OPERATIONS
WHITEPAPER

Peraton

CYBERVAN FOR SPACE

HIGH-FIDELITY NETWORK MODELING AND SIMULATION PLATFORM

INTRODUCTION

Modern life literally revolves around services from space, and modern warfare critically depends on space systems. But space is hard, and space is unforgiving. Satellite networks require years of design, engineering, and manufacturing, millions of dollars of investment, and enormous effort to launch and operate.

High-fidelity modeling and simulation of space mesh networks and the terrestrial networks they support is essential since "getting it right" at every phase of design, construction, and operations is imperative; and "getting space right" is at the core of the support Peraton's CyberVAN for Space (CV4S) provides.

Just imagine designing and building a modern airliner or jet fighter without a cockpit simulator—it would be an impossible task. CV4S provides a cockpit simulator for space systems architecture, design, and operations, supporting every life cycle phase involved in attaining the ultimate high ground—space.

Hybrid Network Emulation

Peraton's unique CyberVAN hybrid network emulation (HNE) technology enables modeling every layer of an integrated terrestrial/celestial communications network and running simulations at real world network speeds. HNE is comprised of discrete-event-simulated links and networks, and a layer of virtual machines (VMs) that send and receive traffic through such links and networks. It allows testing network applications (rather than their models) on simulated target networks; in particular, the integrated terrestrial/celestial space mesh networks that are rapidly emerging.

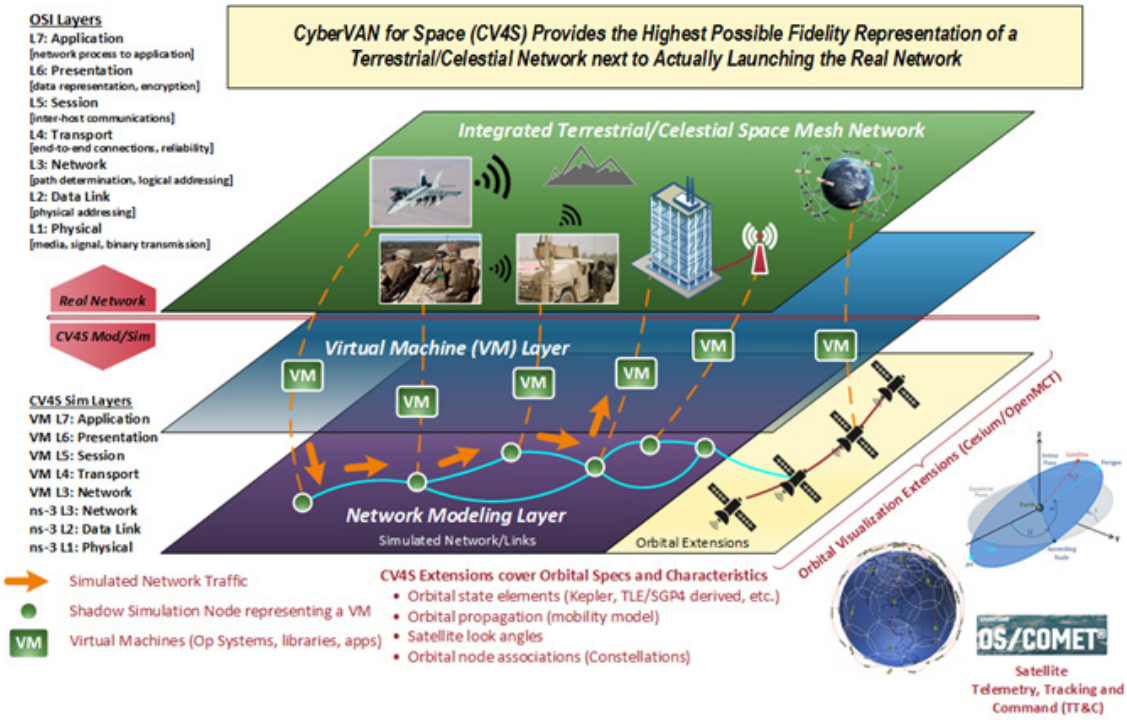
HIGH-FIDELITY NETWORK MODELING AND SIMULATION

CV4S provides the highest possible fidelity representation of an integrated terrestrial/celestial network next to actually launching the real network. CV4S models and simulates data and commands transported across the depth and breadth of an integrated terrestrial/celestial network.

CV4S is an extension of Peraton's Cyber Virtual-Assured-Network (CyberVAN) testbed, an HNE platform for evaluating the performance and characteristics of hypothetical or actual networks. Using the HNE approach, CyberVAN supports applications running in their native operating system (OS) without any code modification, so the same executable binary that will be running in the real network can be running in the HNE environment.

CyberVAN achieves this through a virtual machine (VM) layer on top of its network modeling layer that can run actual malware, cyberattacks, and/or compromise toolkits, along with actual threat or intrusion detection systems. Using this unique multi-layer approach, CyberVAN can model and simulate the entire network performance and cybersecurity ecosystem that space mesh networks must successfully support. CyberVAN easily models Blue on Red data, malicious hacking tools, and sophisticated cyber-attack techniques within its VM layer.

CV4S extends CyberVAN capabilities into the space domain by modeling arbitrary user-defined, earth and lunar-orbiting satellite constellations. CV4S simulates satellite constellations by including the orbital mobility of each satellite vehicle, its networking roles, and features, the intersatellite links moving data between vehicles (in-plane and cross-plane), and the data routing protocols directing data through the mesh network.



CV4S Operational View

Simulation runs occur in an isolated experimentation enclave where designers and researchers can evaluate network performance, analyze design tradeoffs, and apply cyber effects under controlled scenarios to experiment with cybersecurity attacks, controls, and counter measures. The figure below shows how the key elements of CV4S interact and operate to model and simulate integrated terrestrial/celestial space mesh networks.

CV4S uses projected or actual orbital specifications to calculate the position and speed of each space vehicle in the constellation and applies widely accepted propagation algorithms to determine the time-varying position of each vehicle as it travels throughout its orbit.

This position data that feeds into the CV4S simulation runs to support data and message routing algorithms, intersatellite and ground contact calculations, and produce a wide range of other outputs during a sim-run.

CV4S supports modeling of Ground-to-Space (G2S), Space-to-Space (S2S), and Space-to-Ground (S2G) communications via RF and/or optical links. An array of physical characteristics and related networking parameters can be modeled, including orbital line of sight status, free space path loss, atmospheric loss, Optical Communication Terminal (OCT) configurations, and/or Optical Intersatellite Links (OISL), among others.

CV4S supports modeling using well-known industry standard waveforms and protocols, as well as space-focused standards and protocols such as Contact Graph Routing (CGR), delay tolerant networking (e.g., Bundle Protocol (BP)), and Multi-Protocol Label Switching (MPLS).

CV4S AUDIENCES

The CV4S ability to support total depth and breadth network modeling enables creation of simulation scenarios covering every phase of engineering and operational life cycles. Creating tailored networking scenarios across life cycle phases is a powerful tool for guiding teams through the phase-to-phase refinement necessary to transform abstraction into concrete specification and transform ConOps vision into working operations manuals.

CV4S support is targeted to:

- Space services providers who design, develop, manufacture, and launch constellations of satellite vehicles
- Suppliers who operate space mesh networks to transport and deliver data and communications services, or platform services for earth observation payload
- Government agencies or users dependent upon space assets or space mesh networks for mission critical services.
- Space-based assets have quickly become a critical national resource driven by world events. Rapidly developing, launching, and operating satellite constellations is a complex and costly engineering endeavor, and when completed, protecting these critical space assets in the face of escalating cybersecurity threats is a national priority.

Engineering and operating orbiting networks of communications satellites is a problem involving deep layers of systems-within-systems. Without design support tools, the advanced networking architectures and complex configurations involved in space mesh networks challenge even the best engineer's ability to transform mission concepts into concrete design specifications.

User Groups Who Can Engage CV4S Support in their Work

Network Researchers involved in investigating and evaluating space-oriented protocols, space networking techniques, and/or space mesh network optimization employing techniques such as:

- Time-Driven Satellite Routing Protocol (TDSRP)
- Delay Tolerant Networking/Bundle Protocol (DTN/BP)
- Multi-Protocol Label Switching (MPLS).
- Protocol scaling studies

Satellite/Network Engineers involved in:

- Network design/performance trade-off studies
- Designing, configuring, and tuning space mesh network constellations

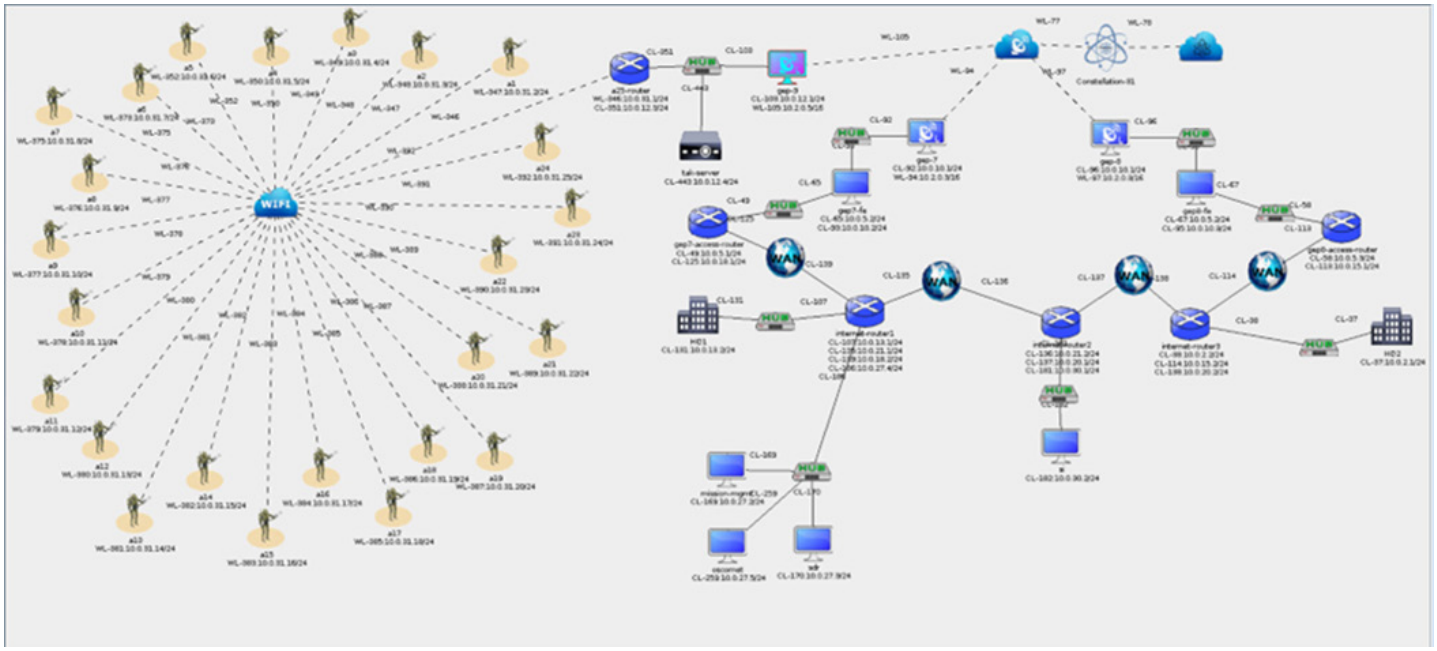
Cybersecurity Researchers involved in:

- Network attack-surface simulation and evaluation
- Threat/risk simulation and evaluation
- Countermeasure simulation and evaluation

Satellite Operators involved in:

- Satellite operations planning and scheduling
- Network tasking evaluation and assessment
- Network operation training

A key tool in these arenas provides the capability to build high-fidelity models representing all critical network elements and behaviors, capable of simulating an expansive variety of network traffic scenarios and uses, and capable of simulating cyber-attacks of various forms, analyzing the results of the attacks, and designing robust cybersecurity defenses through countermeasures and tailored security controls. CV4S is such a tool.



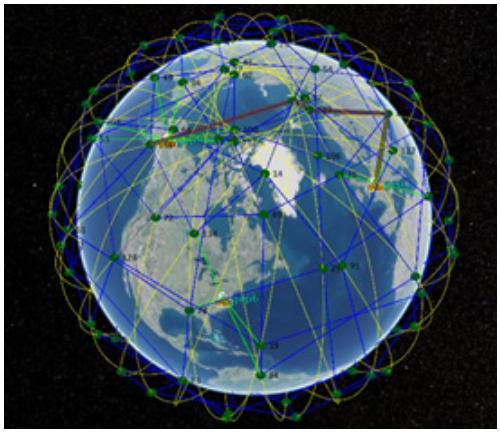
CV4S Scenario Generation GUI Design Canvas

FEATURES AND CAPABILITIES

CV4S provides a wide range of features and capabilities to support the network modeling and simulation needs of its users.

Satellite Constellation Modeling

- Highly scalable modeling of multi-body, multi-plane, and multi-satellite constellations
- Orbit propagation via industry-standard orbit determination and propagation algorithms



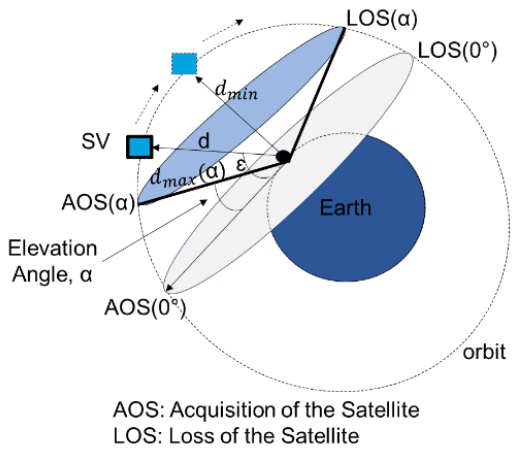
120 Satellite, 6 plane Constellation

Terrestrial/Celestial Network Modeling

- Modeling of LAN, WAN, and Wi-fi network segments, and data and message transport across integrated terrestrial/celestial networks, and mobile networks formed by advanced terrestrial vehicles (drones, airborne C2 aircraft, naval task forces) and/or mobile ground forces
- Modeling uplink of commands to satellite vehicles and downlink of vehicle health and status through ground entry points and ground stations
- Assembling and generating networking scenarios via a drag and drop GUI canvas covering every layer of the networking stack
- Incorporating VM objects generating real or emulated data and communications traffic via actual applications and/or synthetic internet representations

Network Link Modeling

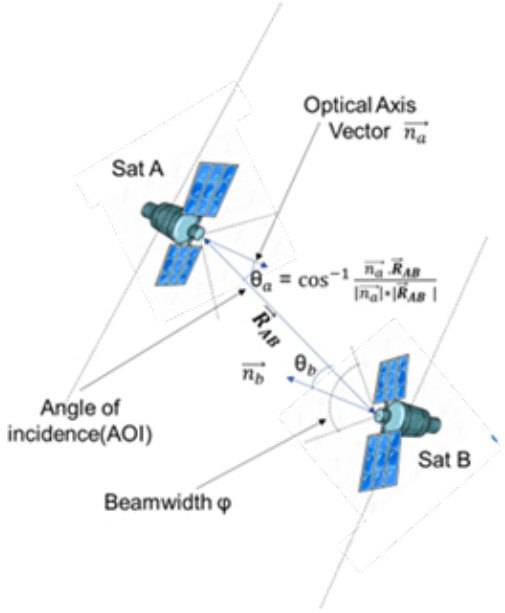
Modeling high-fidelity space-to-ground and satellite-to-satellite links that incorporate the orbital physics and mobility affecting the network link layer across the space mesh network.



Satellite Contact Window

Satellite Network Device Modeling

Modeling on-orbit network devices, including the key physics factoring into optical inter-satellite links. CV4S physics algorithms derive accurate OISL setups, time-to-live, and teardowns across the entire range of inter-satellite interactions occurring at any epoch in time.



Intersatellite Link Setup

Data Transport Modeling

Support for a wide variety of communications techniques and protocols, including space-oriented, military-oriented, and commercial waveforms.

EMANE Model Library

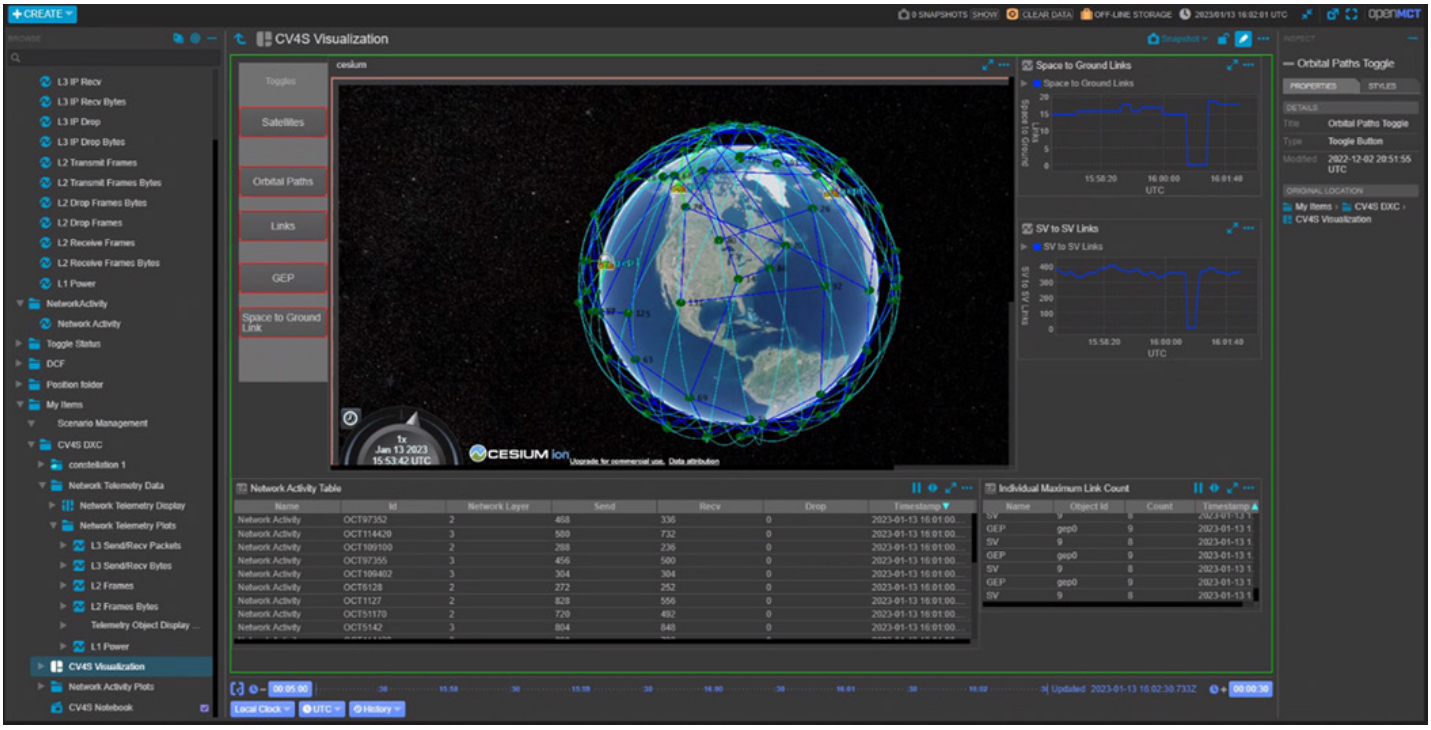
Focus on Military Waveforms

- Extensive library of military waveforms:
- High fidelity, validated models

ns-3 Model Library

Focus on Commercial Wireless and Wired Network Technologies

- Commerical waveforms
  - LTE, 802.11a/b/g/n/ac/ah, 802.15.4, 802.16, LoRaWAN, WRAN, etc.
- Spectrum-based wireless propagation loss models
  - Free-space, Terrain-aware, etc.
- Wired Models: 802.3, WAN links, etc.
- Routers, switches, hubs, Firewalls, NATs
- Layer 3 protocols
  - DHCP, DVRP, OSLR, BGP, SMF, BATMAN
- SDN (OpenFlow)
- DVB-S2 Satellite Waveform
- Transport and queing models



CV4S Data eXploration Console (DXC)

Sim-Run Data Exploration

Data eXploration Console (DXC) animates the 3D configuration and motion of orbiting satellites as they form the space mesh network and visualizes communications links as they dynamically form and dissolve to channel and transport data across the constellation.

CV4S telemetry services deliver simulation results to the DXC as each sim-run proceeds. Integrated charting and graphing tools display sim-run network activity and results to the user for investigation and deeper examination in sim-run time.

Telemetry, Tracking and Control

CV4S incorporates the Peraton OS/COMET® satellite telemetry, tracking and command system as a CV4S VM for use in modeling ground systems command and control elements.

OS/COMET® can model all aspects of satellite operations, ranging from data uplinks and downlinks to command preparation, testing, and execution, and to satellite health monitoring and system checks.

Peraton's OS/COMET advanced satellite TT&C operates USAF GPS satellites, NOAA GOES-R weather satellites, and has supported NASA's Artemis-I Onion mission to the Moon.

APPLICABILITY

The modeling and simulation capabilities of CV4S are applicable to a variety of engineering and operational challenges where terrestrial and/or celestial space mesh networks are involved. Some of the following examples illustrate the use of CV4S to provide key support where users depend upon space assets or space mesh networks for mission critical services.

Design, Development, Test, and Evaluation (DDT&E) Baselines

Engineering, building, and launching integrated space mesh networks involves multiple challenges, including:

- Stretch networking requirements
- Complex satellite constellations
- Constrained resources and topology within a hostile environment

The network models and simulations built and run in CV4S provide development teams with a guide through the phases of the engineering life cycle.

The life cycle is often referred to as the engineering "V" due to its shape when shown in many common depictions – but is also frequently called the "Valley of Death" due to the numerous challenges and pitfalls encountered while traversing the life cycle that have been the cause of failure for a startling number of projects.

Successful projects provide tangible roadmaps for members so they can proceed with the "ends in mind", and these projects continue to refine their roadmaps as the engineering lifecycle's journey of discovery unfolds. CV4S mod-sim scenarios provide such roadmaps, as described below, through stepwise refinement across the breadth and depth of a network modeling catalog that supports the engineering life cycle:

- Network ConOps models support mission formulation through mod-sim scenarios constructed to depict macro-level behavior of the network support required for success
- Major network elements depict the primary sources, transport, and consumption of network traffic. A high-level model reflects an initial network configuration and set of parameters that supports the ConOps and provides a point of reference for review and discussion of alternative configurations and approaches
- Refinement of ConOps models creates prototype models supporting solution architecture development and studies focused on specific topics and domains (trade-offs, feasibility, cybersecurity, operations etc.)
- Refinement of prototype models creates design models supporting performance analysis, scaling predictions, and process engineering (quality of service, traffic engineering, etc.)
- Finally, as-built models support operations training, on-orbit troubleshooting, operator certifications, etc.

Mission Planning and Scheduling

Mission success hinges on reliable, performant, and resilient communications networks. CV4S models and scenarios enable mission planners and schedulers to define the network traffic patterns and coverages that are necessary for successful operations. Running simulations of the installed baseline of network assets and capacities enable mission planners to gauge the adequacy of an existing network configuration and/or identify and fill gaps in network support by specifying necessary augmentation.

Once satisfied, planners can task terrestrial and celestial network assets via scheduling products or processes to position these key assets in support of mission operations plans.

Operational Exercises and Post-Op Evaluations

Wargaming and post-operational exercises are valuable techniques to prepare for and achieve high levels of mission readiness and to incorporate after-action feedback into refinement of mission support postures.

CV4S supports integration with wargaming platforms to provide highly accurate estimates of network availability and support for data and messaging traffic cross the duration of the exercises.

Augmenting the satellite entities in wargaming platforms with CV4S's high-fidelity emulation of communications availability and capacities enhances the accuracy and realism of operational exercises and post-ops evaluations.

HISTORY

Peraton's CyberVAN evolved out of the needs of the United States Army for rapid development and deployment of mobile communications networks supporting theater operations.

Collaboration between the Army Research Laboratory (ARL) and industry researchers beginning in 2008 produced a prototype to model and simulate a Virtual Ad-hoc Network (VAN) reflecting the Army's requirements.

Continued industry/ARL collaboration evolved its features and capabilities and resulted in a name change to CyberVAN to reflect its evolved emphasis on cyber.

CyberVAN extensions developed in 2022 focused on space mesh network modeling and simulation, and integrated terrestrial/celestial networking scenarios. These extensions produced the CyberVAN for Space feature set described in this paper.

ENGAGING CV4S

Access to the CV4S enclave is through the Peraton CyberVAN portal. A portal account provides access to documentation, tutorials, case studies, scenario libraries, and experimentation environments.

Email cybervan@peratonlabs.com and provide your name, organization, and anticipated use of CV4S. A member of Peraton's business development team will respond to discuss avenues for service agreements and support contracts enabling use of the CV4S network modeling and simulation platform.

Peraton

ABOUT PERATON

Peraton drives missions of consequence spanning the globe and extending to the farthest reaches of the galaxy. As the world's leading mission capability integrator and transformative enterprise IT provider, we deliver trusted and highly differentiated national security solutions and technologies that keep people safe and secure. Peraton serves as a valued partner to essential government agencies across the intelligence, space, cyber, defense, citizen security, health, and state and local markets. Every day, our employees do the can't be done, solving the most daunting challenges facing our customers.

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cybervan@peratonlabs.com