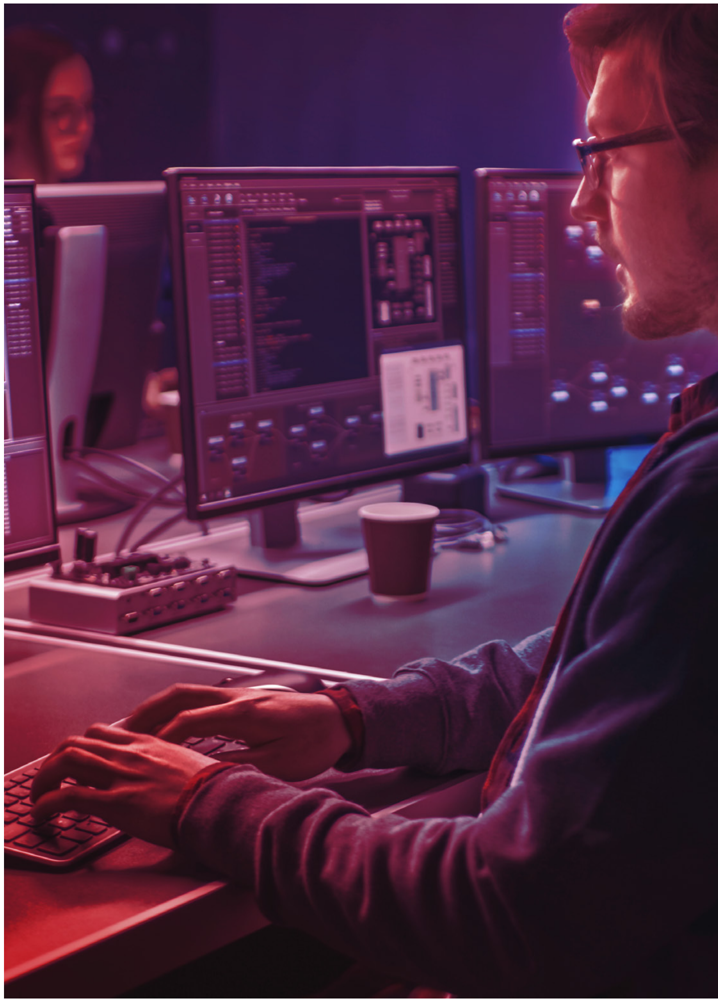
Keysight has developed an ecosystem of tools to assist the user in automatically creating network digital twins as well as modifying, executing, visualizing, and analyzing their performance. Use our real-time network digital twins to model and analyze the terrestrial, sub-terrestrial, and satellite RF environments under various operating conditions, including cyberthreat exposure, while capturing the network metrics at each protocol stack layer.

A path to speed and security

Creating test cases manually for every possible action and scenario is arduous and time-consuming. In the complex space environment, testing is even more of a challenge. For a SATCOM innovator to maintain a competitive edge amidst shortened development cycles and fulfill mission-critical requirements, automating software testing is imperative. Software test automation can help reduce multiple challenges associated with budgets, regulatory requirements, technical complexities, limited resources, timelines, and safety.



Software test automation simplifies, accelerates, and delivers robust end-to-end testing across the product life cycle. Our model-based, AI-powered test automation software provides visibility into how applications and interfaces can potentially succeed or fail at any moment — all at machine speed. Explore our software test automation solutions to ensure flawless operation before your device launches into space.



Testing Mission-Critical Black Box Software with Automation

The space and the defense industries have unique conditions that challenge traditional testing methods — a need for confidentiality, diversity of technologies and systems, and the integration of multivendor software systems. Testing mission-critical software requires automated black box testing techniques that facilitate full system testing without having to access the internal architecture, code, algorithms, data, or design details of the software or system under test.

Keysight test automation software combines computer vision with advanced artificial intelligence (AI) to interface with secure systems without requiring access to the underlying source code or installation of an agent on sensitive, proprietary, or other closed-system hardware.

A combination of two techniques achieves non-invasive automation:

- Use a two-system model that allows the testing software to sit on a separate machine from the system under test (SUT).
- Perform testing via the user interface (UI) rather than through access to the source code or object layer, as standard automation tools may obscure or lack access to these two areas.

Keysight's non-invasive testing reduces manual testing time and ensures safer, more reliable software for space and defense applications. NASA, the US Army, and numerous defense contractors use our test automation software to test some of their most sensitive systems.

> Using Keysight Software Test Automation, the team was able to replicate the tests for different scenarios required. It could then execute the tests during off-hours to complete multiple test runs without a tester being present.
>
> Keysight enabled the team to move from completing a 10-hour test event every three days to running a 24-hour test event every day.
>
> The US Army

View the video for advanced solutions for mission-critical software

For more information about Keysight solutions for shortened development cycles, visit this page

TREND 2

Advanced Payload Systems

Ensuring Payload Performance in Orbit

Advanced payload system technology plays a crucial role in enabling spacecraft and aircraft to achieve their mission objectives. This technology supports a wide range of applications and industries. Once the satellite is in orbit, all complex systems and payload components must function flawlessly to ensure optimal performance. Satellite payload designers and manufacturers must thoroughly test each part of a satellite during production and assembly to validate the spacecraft's payload performance before it leaves the launch pad. Testing should encompass not only the validation of the payload device in isolation but also the examination of how the payload interacts with other circuitry and the environment within and around the satellite.

> The complexity of satellites, with their nature as a system of systems, makes testing and evaluation a critical aspect of ensuring mission success.
>
> Greg Patschke, general manager, Keysight Technologies

Regenerative payloads — easier to manage, harder to test

Within a satellite, regenerative payloads are mixed-signal systems that carry analog and digital representations of modulated signals. Challenges inherent in bent-pipe satellite testing differ significantly from those posed by other methods. Digital modulation formats can vary in terms of being wideband, higher-order, or customized.

During testing, managing the format changes that occur as signals travel through the transmitters and receivers can be difficult. Successful troubleshooting often requires cross-format analysis between the digital and analog parts of the system.

The bit error ratio puzzle

System operators need a predictable and consistent bit error ratio (BER) digital signal across all user terminals. However, signal quality can vary when switching from one ground station to another, making it challenging to guarantee acceptably low levels of BER in all situations. Testing the BER is especially complex because it varies with signal level and a variety of component characteristics. This variability makes it difficult to determine which parameters to test and the locations for measurement.

Preparing for the extremes of space

A satellite in space can encounter extreme temperature fluctuations reaching up to 260 degrees Fahrenheit. Equipment for space applications requires stringent environmental and mechanical tests to prove its ability to withstand the extreme conditions of launch and space environments.

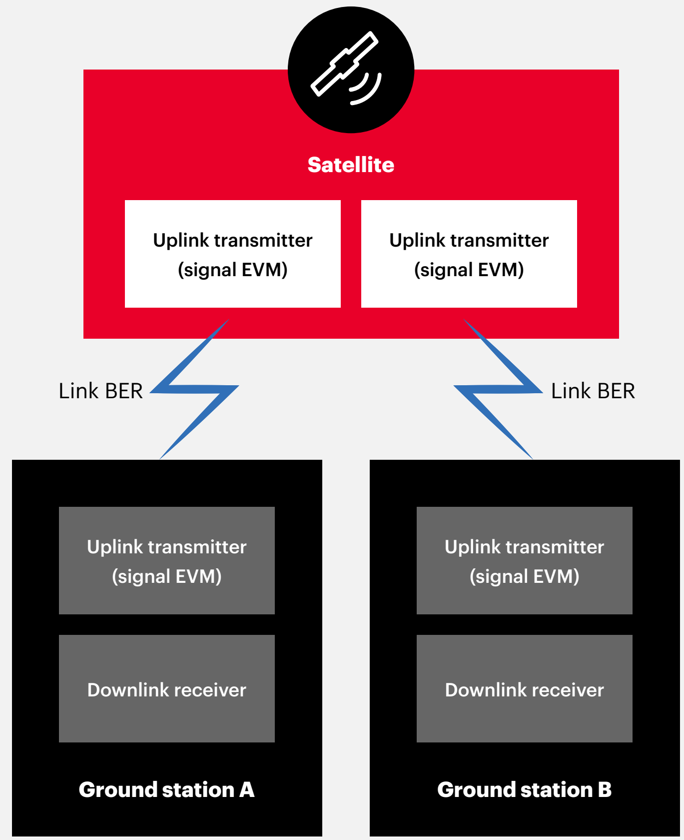


Figure 3. Link BER defines the end-user's experience while EVM characterizes the signal quality of analog and digital modulated signals

Thermal vacuum chamber testing — the next best thing to being there

One of the best test tools for ensuring a payload's survivability under space conditions is a thermal vacuum chamber (TVAC), which accurately simulates the extreme environmental conditions of space. The TVAC encloses the entire satellite or satellite component modules. Typically, the positioning of the measurement equipment, such as the power meter and sensors, is outside the chamber. These instruments connect to the satellite or components using hermetically sealed connector feedthroughs via switch matrixes or a test interface subsystem.

TVAC testing challenges

Thermal vacuum chambers create complex testing environments during the satellite manufacturing process. Connecting the device under test to the measurement equipment typically requires long cable lengths. These extended RF cable lengths can result in accuracy degradation due to poor standing wave ratio (SWR) and insertion loss. Calibrating the path loss involves complex calibrations due to the variability of the RF cable performance with temperature.

Typical TVAC Test Group

RF power meter and sensor are typically installed outside the chamber and being routed into the chamber via long RF cables.

- Degraded accuracy
- Complex test setup
- Complicated calibration routine

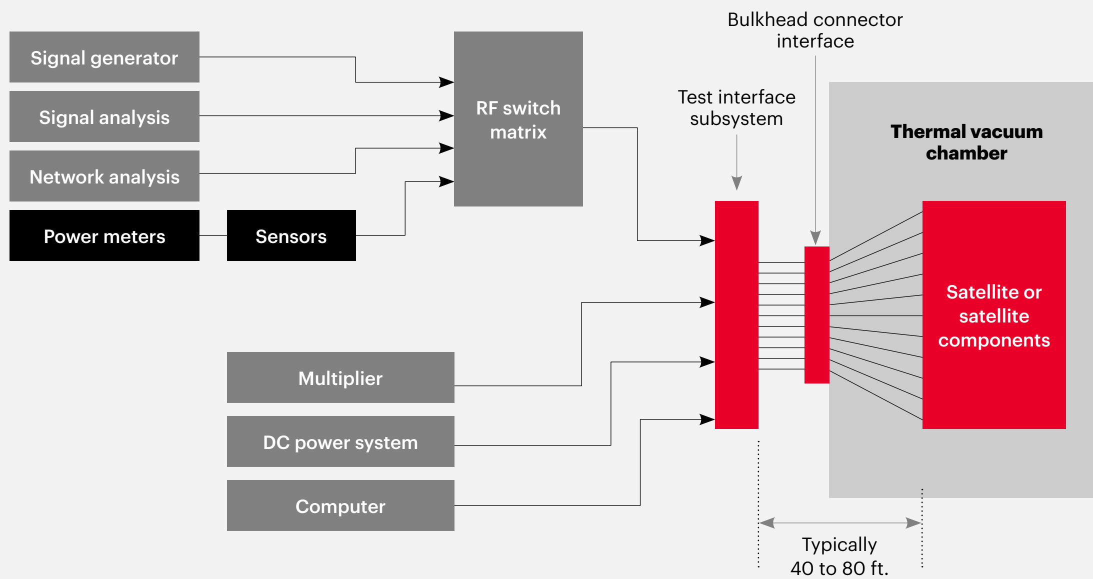
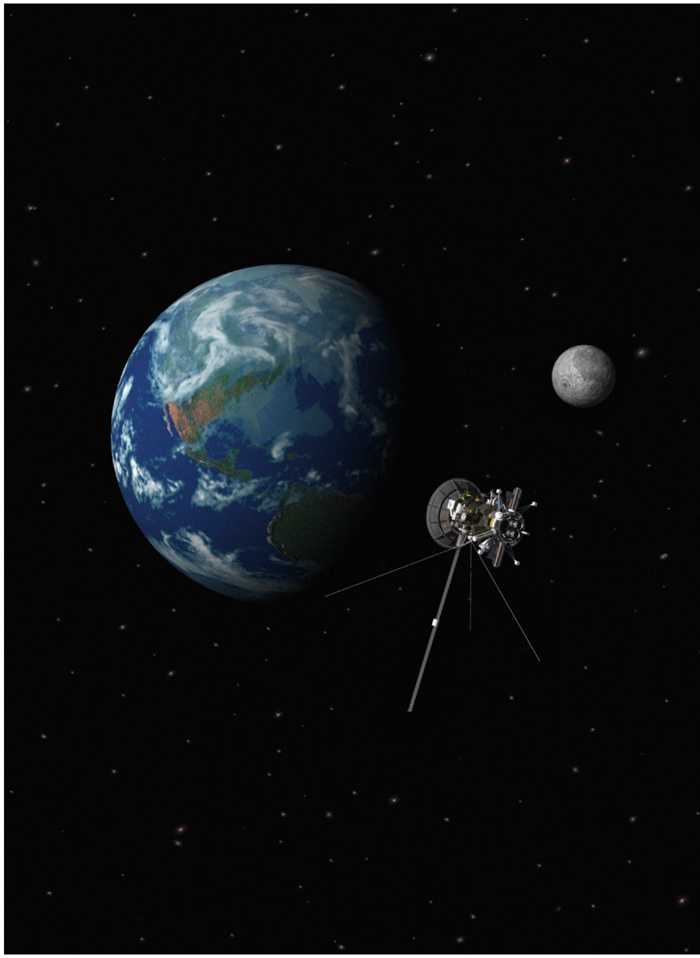


Figure 4. Typical TVAC test setup with all the measurement equipment located outside the chamber and connected to the satellite or components via switch matrices or a test interface subsystem

Accuracy in Testing Means Confidence at Launch

Reliability, consistency, flexibility, and ease of use are key considerations when looking for a solution. Given the variety and complexity of advanced payload systems, testing for a wide range of capabilities before launch is essential — from calibration to thermal compliance. High-quality instrumentation and uncompromising development standards define a test system that reports results to the test operators that are highly accurate and repeatable over time.

The Keysight Payload Test System (PTS) platform meets this critical criteria. The PTS solution is a complete integrated set of instrumentation, signal conditioning, and measurement calibration hardware and control software to test the satellite RF payload extensively and robustly. Experience calibrated payload characterization and testing through a comprehensive turnkey solution supported by Keysight's expert engineering teams.



Reliability and support in one package

The result of Keysight's experience in test system software, the PTS solution has an efficient control flow, intuitive user interfaces, and test automation that minimizes potential manual errors when running tests.

Benefits

- Maximizes flexibility and ease of upgrade through modular construction.
- Provides expansion space in the rack for additional switching, a digital oscilloscope, and other equipment.
- Uses system calibration and verification methods with the best available technology for Keysight PNA-X network analyzer solutions.
- Employs highly automated methods and improves confidence in measured data.
- Simplifies the calibration in remote locations such as thermal vacuum chambers using the Keysight unique auto-calibration module (ACM).

Achieve accurate RF and microwave power measurements

A major leap forward for today's accelerating space race, the Keysight U2049XA (Option TVA) and Keysight L2065, L2066, and L2067XT are thermal vacuum compliance LAN power sensors that you can place inside the chamber and connect directly to the satellite or component under test.

The new U2049XA (Option TVA) test, in contrast to traditional external TVAC test methods, minimizes accuracy degradation and path loss, enabling:

- Experience a test setup with less complex calibration routines that deliver accurate output power measurements without path loss calibration.
- Get reliable and accurate power measurements that eliminate the power measurement uncertainties due to insertion loss, poor SWR performance, and temperature effects.
- Perform tests and deliver reports more thoroughly and efficiently with software that integrates all the instruments.
- Connect to a shared network using a web browser and the Keysight BenchVue BV0007B software to remote control and monitor anytime, anywhere.

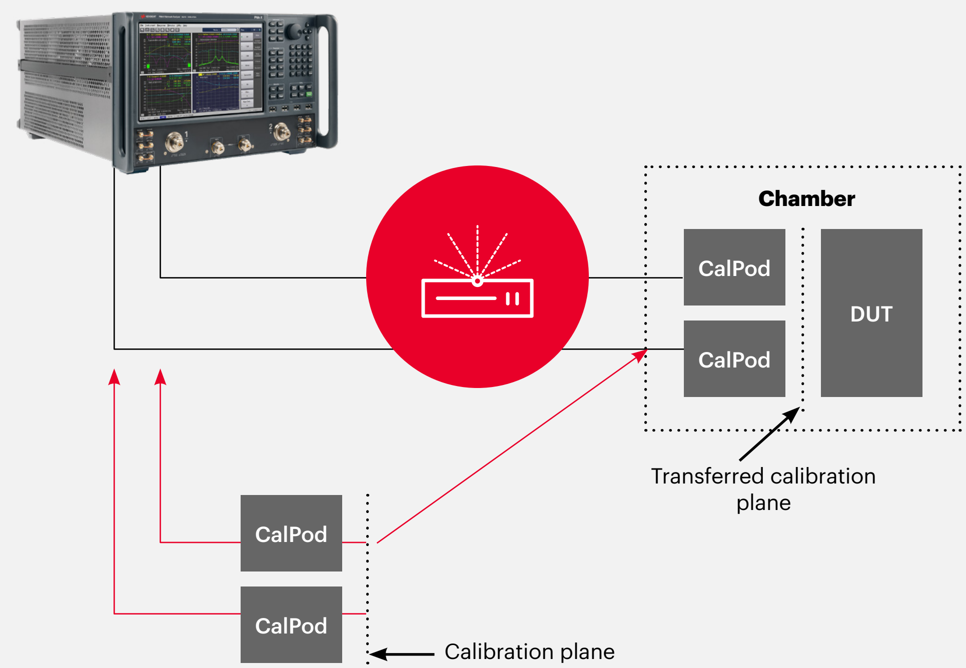
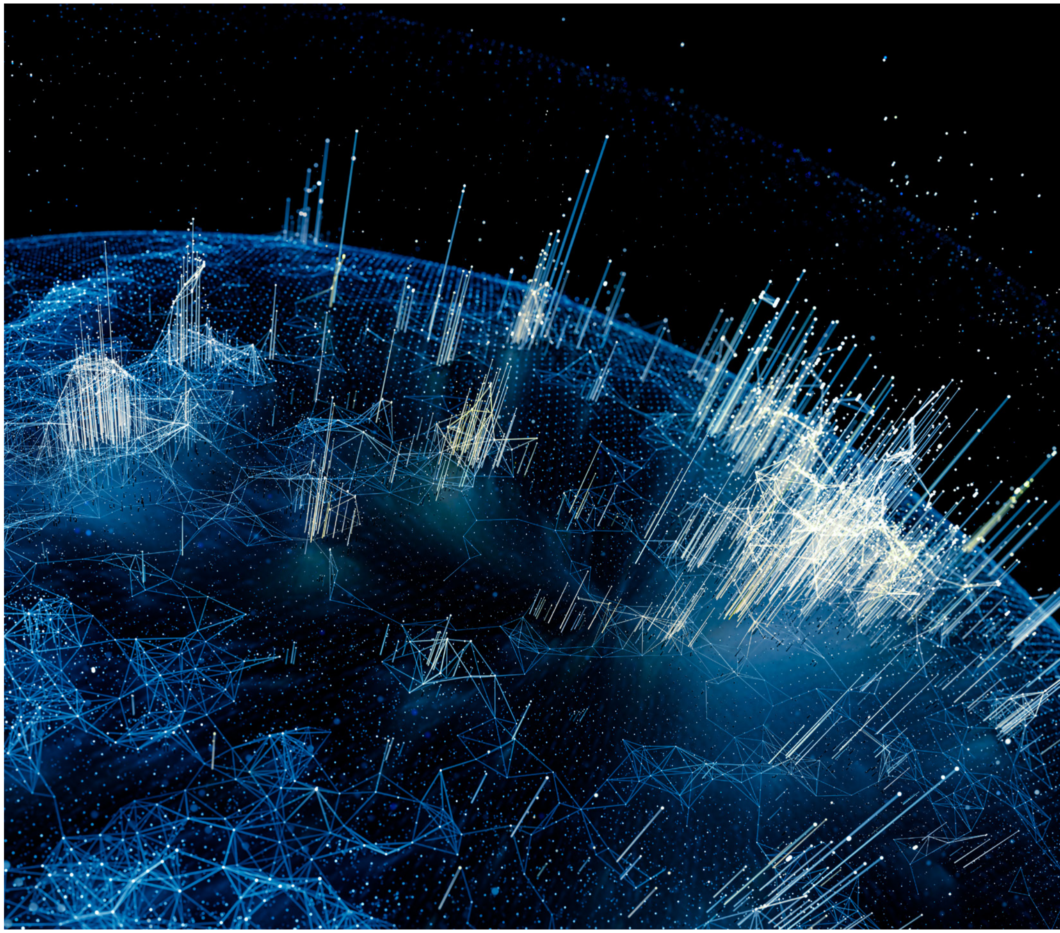


Figure 5. Use CalPods for in-situ calibration at the DUT

Performance Assured as Your Needs Change

Our satellite payload and TVAC testing are scalable and modular, capable of handling various test scenarios. The automated software minimizes manual intervention and testing time, while the fully automated calibration alleviates the need to calibrate each instrument in your setup individually.

Whether you are a start-up with focused goals for now or a large leading operator with more complex requirements and more significant investments, Keysight has the advanced testing systems to launch you into the space race with confidence, now and into the future.



Reduce risk with simulation

Keysight PathWave System Design (SystemVue) software brings teams multi-domain modeling and simulation in one collaborative design environment for complex RF systems with analog and digital sections. It goes beyond math-based modeling with a complete RF-aware design workflow, plus decades of Keysight measurement science in RF instrumentation, ready for any system architect.

PathWave System Design delivers an advanced system design exploration and validation platform, offering accelerated simulation speeds and near-circuit fidelity essential for addressing the challenges of satellite payload systems. With comprehensive libraries tailored to radar, satellite, and 5G applications and seamless third-party integration capabilities, it is a robust tool to overcome the complexities of advanced satellite payload systems.

TVAC Testing with Less Loss, More Accuracy

Simulating space conditions with a thermal vacuum chamber gives payload engineers a design advantage. Learn how to overcome the disadvantages of using long cable lengths that lead to accuracy degradation and path loss.

Keysight has overcome the most significant challenges of TVAC testing by developing test equipment that connects directly to the satellite inside the chamber. Figure 6 is an illustration of a traditional TVAC test setup. Keysight's new TVAC test setup changes the approach by placing power sensors inside the chamber and connecting directly to the satellite or components. Engineers benefit from a simplified test setup and more accurate and reliable microwave power measurements for TVAC testing of satellite equipment.

For more information about Keysight solutions for advanced payload systems, visit this page

Typical TVAC Test Group

RF power meter and sensor are typically installed outside the chamber and being routed into the chamber via long RF cables.

- Reliable solution
- High accuracy
- Siimplified test setup
- Remote monitoring

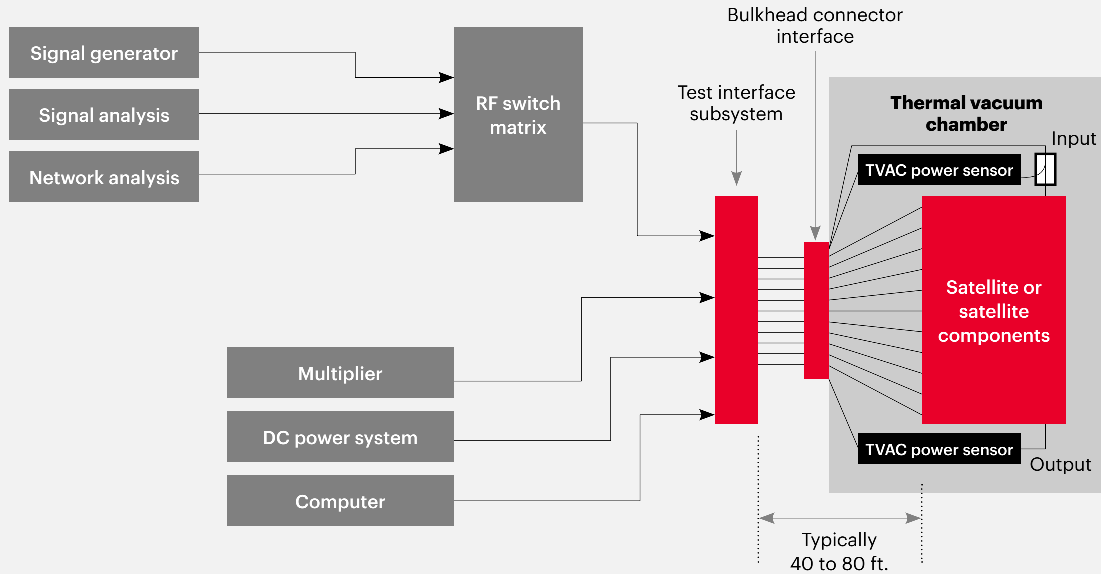


Figure 6. New TVAC test setup with sensors connected directly to the input or output of the satellite for improved accuracy and simplified test setup

TREND 3

Advanced Ground Systems

Performance in Orbit Requires Precision on the Ground

Innovations in telemetry, tracking, and command-to-control satellites make next-generation ground systems a top satellite technology trend. Ground stations use RF communication terminals, including electronically steered and phased array antennas, to track satellites with minimal human intervention. On the commercial end, ground stations are empowering software-defined satellites by enabling virtualized ground networks. These technologies enable satellites to autonomously reallocate, reconfigure, and handle massive bandwidth, as per demand, to support a growing number of end users.

Developers of advanced ground systems supporting space missions face a number of key technical challenges. Modern satellite networks operate at higher frequencies. Increasingly, advanced ground systems are evolving from parabolic reflector antennas to active phased array antenna systems that enable the ubiquitous connectivity and sensing requirements of next-generation satellite communications.

Phased array antennas: More flexible, more reliable, and more complex

Phased array antennas have advantages over parabolic reflector antennas. A parabolic antenna can leverage its surface area to maximize the received signal power from the spot in the sky to which the dish points. Using electronic means to steer beams to precise locations, phased array systems offer more flexibility and higher reliability. They have the key ability to maintain satellite communications links with a low Earth orbit (LEO) satellite traveling at approximately 27,000 kilometers per hour. Phased arrays also offer improved performance advantages, such as enabling multiple beams, agile beam steering, and beam pattern optimization.

Testing these highly integrated systems, however, is a complex and time-consuming task resulting from multiple requirements and features. They include the need to manage large amounts of data and to enable automation, integration, security, and distributed operations.

The need to handle massive amounts of data

State-of-the-art sensors and instruments generate enormous data volumes. Reliably processing and storing the data, and making it accessible to users, requires high-bandwidth communication links, advanced computing capabilities, and specialized algorithms.

System autonomy and automation

Spacecraft and instruments operate at great distances, so ground systems need increased autonomy and automation to function safely and optimally without constant human intervention. Detecting anomalies and triggering appropriate responses hinges on automated analysis.

Complex subsystem integration

Modern ground systems comprise many interconnected subsystems for managing spacecraft vehicle health; mission planning and sequencing; tracking, telemetry, and command; data distribution; and more. Seamlessly integrating these subsystems is an ongoing challenge.

Information security

Protecting against data theft or corruption is critical but exceedingly difficult, given the increasing connectivity with external networks and devices. Advanced cybersecurity measures are essential.

Coordinated distributed operations

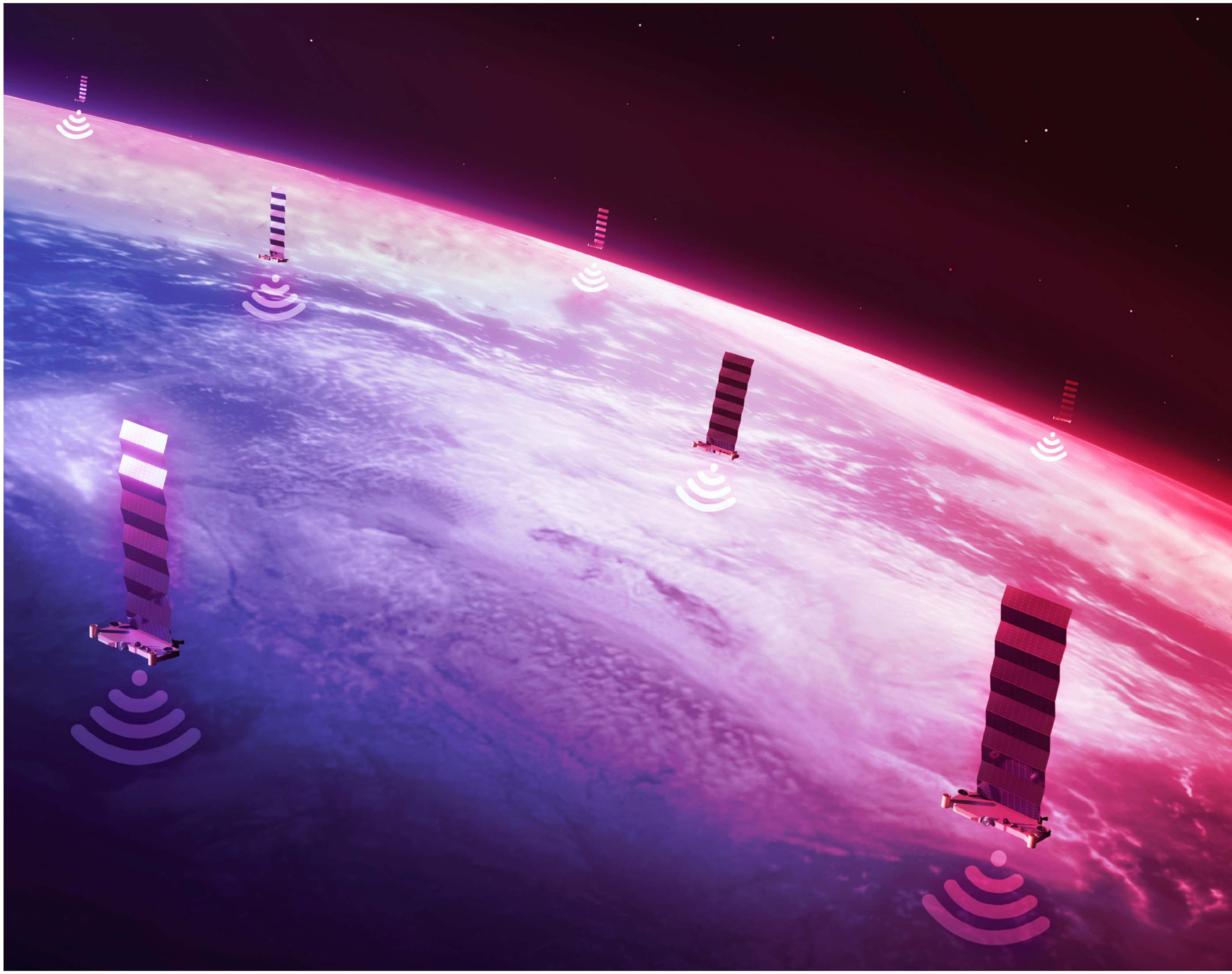
International partnerships and globally distributed sensor networks drive requirements for seamlessly interconnecting ground infrastructure across vast distances. This process demands common standards and communication protocols.

With rising mission complexity and costs, advancing ground system capabilities is vital to 21st-century space exploration and discovery. Developing robust, flexible, and secure ground systems requires pushing boundaries in areas like software engineering, system modeling, simulation, automation, standardization, and security.

Advanced Ground Systems: **The Solutions**

The phased array design and development process is complex as well as time- and resource-consuming. Designers and manufacturers need reliable and fast over-the-air testing to calibrate and verify the performance of phased arrays quickly and efficiently. The Keysight phased array antenna control and calibration solution meets this need by enabling satellite designers to rapidly test their designs during early validation.

The solution combines a compact antenna range with commercial test equipment and measurement software to provide an economical and fast way to calibrate and test the performance of these antennas. It's a flexible measurement solution that improves signal-pointing accuracy by optimizing the frequency, gain, and phase response of active antenna array elements.



Calibrate your array in minutes, not hours

Antenna array calibration is critical for phased array systems as accurate beam pointing demands precise phase and amplitude control. The calibration process compensates for relative RF variance between channels caused by manufacturing differences in RF components, the printed circuit board, and the beamforming network. In addition, electronic components vary with operating conditions, such as frequency and temperature, and require stored calibration files as operating conditions change.

The phased array calibration and characterization test solution offers a comprehensive and user-friendly software interface. To deliver fast, fully automated measurements, it integrates and synchronizes digital control of the high-performance Keysight PNA-X vector network analyzer, VXG-C vector signal generator, and compact antenna range (CATR) with a positioner, as well as the phased array antenna beamforming integrated circuit channels.

Pairing the CATR with the PNA-X vector network analyzer enables a suite of calibration routines and beam pattern measurements that sweep across azimuth and elevation. The Keysight phased array antenna calibration software characterizes the amplitude and phase of each array element with high levels of accuracy, reducing calibration time from hours to minutes.

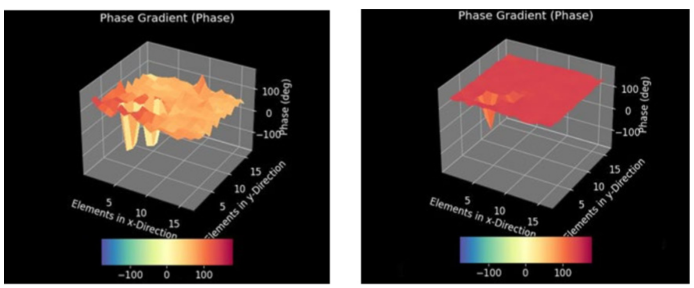


Figure 7. The images show a 256-element array before calibration (left) and after calibration (right). Two defective elements appear in both images.

Figure 8. The PNA-X vector network analyzer offers the world's most integrated and flexible microwave test platform for active device characterization

Figure 9. The M9484C VXG is the industry's first vector signal generator capable of generating signals up to 54 GHz with 2.5 GHz of modulation bandwidth per channel. The VXG vector signal generator helps you deliver the next frontier of wireless technology such as 5G and satellite communications with a fully integrated, calibrated, and synchronized solution.

Get the most accurate results

Over-the-air CATR solutions from Keysight integrate with the device development workflow from the early chipset and device prototyping through design verification, conformance, and carrier acceptance testing. The CATR is a shielded anechoic chamber with a rolled-edge reflector and a roll-over azimuth positioner. It provides a measurement environment for characterizing antenna system performance from microwave through millimeter-wave frequencies.

By using a reflector, the fixed CATR method enables far-field measurements of individual elements and the full array in a much shorter distance than is possible with direct far-field measurement. Ultimately, the CATR chamber provides lower signal path loss in a small, compact, and portable anechoic chamber for the most accurate results possible.

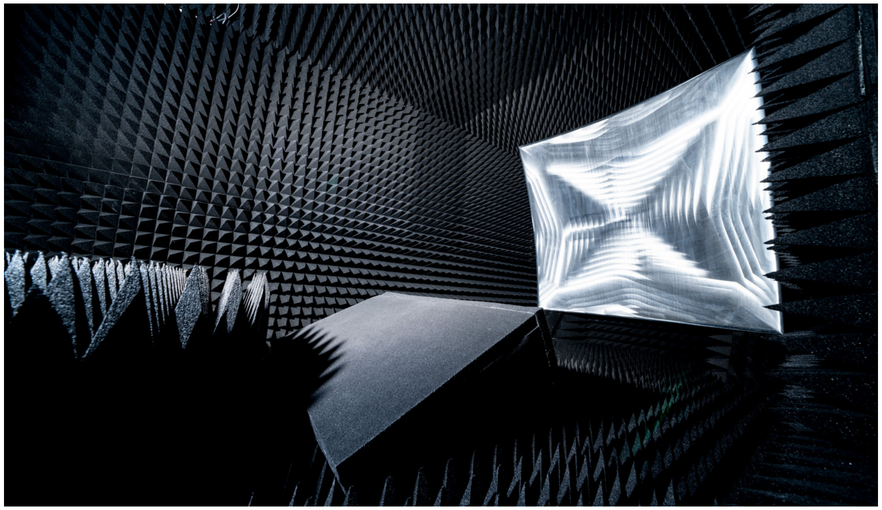


Figure 10. The S7601A Antenna Measurement Toolset is a comprehensive solution to test and verify different types of antennas for cellular, automotive, and satellite communication

Calibration and verification with element-level accuracy

The phased array antenna control and calibration solution hands engineers a complete solution for the design and development of phased-array antennas for satellites. Its advantages include the following:

- A wide variety of verification tests, including fast gain and phase calibration, effective isotropic radiated power, radiation pattern versus beam scan angle, beam scan and range loss, cross-polarization isolation, gain compression, gain-over-noise temperature, and modulation distortion (error vector magnitude).
- An integrated solution with a single user-friendly software interface that controls the antenna under test, high-performance Keysight test instruments, and a Keysight compact antenna test range positioner and temperature control unit.
- The ability to maximize existing test chambers by retrofitting into existing anechoic chambers with the addition of a PNA-X vector network analyzer and the phased array antenna control and calibration solution.

Learn more about antenna pattern measurements and phased array calibration

Speed and fidelity for phased array design

The Keysight PathWave System Design W4503E phased array kit addresses the critical challenges faced by phased array designers in satellite communications. It offers industry-leading simulation speed and fidelity approaching that of electromagnetic (EM) solvers. It seamlessly integrates antenna patterns and element-to-element coupling matrices from various EM tools for precise active impedance modeling. Designers can evaluate RF, digital, and hybrid beamforming architectures efficiently with the support for time and frequency-domain analyses.

With features that account for RF nonlinearities, noise effects, quantization, and Monte Carlo variations, the kit enables accurate assessment of beam quality, sidelobe levels, and effective radiated power. Integrated with other satellite and 5G non-terrestrial network PathWave System Design (SystemVue) tools and third-party products, it provides comprehensive insights to optimize phased array performance in satellite communication systems.

Keysight Ka-Band Phased Array Development Platform

The satellite communication market continues to grow rapidly with advances in technology. However, the cost to build and validate a proof of concept can be discouraging, especially for first-time entrants exploring the application space. To help ease the barrier to entry into the phased array technology space for satellite communication, Keysight collaborated with Analog Devices to create a Ka-band phased array development platform that combines a compact antenna range with commercial test equipment. This innovative platform enables engineers to design, test, calibrate, and validate phased array antennas economically and quickly.

The platform consists of a 256-element antenna array with beam steering capabilities for both transmit (27 to 31 GHz) and receive (17.5 to 20.5 GHz) bands. It also integrates Keysight's RF and millimeter-wave components, beamforming integrated circuits, data converters, power management, and a field-programmable gate array or modem for back-end digital signal processing.

The solution is well-suited for exploring the application space of satellite communication, radar, and other millimeter-wave systems. It serves as a springboard to accelerate proof-of-concept prototyping with minimal investment cost and risk. It also enables algorithm development for calibration, beam steering, or system networks before the final hardware is complete.

For more information about Keysight solutions for advanced ground systems, visit this page

TREND 4

Non-Terrestrial Networks

Fulfilling the Promise of Non-Terrestrial Networks

5G non-terrestrial networks (NTNs) are set to revolutionize global connectivity by leveraging satellites and high-altitude platforms to provide ubiquitous 5G coverage. As defined in 3rd Generation Partnership Project (3GPP) Release 17, 5G NTNs will expand the reach of 5G networks to help close the digital divide in remote areas, provide connectivity to moving platforms such as ships and aircraft in flight, and ensure service continuity and emergency communications during natural disasters.

NTNs can also augment service continuity for machine-to-machine and Internet of Things (IoT) devices for industries as varied as agriculture, transportation, environmental monitoring, and asset tracking. By adding a layer of resilience and redundancy to the existing 5G network, NTN will also bolster the reliability of mission-critical communications.

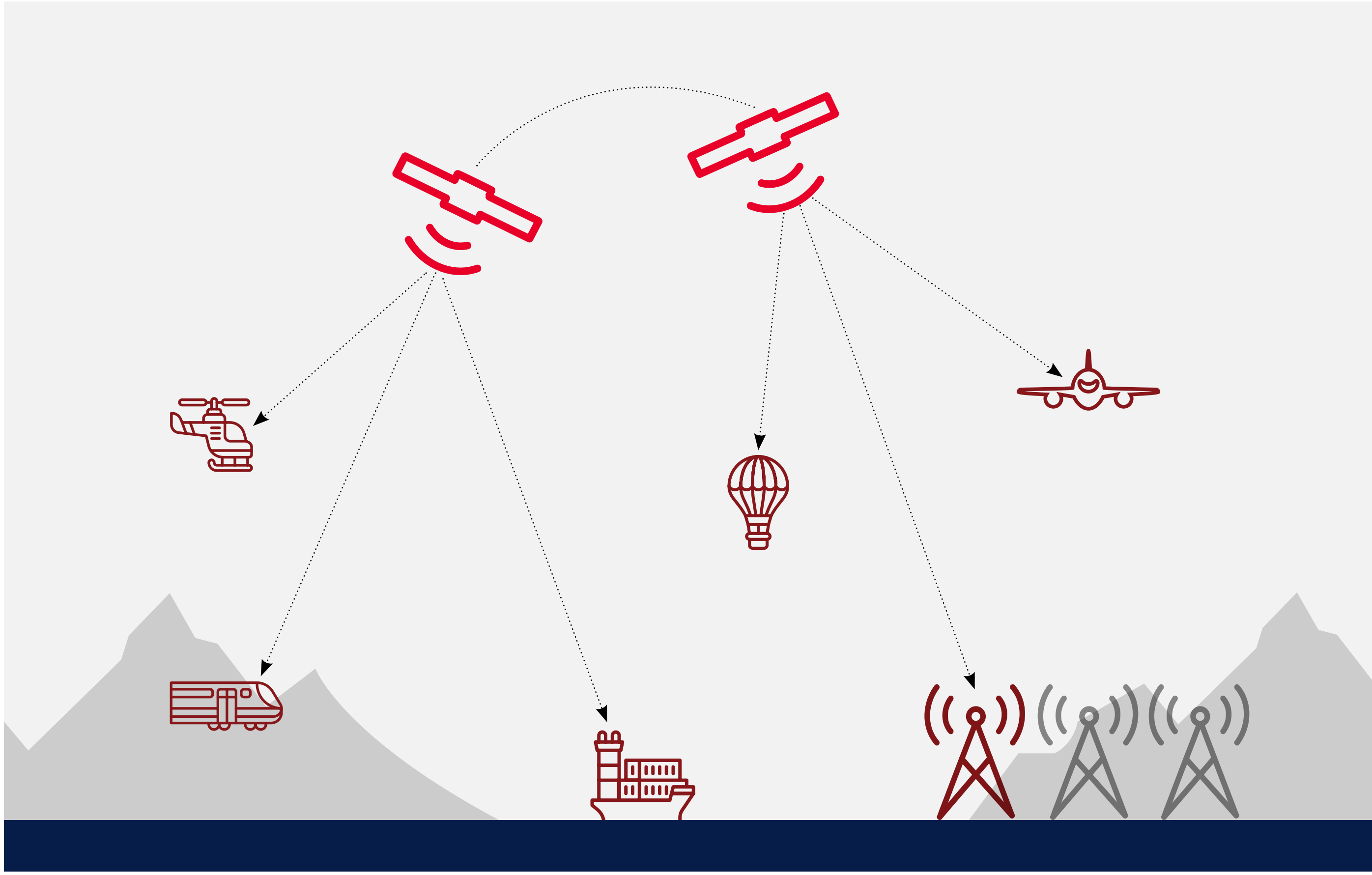


Figure 11. Satellite links bring 5G connectivity to moving and isolated platform

Challenges in deploying 5G NTNs

Deploying NTNs requires addressing technical and regulatory challenges. Unlike terrestrial networks where the base station is stationary, NTNs mainly depend on satellites in low Earth orbit (LEO) speeding at several kilometers per second and orbiting anywhere from 160 to 1,600 km (about 100 to 1,000 miles) above the Earth. The distance on Earth might be a few hundred miles. In contrast, the signal from an LEO satellite to the user on the Earth's surface must travel miles through varying atmospheric conditions, leading to a much higher path loss.

Large Doppler shift and delay
Satellites in NTNs will often use LEO to minimize latency, but these introduce large Doppler frequency shifts and delays compared with terrestrial networks. Networks and devices need advanced capabilities to estimate and compensate for these effects.

Challenging radio environment
The long signal transmission distances to and from satellites result in higher attenuation and channel impairments. Devices need more complex algorithms and larger antennas to close the link budgets.

Updating networks and devices
NTNs must include the kinematics of the moving constellation, the latency in signaling and dynamic fading into the scoping of the devices in the network, and the network itself. These require standards development and updating fielded equipment.

Distance and path loss also affect the network's performance, as measured by latency and capacity. A combination of these factors and a greater susceptibility to interference presents a complex challenge for design engineers.

Expose Trouble in the Lab to Avoid Calamity in Orbit

Rigorously testing 5G NTN systems prior to deployment is critical to ensuring performance. When your satellite is miles above the nearest service center, you're much better off detecting problems before launch. Issues discovered in operational satellite communications systems are more costly to resolve than the same errors uncovered when specifying the system's characteristics.

How do you reveal issues that may only manifest in the operating environment of space? You must emulate as accurately as possible all the various phenomena that may impact the communication links and devices.

Once in operation, a 5G network continuously evolves at both the physical layer, with the addition and removal of nodes and devices, and at the protocol and application layers.

Keysight offers a suite of test solutions to validate 5G NTN performance.

System-level simulation

The complexity of 5G NTN systems is stressing development life cycles. Engineers need commercial software solutions that seamlessly integrate into their existing environments, enabling virtual prototyping of their systems within application-specific contexts. Simulations leveraging measurement-derived models offer heightened fidelity, particularly in mission-critical domains like satellite communications and aerospace defense. System architects aspire to explore real-world "what if" scenarios preemptively, mitigating technical risks and compressing time to market.

The Keysight W4516E PathWave 5G NR NTN channel model kit complies with 3GPP TR 38.811 focused on the service link. It offers flexible configurations to support GEO, MEO, LEO, and airborne platforms, flexible antenna pattern configuration, and seamless integration with Keysight's 5G library for link-level simulation. Keysight offers large-scale modeling and fast-fading modeling support and an intuitive graphical user interface to display satellite trajectory information with playback mode. The channel model also supports trajectory data from Keysight PROPSIM geometric channel modeling (GCM) software and Ansys AGI STK scenario simulation software. Validate your system design for 5G NTN operation and estimate link budgets and configuration trade-offs for different scenarios with the Keysight W4812B PathWave System Design 5G and cellular bundle.

Channel emulators

Today's space applications introduce advanced technologies, including wider signal bandwidths, higher frequencies, and beamforming. To address associated complexities, the Keysight channel emulation solution offers the widest signal bandwidth and the highest number of fading channels to test the performance of 5G NTN aerospace and terrestrial links in a single unit. With the coexistence of terrestrial and non-terrestrial networks, network-level integration and various node-to-node interoperability testing become possible, in addition to traditional link-level satellite system performance testing.

The Keysight S8825A Satellite and Aerospace Channel Emulation Toolset, based on the PROPSIM channel emulator, enables satellite, aerospace, and airborne radio system performance validation under uncompromised, coherent, real-world complex 3D propagation conditions. The PROPSIM channel emulation solution enables users to create high-velocity test environments that meet the highest requirements. Solution users can create test scenarios with PROPSIM tools or import scenarios from most third-party tools, such as MATLAB, Ansys STK, and ray-tracing tools.

The PROPSIM channel emulation solution uses file-based emulation of test scenarios. This approach ensures accurate, realistic, and repeatable test conditions for wireless aerospace, telemetry, satellite, and high-mobility broadband communications applications.

5G network emulators

The Keysight UXM 5G wireless test platform is a highly integrated, all-in-one signaling test solution. It can simulate a full network emulator with configurable NTN parameters to test user terminals. The solution performs signaling tests for device RF characteristics, protocol compliance, and functional key performance indicators. It supports all cellular technologies, including LTE, 3G, 2G, eMTC, Narrowband IoT (NB-IoT), Wi-Fi®, and C-V2X signaling formats.

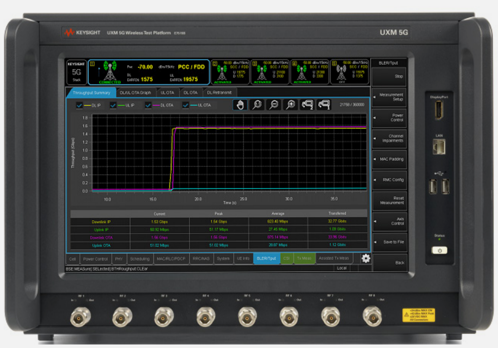


Figure 12. E7515B UXM 5G Wireless Test Platform

Channel modeling software

Testing NTN system performance before deploying the satellite network and updating the cellular network requires simulating and testing the operational environment. You can use channel emulation with channel models for testing with prototype and commercial-grade hardware.

The Keysight Channel Studio GCM tool is a complete channel model creation environment. It contains ready-made standard models, including the 3GPP TDL and CDL models, and user-defined models for cellular and satellite networks. The output of the ephemeris data file used for defining the satellite link information broadcast to the user terminal in the system information block is available for the UXM 5G network emulator or the real base station in the test setup.

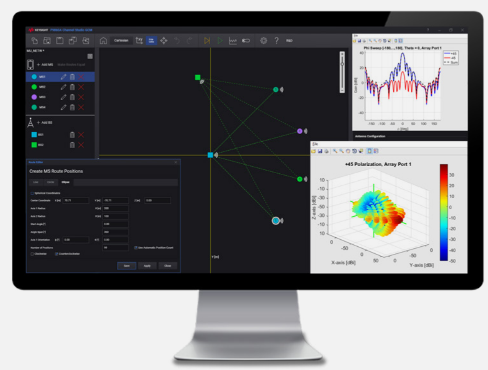


Figure 13. Keysight Channel Studio software shows the satellite trajectory and resulting channel model parameters

Launch Tomorrow's Networks from a Solid Foundation

By leveraging Keysight solutions for emulating, modeling, and testing 5G NTN systems, developers can validate performance prior to costly real-world deployments. Keysight's proven test solutions pave the way for realizing the potential of 5G and next-generation NTNs.

Enable Next Generation Non-Terrestrial Networks

Narrowband NTN Device Certification Program with Skylo

The use of 5G satellite-to-ground connections is rapidly gaining traction as mobile operators and their customers look to extend secure, reliable, and high-bandwidth connectivity across their geographical footprints and surrounding waters. Widespread NTN deployments can enable industries such as agriculture, energy, healthcare, and transportation by using low-cost and low-powered NB-IoT devices for applications including remote sensing, asset tracking, and surveillance.

Keysight and Skylo have collaborated to create the industry's first certification program for narrowband NTN devices. Keysight NTN device acceptance solutions build on Keysight 5G network emulation solutions, with the only wireless network emulator supporting both 5G NR and NB-IoT NTN technologies in a single platform. The NTN device acceptance solution includes orbit emulation technology from Keysight 5G channel emulation solutions, designed to emulate the impairments of complex 3D real-world radio channel conditions.

Skylo's network is based on 3GPP 5G Release 17 specifications and is live in certain regions. While grounded in 3GPP specifications, much of the network development operates on Skylo's Standards Plus approach.

Military-Grade 5G Use Cases and Challenges

5G NTN promises transformative improvements for military and government agencies worldwide. 5G NTNs will extend the capabilities of critical communications, allowing 5G network deployment on bases both inside and outside the US, in emergency scenarios, and on the battlefield — anywhere traditional terrestrial networks may not be available.

5G NTN enables a broad variety of military and government applications. Planes, ships, Humvees, and other vehicles are integrating 5G connectivity. 5G robotics enables smart warehousing and telesurgery. Self-driving military vehicles create new opportunities and use cases. 5G seeks to secure communications and uncover security gaps. Evolving 5G NTNs are set to make all of these new applications a reality.

Here are some military use cases that stand out as the most promising and the most challenging for testing.

Tactical communications

5G NTN offers access to higher-speed downloads and the sharing of data-intensive tools such as maps and video. It provides increased flexibility for tactical communications covering use cases such as enhanced mobile broadband, ultra-reliable low-latency and massive machine-type communications, and increased security. Tactical networks could provide augmented or virtual reality in combat and combat training, battlefield telesurgery, tactical self-driving vehicles, ad hoc secure communications, and connected battlefield assets such as planes, ships, and missiles.

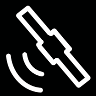
Robotic surgery

5G enables a new application that promises to transform medical care for military personnel: robotic surgery. Robotic surgery will save lives on the battlefield and in emergency scenarios such as natural disasters. For this application to succeed, 5G will have to enable very low-latency connections that allow doctors to remotely direct surgeries.

Ensuring performance for these mission-critical applications — some of which don't yet exist — requires a unique approach to design and testing founded on software simulation. Keysight takes a multistep approach, combining software emulation, hardware-in-the-loop prototyping, development and integration testing, and performance characterization of the complete 5G system. The final step is testing and assessing the security of the finished product.

This approach helps ensure that your product seamlessly integrates into the final design and that your design meets 5G's promise for military and government applications.

For more information about Keysight solutions for non-terrestrial networks, visit this page



TREND 5

Satellite Interlinks

Assure Satellite Interlinks with Pre-Launch Testing

The growing commercialization of space continues to fuel massive innovation, with private companies leading the charge. The falling costs and reusable rockets in the space industry have significantly lowered the expenses associated with launching new satellites, making it more cost-effective than ever before. As a result, companies are rushing to build vast networks of communication satellites, especially in low Earth orbit (LEO). These satellite mega-constellations promise global, high-speed internet access. Engineers must first solve the technical hurdles of interlinking satellites using optical communications.

Seeing the light

Figure 14 on the next page illustrates that using lasers for inter-satellite links (ISLs) instead of radio waves offers significant advantages over traditional wave methods. Optical communication offers far more bandwidth, enabling satellites to transmit data at speeds exceeding 100 gigabits per second, more than 10 times faster than traditional methods. Inter-satellite links also consume less power and disperse less energy than radio frequency alternatives. Moreover, optical links are more secure and focused on tight beams that are harder to intercept.

Fast-steering mirrors achieve precise pointing in space, eliminating the need for phased array antennas for beam steering, reducing energy dispersion, and enhancing efficiency.

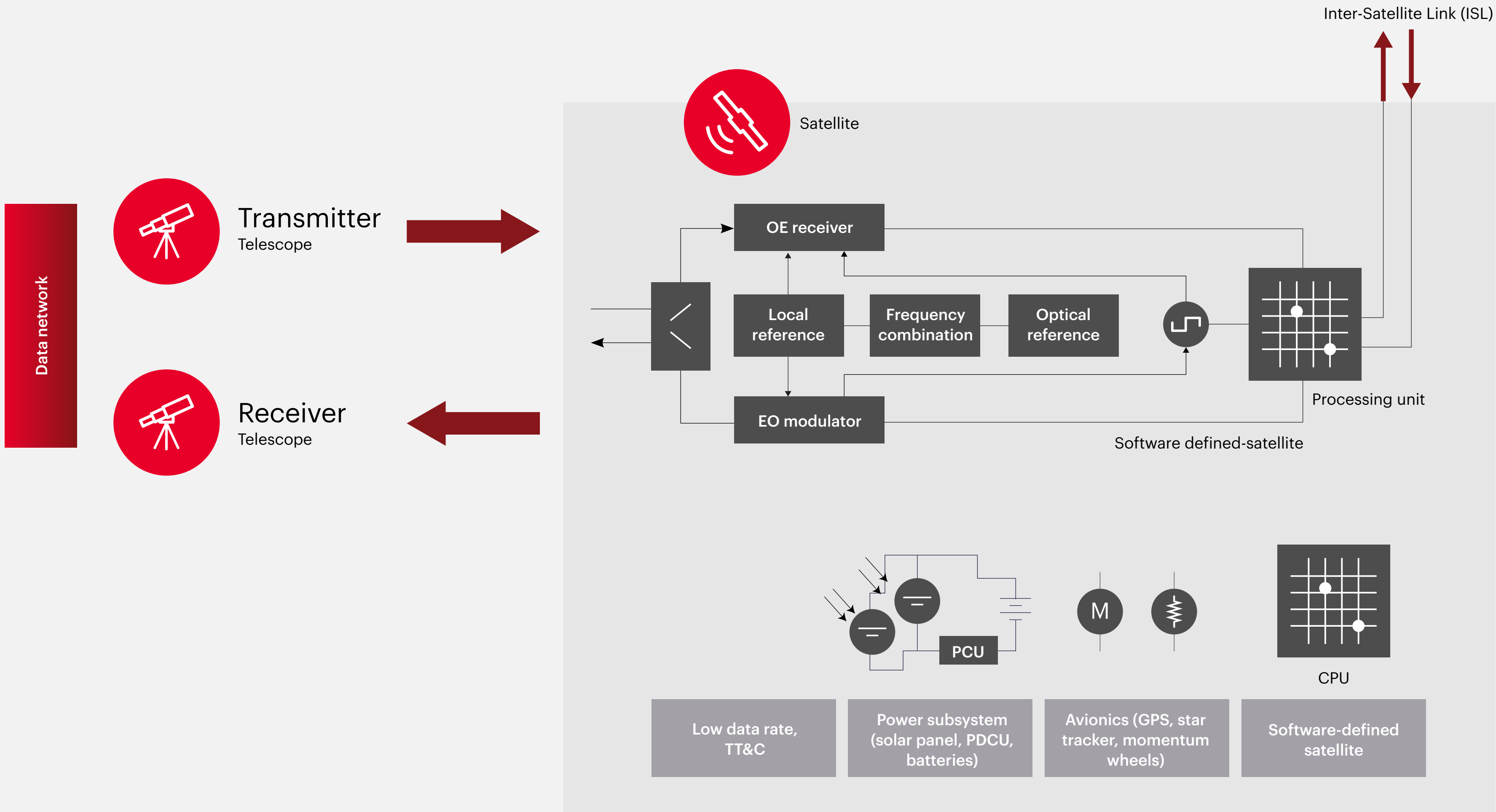


Figure 14. Simplified optoelectronic satellite communications system

The case for optical communications

Higher data rates

100+ Gbps

Increased security

- Tight, precise laser beam
- Protects from eavesdropping
- Resistant to jamming and spoofing
- Suited to confidential and military use communication

Less energy dispersion in space

- Precision pointing using fast-steering mirrors
- No need for phased array antenna for beam steering

The challenges of optical communications in space

Optical inter-satellite links (OISLs) can combine with intelligent routing to form a secure, robust network that rivals the terrestrial internet in speed and efficiency. Data remains in orbit, and AI algorithms determine Earth's most efficient ground station to deliver the information to the end user.

However, beaming lasers between fast-moving LEO satellites pose challenges. The terminals must maintain precise pointing despite orbital motions, necessitating continuous compensation for Doppler shifts in signal frequency. The electronics must withstand temperature fluctuations ranging from -170°C in eclipse to over 120°C in sunlight, with the added challenge of radiation exposure compromising component reliability.

Engineers are addressing these issues by adapting commercial off-the-shelf (COTS) fiber optic telecom components for space.

The shift to off-the-shelf components

The growing commercialization drives an increasing need to integrate proven technologies quickly. As a result, organizations striving to be first-to-market in the optical communications race leverage COTS components to reduce costs and speed deployment.

Commercial off-the-shelf components are standards-based so that designers can use components from different manufacturers. Industrialized production of these components enables designers to leverage rapid assembly and shorter lead times. For example, new satellite systems launched in LEO integrate COTS components to speed up data transfer.

The elements, proven in the telecommunications and industrial sectors, must now undergo evaluation to ascertain their suitability for space. Components like optical modulators and receivers necessitate comprehensive testing to verify performance post-exposure to launch stresses, debris impacts, power fluctuations, and other potential hazards.

Bring Outer Space into the Lab

To determine the performance of optical inter-satellite links under the conditions in space, we need to recreate space on Earth and test space performance in the lab with simulated versions of systems and subsystems.

Digital twins

These emulations, known as digital twins, can significantly accelerate design development and decision-making processes. Digital twins enable designers to identify and address issues in the design phase rather than discover them after incorporating the component into a space system. Digital twins can expose mission risks that might not be evident via traditional testing solutions.

Digital twins also provide insights into how various components will perform together in space conditions, serving as a laboratory-based or deployable system integration, analysis, and test tool. With digital twins, manufacturers and designers can speed up the early stages of design and prototyping, make better models, validate their designs as they build hardware, reduce the likelihood of failure in orbit, and ultimately accelerate deployment.

There are two areas of operation that are essential for validating COTS optoelectronic systems — the power system and the dynamic channel.

Key tests to consider

Two areas of operation that are essential for validating COTS optoelectronic systems are power and the dynamic channel

Power system simulation

With no power source in space, the satellite must be self-sufficient once in orbit. Leakages or drains that exceed the satellite's ability to generate and store power are comparable to equipment failure. You can test this in the lab using solar array simulation and battery emulation to provide realistic, operational power to the systems and subsystems. Power analysis hardware must also be employed to monitor the power distribution and current draw in an emulated environment.

Dynamic channel emulation

It is critical to examine how Doppler, absorption, and scattering occur over time between communicating terminals — and how these change based on orbits. Other variables include vibration and forces, radiation damage, outgassing, space debris, and the components' ability to withstand temperature extremes.

Space-ready optical communications solutions

Creating digital twins and testing for harsh space conditions requires specialized equipment and an extensive knowledge of testing best practices. Because the process can be costly for COTS manufacturers to develop and maintain in-house, many rely on a trusted third-party entity for these and other testing requirements.

Keysight N4391B optical modulation analyzer

The Keysight N4391B optical modulation analyzer contains precision reference receivers to emulate near-ideal detection of complex modulated optical signals. Multiple analysis tools qualify signal integrity and bit error rates. Flexible software lets users add custom algorithms relevant to their satellite link designs.

Keysight W3071E VPI optical link

The Keysight W3071E VPI optical link enables you to fully analyze your transceiver, from electrical to optical back to electrical. You can analyze the entire link passing through electrical, optical, and electrical domains, simulate the design in the complete link within a specified bit error rate (BER), and characterize transceiver performance by modifying parameters, including fiber length or laser power.

Satellite Interlinks:
The Solutions

For system-level environmental testing, Keysight provides thermal vacuum chambers capable of replicating every phase of a satellite's orbital cycle, clearing COTS components for space deployment to reduce mission risk.

Keysight PathWave system design and simulation software integrates models from components to full systems. Satellite developers can optimize and validate the performance of optical communications entirely in software. Developing digital twins in this manner reduces development costs compared to physical prototypes, while virtual testing reveals flaws that are otherwise undetectable through traditional methods.

Keysight Technologies has a distinctive history intertwined with the evolution of the space industry — including providing test support for NASA's Orion spacecraft and collaborating with various aerospace and defense organizations. With our solutions, you can launch with confidence, knowing that your designs are ready for the rigors of space.

Learn more

Space-Ready Optical Communications

The space gold rush is creating an array of possibilities as organizations are in a race to deploy cutting-edge technologies and systems. Optical communications are transforming satellite systems, which is just one example of the possibilities. Using light to transmit data in space brings significant benefits, including higher data rates, improved security, and less energy dispersion. As organizations build mega-satellite constellations, they increasingly turn to COTS components to reduce costs and speed deployment. For manufacturers looking to harness COTS, the ability to evaluate if those components are space-ready is the pathway to participating in the boom.

A typical use case scenario is a receiver optical sub-assembly (ROSA) designed to convert an optical signal to an electrical one. A typical goal when testing this application is determining the wavelength-dependent responsivity of the photodiode and its polarization-dependent loss.

Within the laboratory setting, the calibrated optical signal stimulates the receiver. In instances where the receiver exhibits sensitivity to polarization, a polarization synthesizer is employed. The signal splits, and a calibration instrument measures one branch while the other goes to the receiver. The precise measurement of both current and voltage from the sub-assembly output is enabled by measuring the electrical output of the latter with precision source measure units (SMUs). By automating the entire measurement for fast, user-friendly testing, you have insight into the receiver’s isolation of channels, linearity, and flatness.

This space use case is one example of how testing can provide commercial off-the-shelf manufacturers with a competitive advantage, enabling them to reduce costs and mitigate risks.

For more information about Keysight solutions for satellite interlinks, visit this page

TREND 6

Cybersecurity for SATCOM

Securing Satellite Communications

Satellite communication networks play a vital role in supporting commercial, government, and military communications, emergency response, navigation systems, weather tracking, banking transactions, and more. These operations demand accuracy, precision, and nearly absolute reliability.

However, while connectivity technologies have rapidly advanced, satellites face increasingly sophisticated threats. Malicious hackers, hostile state actors, and other entities can now jam, spoof, and infiltrate satellite systems if unprotected. These threats include every component of the connection — ground terminals, satellites, and the links between them. Disabling assets through jamming or injection techniques — disrupting the signal or providing false information — can result in the cut-off of critical services.

For example, in February 2022, the AcidRain malware bricked thousands of Viasat modems, impacting the remote control of more than 5,000 wind turbines in Europe, among other critical systems. In the same year, a $25 homemade device successfully hacked SpaceX's Starlink terminals. Additionally, during the conflict in Ukraine, Starlink terminals encountered interference issues known as jamming.

In response, the US Cybersecurity and Infrastructure Security Agency (CISA) and the Federal Bureau of Investigation (FBI) issued a cybersecurity advisory about threats to US and international satellite communication (SATCOM) networks. The warning strongly encourages critical infrastructure organizations and other entities that either provide or consume SATCOM services to review and implement a range of mitigations to strengthen SATCOM network cybersecurity.

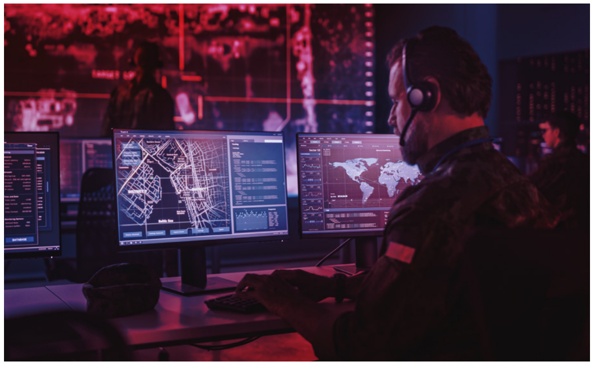
Furthermore, SATCOM providers must understand their vulnerabilities and implement comprehensive cybersecurity measures to protect the SATCOM infrastructure that underpins everything from national defense to the global economy.

Know the enemy

Bad actors are abundant — and abundantly creative. Understanding the wide range of potential cyber risks satellite communications face is crucial.

Jamming

Jamming is a standard tactic and an integral part of modern conflict, encompassing every aspect of the connection, such as ground terminals, satellites, and the links between them. By jamming, assets get disabled — disrupting or overpowering signals — leading to the shutdown of critical information streams. Noise-based signal jamming can temporarily disrupt or degrade both uplink and downlink transmissions. Moreover, more sophisticated smart jammers target specific satellites to enhance effectiveness. Jamming is not particularly difficult or costly — satellite jammers are readily available for online purchase.



Spoofing

Spoofing involves hijacking satellite command and control functions through the mimicry of legitimate signals. If successful, adversaries could manipulate antennas or deactivate components entirely. Additionally, an element of misdirection exists, leading sensors to believe that certain assets exist at a specific location. Both of these electronic warfare tactics threaten the availability of critical satellite connectivity.

Hacking

Hacking presents additional concerns as malicious actors attempt to penetrate network infrastructure to extract data or seize control. As semiconductors advance in sophistication, the emergence of security flaws creates opportunities for attackers to exploit. Compromised credentials or unpatched software bugs also serve as vectors for intrusion. Furthermore, bugs and backdoors could persist indefinitely in orbit if introduced before launch since satellites are not easily repairable. As a result, developing rigorous cyber protections across supply chains is necessary.

Factors that increase risk

Several cybersecurity trends may expand the scope of vulnerabilities within satellite communications. Start-ups and small companies face limited resources and can only invest a certain amount in hardening their systems.

Moreover, the industry's increasing commercialization necessitates rapid integration of proven technologies. Consequently, organizations vying to be first to market in the optical communications race are turning to commercial off-the-shelf (COTS) components to reduce costs and expedite deployment. For instance, new satellite systems launching in low Earth orbit (LEO) incorporate COTS components to enhance data transfer speeds.

While these elements may undergo field testing in the telecommunications and industrial sectors, they now require evaluation to ensure their security in the SATCOM environment.

Be Proactive with Emulation and Test

Adopting a proactive strategy based on emulation and testing is essential to stay ahead of threats. Like any advanced system, ensuring the performance and security of satellite communications is crucial through thorough testing and validation before deployment.

Prove your network is secure

Simulate attacks to expose security gaps, and course correct with step-by-step fixes.

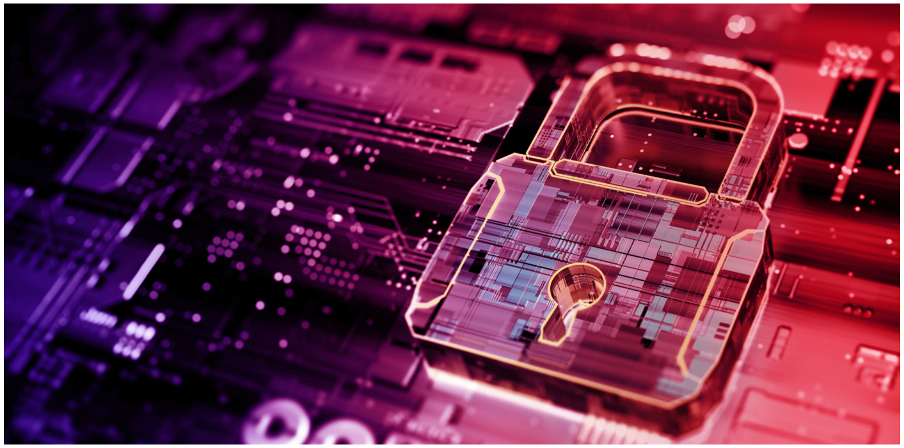
Protect payloads

Increase your security systems' efficiency, performance, and reliability.

Eliminate vulnerabilities

Expose blind spots, misconfigurations, and weak points in the network.

Threat models must encompass the entire attack surface and kill chain, including satellite payloads, ground stations, terrestrial networks, and user terminals. Security controls must employ a layered defense-in-depth approach, integrating organizational policies and processes with hardware protections and software defenses to establish multiple barriers. Ensuring the reliability of satellite communications in contested environments poses a multifaceted technical challenge.



See what you are missing

The most effective way to proactively address risks is by obtaining a hacker's perspective of your network. Using threat simulator software, you can identify your vulnerabilities, determine potential gaps in your defenses, and prioritize resolving these issues.

The Keysight Threat Simulator solution provides extra visibility that helps SATCOM security teams see where security tools are ineffective and then take proactive steps to mitigate vulnerabilities.

Validate your security posture and stay safe from the latest threats

Real-world testing for real-time challenges

The threats are real. It is crucial to validate the security posture of your networks using real applications and a comprehensive range of threat vectors within a controlled lab environment. Keysight BreakingPoint accomplishes this by simulating real-world legitimate traffic alongside distributed denial of service (DDoS) attacks, exploits, malware, and fuzzing. This validation process ensures the integrity of the satellite security infrastructure and provides a realistic, high-fidelity assessment by leveraging insights from production network traffic configurations. Security stacks, both in space and on the ground, are verifiable at scale, guaranteeing interoperability, ease of use, greater agility, and reliability.

Learn more about all-in-one applications and network security testing platform

Ensure performance and security in the distributed cloud

Keysight CyPerf represents the industry's pioneering instantly scalable cloud-native network test solution, realistically replicating real-world distributed zero-trust network traffic and complex application mixes. CyPerf achieves this by recreating every aspect of a realistic workload across various physical and cloud environments, creating a digital twin of users, authentication mechanisms, applications, and threats.

This solution delivers insights into end-user experience, security posture, and distributed cloud and hybrid network performance bottlenecks. CyPerf's elastic performance for distributed cloud networks determines the optimum balance between security and user experience.

Learn more about CyPerf

Model and visualize satellite networks and cyber threats with digital twins

To effectively determine performance and security under space conditions, you must recreate the network — and the potential cyber threats — with simulated versions or digital twins. Network emulation software using digital twins offers a cost-effective method for evaluating new network technologies before building actual systems or networks. This solution can significantly expedite development and decision-making processes.

Keysight EXata network modeling software empowers you to create a network digital twin, enabling real-time network simulation and emulation that mirrors the behavior of a network. With an exact, high-quality reproduction of external behavior, developers can realistically test for vulnerabilities and markedly expedite development and decision-making processes.

Discover Network Digital Twins

US Army National Guard's Cyber Shield 2020 Cyber Training

History has shown that cyberattacks are possible under any circumstances and in any environment. Cyber warriors must train under dynamic and realistic conditions to protect assets across the defense industrial base, including space. Cyber range exercises offer the most realistic method for warfighters to train as they fight. These exercises involve live scenarios where cyberattackers (red teams) try to disrupt information flow within defended environments. The network defenders (blue teams) have the task of keeping their networks up and running by detecting and mitigating the red team's attacks.

During the US Army National Guard's 2020 Cyber Shield cyber range event, Keysight Technologies actively supported Cyber Shield by contributing its expertise. Keysight leveraged its BreakingPoint traffic generators in the exercise to provide authentic and randomized background traffic, with the aim of masking cyberattacks.

BreakingPoint's cybersecurity software is another useful test component in a traffic generation scenario. Similar to application components, multiple strike components can trigger traffic either independently or combined with application traffic components. Furthermore, strike components can initiate traffic based on their individual timelines. Supporting over 40,000 strike traffic flows, including DDoS, malware, exploits, signatures, and predefined cyber kill chains. BreakingPoint can construct entire cyber kill chains and function as an automated red team.

Read the case study in detail

US Department of Defense conducts pre-deployment and ongoing security assessments

The US Department of Defense IT operators value two priorities when it comes to their network:

- Getting the right data to the right place as quickly as possible.
- Protecting the data in transit and at rest.

For example, administrators must ascertain the throughput supported in a next-generation firewall (NGFW) without compromising its ability to identify malicious activity. The initial step is establishing a set of functionality and performance benchmarks through baseline testing to accomplish this objective. Subsequent tests following network changes, firmware upgrades, or signature library updates will offer administrators the assurance that performance and security remain uncompromised.

Additional perimeter devices, such as intrusion prevention systems (IPS), DDoS mitigation, transport layer security (TLS) decryption, and malware sandboxes, can also undergo assessment for performance and inspection accuracy. These devices integrate with the NGFW as a first line of defense. Typically, these security stacks safeguard ground network gateways, providing connectivity to space assets. The defensive cyber operations for space (DCO-S) platform conducts continuous security investigations within the perimeter. In this context, you can also leverage AI / machine learning (ML) analysis.

BreakingPoint supports over 60,000 attacks, including remote exploits, malware / ransomware, evasion techniques, DDoS, advanced persistent threats, SZLi, cross-site scripting (XSS), fuzzing, and even exfiltration. These attacks receive daily updates to ensure your tests remain as current as possible.

For more information about Keysight solutions for cybersecurity, visit this page

TREND 7

Small and High-Throughput Satellites in LEO and GEO Orbits

Shortened development Cycles
Advanced payload systems
Advanced ground systems
Non-terrestrial networks
Satellite interlinks
Cybersecurity for SATCOM
Small and high-throughput satellites in LEO and GEO orbits
Conclusion

Assessing the Deployment Challenges for LEO, GEO, and High-Throughput Satellites

Keysight's comprehensive survey of the space tech industry, *Defying Gravity: Challenges, opportunities, and innovations in the space tech industry*, identified the top ten most important trends in the satellite industry. Among the outstanding trends were three categories of satellites — small geosynchronous equatorial orbit (GEO) satellites, large constellation systems in low Earth orbit (LEO), and extremely high-throughput satellites. The study suggests a significant surge in their importance over the next three years.

A new space race is underway, focusing not on conquest but on promoting connectivity. Satellite communications provide connectivity for satellite television, cell phones, broadband internet services, and military communications. Innovators are driving satellite technology to expand the capabilities of global networks to meet the rising demand for wireless connectivity worldwide.

Each satellite type has specific characteristics that significantly impact network design and performance. These factors play a crucial role in addressing the diverse communication needs of our interconnected world.

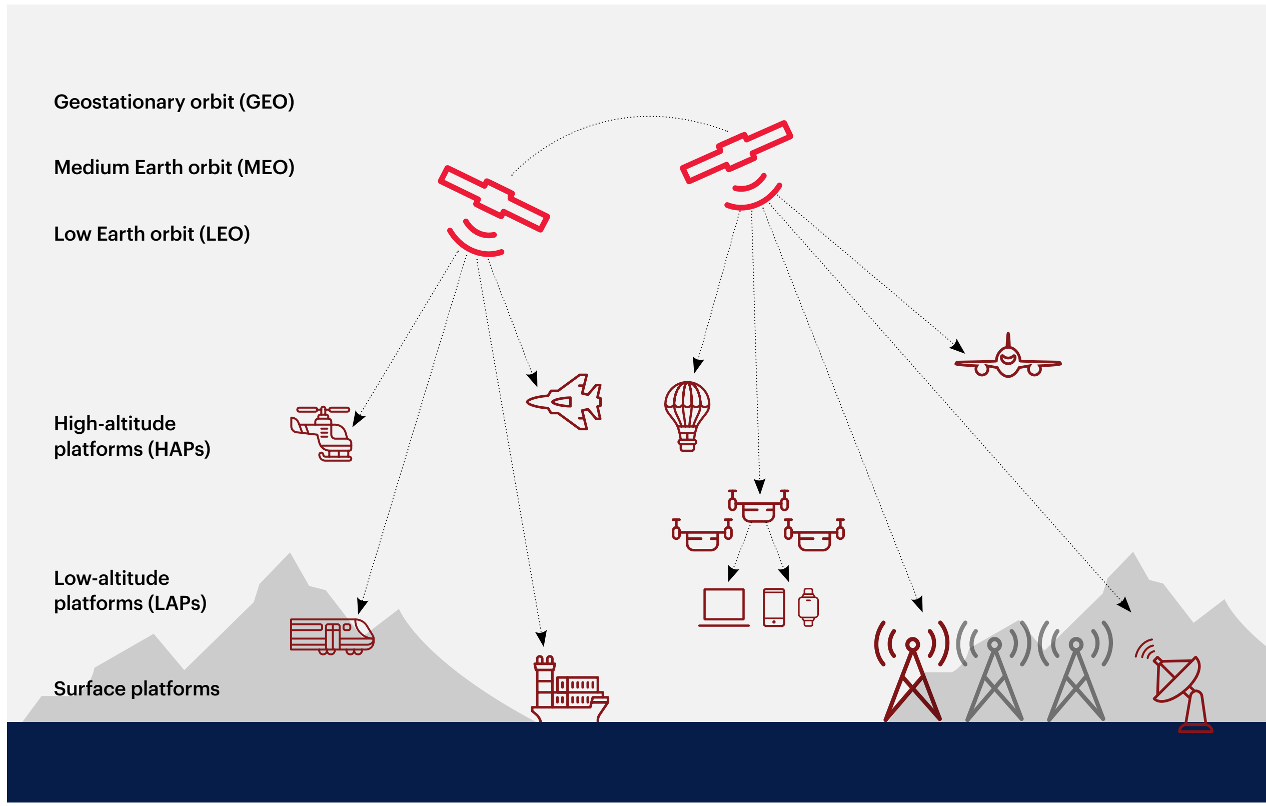


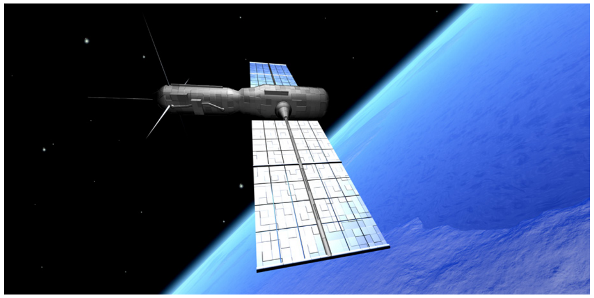
Figure 15. Layers of systems at various altitudes add network capability and flexibility

Satellite Types

Satellite constellations are classified according to their orbital altitude, specifically GEO and LEO. High-throughput satellites (HTS) are a newer category defined by higher data transmission capacity rather than by orbit.

Geostationary / geosynchronous earth orbit satellite

Geosynchronous Earth orbit (GEO) constellations reside at an altitude of approximately 36,000 km or an estimated 22,000 miles above the Earth. The constellations match the rotation of the Earth as they travel, always remaining above the same point on the ground. Due to their high altitude, GEO satellites provide extensive coverage and are particularly beneficial for broadcast services. However, they exhibit high latency and lack coverage in the polar regions. In recent years, GEO has experienced significant enhancements using high-throughput satellites specifically designed for data transmission.



Low Earth orbit satellite

Low Earth orbit satellite constellations operate at altitudes below 2,000 km (an estimated 1,243 miles) and orbit at high speed, around 17,000 miles per hour. Because of their proximity to Earth, they offer lower latency and higher data transfer rates, making them ideal for providing broadband internet services, particularly in areas where terrestrial networks are not feasible or economical.

High-throughput satellites

Demand for satellite mobile and broadband communications is surging, and GEO satellite communication providers respond by increasing their strength and throughput capabilities. With very high-throughput satellites (VHTS), connectivity over land, air, and sea for consumer, commercial, or military applications at unserved and underserved locations is now possible. Currently, high-throughput satellites in orbit mainly consist of GEO satellites. However, the upcoming generation of LEO satellites will also use HTS technology.

Satellite Deployment Challenges

As companies and countries launch more satellites, especially large constellations of low Earth orbit satellites, engineers face growing technical hurdles. Providers face complex obstacles, from tracking fast-moving LEO satellites to enabling flexible satellite payloads. Overcoming these challenges is essential in the satellite industry.

Tracking and communicating with LEO satellites

A significant difference between LEO and high-altitude geosynchronous orbits involves speed. Low Earth orbit satellites orbit at about 17,000 miles per hour from as low as a few hundred miles above Earth. Tracking the satellite with antennas on the ground becomes challenging with parabolic reflector antennas. Maintaining uninterrupted communication with the network would require multiple dishes for signal handoff. That is why electronically steerable phased array antennas are replacing parabolic antennas for LEO constellations. These antennas align single or multiple beams with precision to specific locations.

Phased array systems can maintain satellite communications links with a fast-moving LEO satellite. They also offer improved performance advantages such as enabling multiple beams, agile beam steering, and beam pattern optimization. Originally developed for radar tracking, phased arrays now provide a pivotal LEO communications solution.

However, cost is a key obstacle. Spending tens or even hundreds of thousands of dollars in sophisticated phased arrays is justifiable when protecting billion-dollar ships or major defense assets. However, such expenditures are unnecessary for most consumer and enterprise applications.

Optical Communications Enable LEO Satellite Mesh Networks

Given their low orbit, each LEO satellite can only cover a small territory, unlike GEO spacecraft that can encompass whole continents. Many providers plan to launch hundreds or thousands of networked LEO satellites to offer global service. These spacecraft must hand off signals reliably from node to node.

LEO developers are now starting to exploit the development and progress of optical technology using infrared laser beams to enable optical cross-links from one satellite to another. Optical communication offers far more bandwidth, enabling satellites to transmit data over ten times faster, with some systems reaching speeds above 100 gigabits per second. Optical technology also consumes less power and disperses less energy than radio frequency alternatives.

Furthermore, optical links are more secure, focused on tight beams that are harder to intercept. Integrating these optical relay systems can facilitate seamless LEO mesh networks. However, beaming lasers between fast-moving LEO satellites pose difficulties in maintaining precise pointing despite orbital motions and compensating for Doppler shifts in signal frequency.

The Challenges of Calibrating RF

As satellite communications demand higher frequency bands and wider channel bandwidths to achieve the required data throughput, the challenges of calibrating these channels at RF, microwave, and millimeter-wave frequencies increase. Engineers must develop an accurate and reliable test system that delivers optimal performance to meet the requirements of these technology developments.

Ensuring Power System Reliability

We have seen it happen to NASA's InSight Mars lander and other spacecraft — all systems are go — until the power goes out. Once in space, a satellite must generate, store, and manage its power requirements throughout its operational lifetime. Failure of either the power generation or storage is fatal to a space mission. However, using actual solar arrays to provide power during pre-launch testing is seldom possible. Engineers need a way to simulate the operation and environmental conditions of a satellite's power system — from battery to solar array — to uncover potential faults before launch.

Satellite Communication Solutions

The challenges of the three satellite types are varied and require multiple solutions. We will examine several key solutions that can help you with advanced prototyping and design needs for complex RF systems.

Simulating mission-critical conditions before launch

To ensure performance, engineers must:

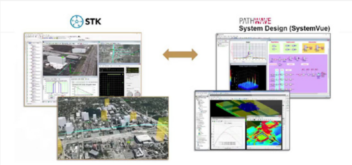
- Predict and increase assurance of satellite communication system performance.
- Allocate different system performance metrics across all subsystems during system design.
- Confirm satellite ground coverage beyond just received signal strength.

Keysight PathWave System Design (SystemVue) provides a single platform for system architecture, design, and verification, bringing real-world scenario modeling to aerospace systems. PathWave System Design goes beyond math-based modeling with a complete RF-aware design workflow backed by decades of Keysight measurement science in RF instrumentation.

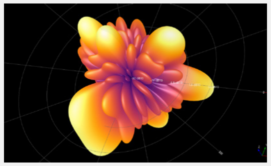
This solution offers the most advanced prototyping and design platform for complex RF systems. Benefit from faster simulation speed, near-circuit fidelity, and a robust library of models for various applications, including radar, 5G, DVBS2 / S2X, and Wi-Fi®. PathWave System Design software seamlessly gives you enterprise integration with numerous software tools within Keysight solutions and third-party products.

Engineers can simulate mission-critical conditions in assorted scenarios by integrating PathWave System Design and AGI's systems tool kit (STK) into the platform. This solution performs a broad set of performance analyses on different subsystems and their interaction during the entire mission kinematics. The platform also performs analyses that include all mission dynamics with different receiver architectures.

PathWave System Design offers the most advanced prototyping and design platform for complex RF systems with faster simulation speed, near-circuit fidelity, and a robust library of models for satellite in addition to radar, 5G, and Wi-Fi®, plus enterprise integration with numerous partners.



With SystemVue and STK integrated platform, engineers can simulate mission-critical conditions in assorted scenarios, perform a broad set of performance analyses on different subsystems and their interaction during the entire mission kinematics, and perform analyses that include all mission dynamics with different receiver architectures.



Calibrate phased array antennas in minutes, not hours

The phased array design and development process is complex as well as time- and resource-consuming. Designers and manufacturers look for reliable and fast over-the-air (OTA) testing to calibrate and verify the performance of phased arrays quickly and efficiently. PathWave System Design facilitates efficient simulation of high-density phased arrays, including active impedance / load pull modeling, allowing accurate assessment of phased array topologies and calibration methodologies.

Keysight's phased array calibration and characterization test solution integrates the Keysight PNA-X Series high-performance vector network analyzer and the Keysight VXG-C vector signal generator with a compact antenna range (CATR) equipped with a positioner. The solution also includes phased array antenna beamforming integrated circuit channels for advanced testing capabilities. This phased array test solution characterizes the amplitude and phase of each array element with high levels of accuracy. The platform delivers fast, fully automated measurements, significantly reducing calibration time from hours to minutes.

The PNA-X Series network analyzer also enables engineers to dramatically improve the simulation accuracy of the power amplifier, helping assure communication service in terms of signal quality and battery life.

Optimize RF performance

Designing satellite communication systems requires tight design margins and timelines, complex modulation, and adherence to stringent standards, presenting aerospace engineers with an entirely new set of design and test challenges.

The Keysight M9484C VXG vector signal analyzer enables engineers to work with wider bandwidths, higher frequencies, and greater system complexity for today's space technologies. The M9484C VXG vector signal generator features up to 54 GHz frequency range and 2.5 GHz modulation bandwidth in a single instrument. Using the Keysight V3080A frequency extender provides up to 110 GHz and 5 GHz with channel bonding, enabling your next breakthrough.

Validate Now for Performance in any Orbit

Developers can validate performance before costly real-world deployments by leveraging Keysight solutions for emulating, modeling, and testing LEO, GEO, and high-throughput satellite systems. Our proven test solutions pave the way for realizing the far-reaching potential of your aerospace innovations — no matter where they orbit.

Maximizing Power Amplifier Efficiency and Linearity

Maximizing power amplifier (PA) linearity while maintaining efficiency requires developing a digital predistortion (DPD) model. The DPD technique needs wideband, calibrated vector signal generation and signal analysis to provide optimal performance.

Engineers use a vector signal generator and a VNA with software-enabled wideband vector signal analysis capabilities to optimize PA efficiency and linearity on a single test bed. The VNA's multi-receiver architecture generates a fully calibrated signal at the PA input.

Watch the demo

Monitoring and Detecting Interfering Signals in Satellite Receivers

Monitoring and detecting interfering signals in satellite receivers at higher frequencies and wider bandwidths requires a test system that can identify and characterize intermittent or transient signals, especially the ones with very short durations. The test system must support wide bandwidth real-time spectrum analysis (RTSA) measurements to detect elusive signals, even if they are very short.

Using a wideband real-time spectrum analysis solution allows the test system to minimize the gap between measurements and detect signals as short as 1 µs 100% of the time. This approach makes it an ideal solution for detecting, observing, and identifying transient signals with up to 2 GHz RTSA bandwidth — known or unknown.

Watch the demo

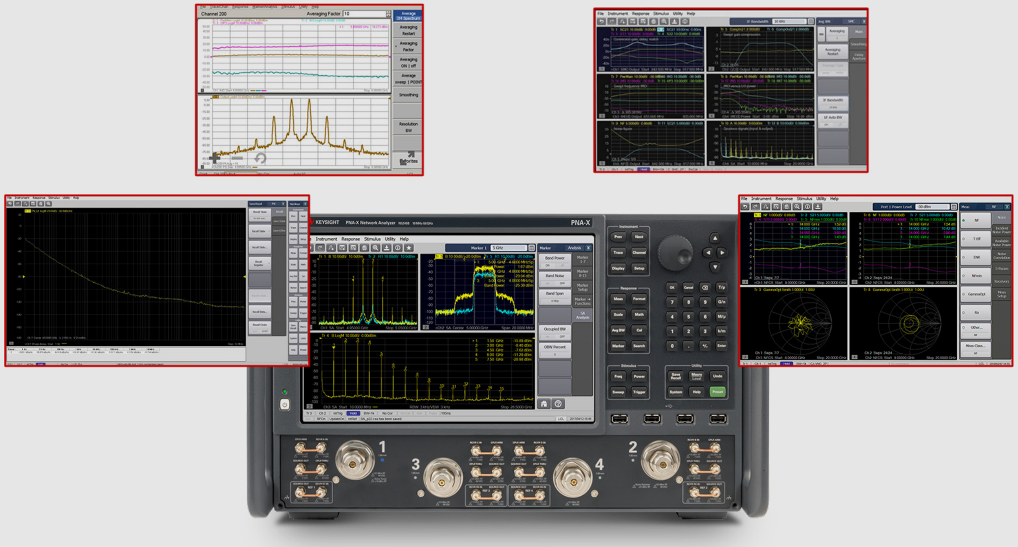
Characterizing SATCOM Mixer Performance

Characterizing mixers and other frequency-translating components requires nonlinear measurements of mixer gain, gain flatness, group delay, gain and phase compression, intermodulation distortion (IMD), and noise figure. You can use a single test bed with a network analyzer and multiple measurement software applications to measure all mixer parameters.

Software measurement applications reconfigure the network analyzer for each frequency-translating mixer characterization test. During testing, the engineer operates multiple measurement applications without changing the configuration of the test setup. The integrated approach improves throughput up to 100 times versus legacy multi-instrument approaches, requiring reconfiguring the test bed for each measurement.

Watch the demo

For more information about Keysight solutions for small and high-throughput satellites in LEO and GEO orbits, visit this page



Conclusion

To Accelerate Your Mission, Start with Keysight

Space is demanding, extreme, and unforgiving of error. By its very nature, space tech requires fresh ideas and creative innovation. With the right partner, however, you can overcome the challenges and reap the rewards. That's why SATCOM innovators come to Keysight to speed up releases, reduce costs, and drive business results.

Learn about our full suite of solutions for the space tech industry

KEYSIGHT