CENIC

An Introduction to CENIC

September 2020

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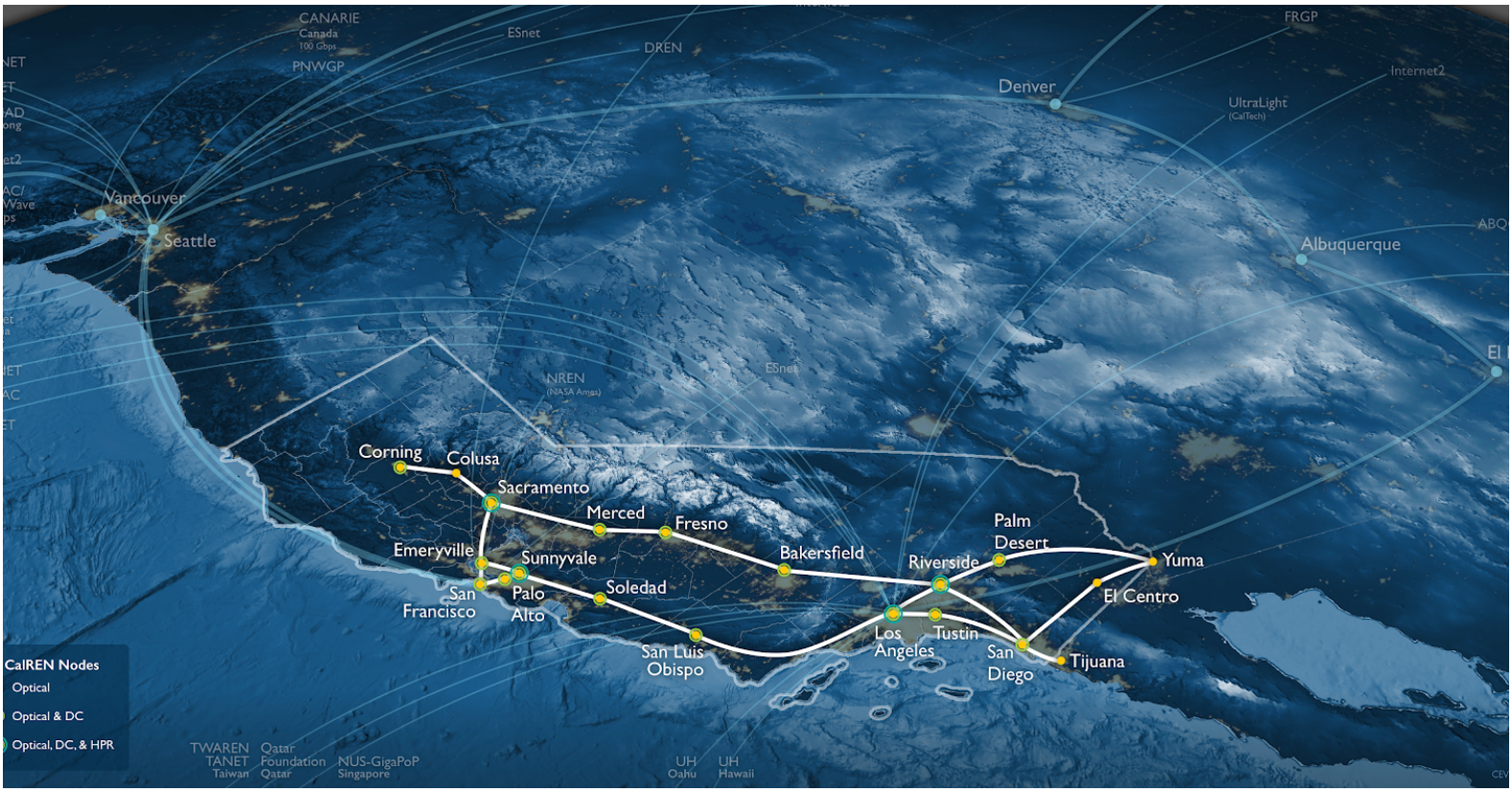

1 | Introduction to CENIC: History & Mission

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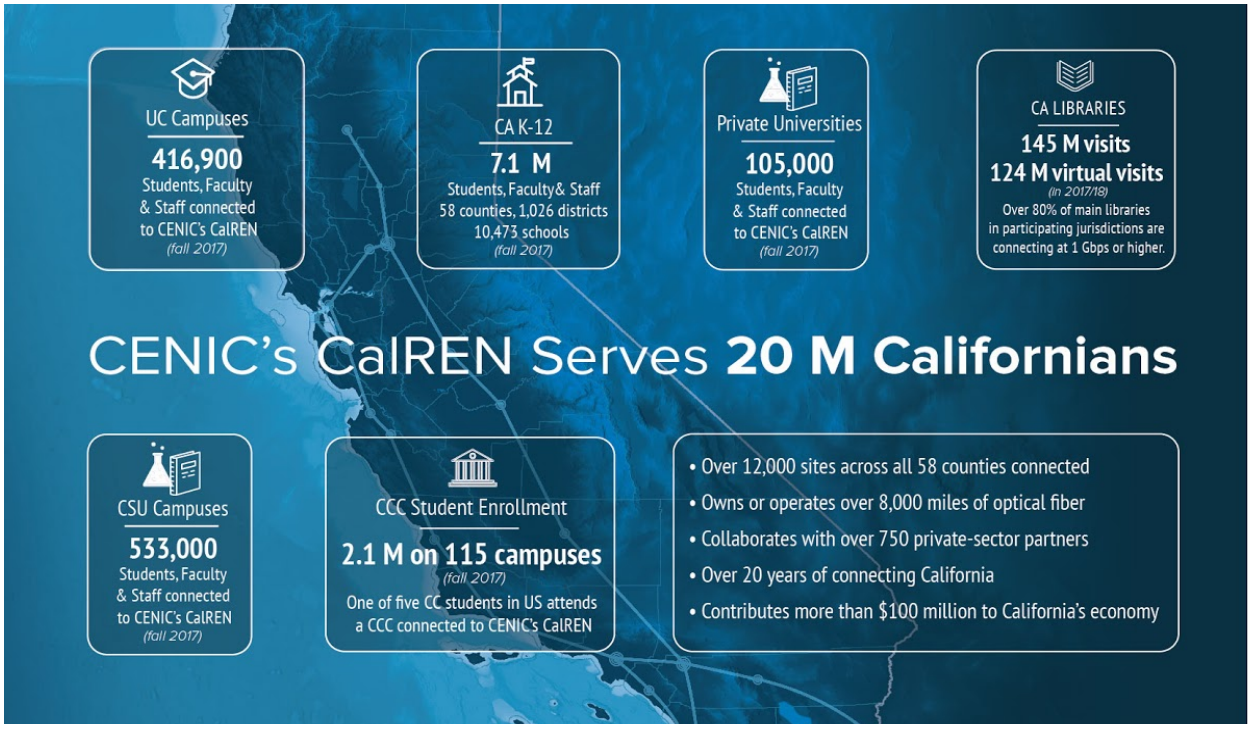

CENIC and the California Research and Education Network (CalREN)

In a series of meetings in 1996, technology leaders from Stanford University, the University of California, the California State University, the California Institute of Technology, and the University of Southern California and its Information Sciences Institute articulated a common vision for the innovative use of communications technology to deliver the next generation of data communications services. Fundamental to this vision is the existence of an advanced wide area communications infrastructure serving all institutions of higher education in California, linked seamlessly with the emerging national advanced network infrastructure.

In 1997, the Corporation for Education Network Initiatives in California (CENIC) was incorporated as a not-for-profit organization to represent the common interests of California's higher education academic and research communities in achieving robust, high-capacity, next-generation Internet communications services. CENIC's leadership was drawn from California higher education institutions and information technology industries. The first objective of CENIC was to facilitate realization of the California Research and Education Network (CalREN), a high-bandwidth, high-capacity Internet network specifically designed to meet the unique requirements of CENIC's research and higher education member institutions.

For a detailed recap of CENIC's genesis, watch an eight-minute video (https://youtu.be/AH5chxLb-VQ) that was prepared for CENIC's 20th anniversary in 2017 and features some of the founders as well as some current researchers using CalREN.

Today, CENIC member institutions include the original five institutions of higher education (Stanford, Caltech, USC, UC, and CSU), the California Community Colleges, the schools of the California K–12 system, the members of the California public library system, and the Naval Postgraduate School, as well as several other independent universities, health systems, museums, and cultural and artistic organizations. CalREN consists of more than 8,000 miles of CENIC-owned and operated fiber-optic backbone. Sites in all 58 of California's counties connect to this advanced network via leased lit circuits obtained from commercial carriers or dark fiber that is lit by CENIC.

CENIC is the parent company of two key limited liability companies (LLCs). CENIC Broadband Initiatives, LLC (CBI) was formed in 2009 as a single-member limited liability company in California for the purpose of facilitating the availability of broadband and related services, and for accessing state subsidies through the California Teleconnect Fund (CTF) under the auspices of the California Public Utility Commission (CPUC). A Certificate of Public Convenience and Necessity (CPCN) as a public utility is required to access CTF and other, related CPUC funds. Thus, CBI Is a registered telecommunications carrier with the Federal Communications Commission and the California Public Utilities Commission. Pacific Wave LLC is a joint project of CENIC and the Pacific Northwest Gigapop (PNWGP), and is operated in collaboration with the University of Hawaii and the University of Washington. It is the official National Science Foundation-funded interconnection and peering facility and Software Defined Exchange (SDX) in the U.S. for Asia-Pacific national R&E networks, and as such is the parent organization for international peering efforts as well as for the Western Regional Network (WRN). Pacific Wave is, increasingly, being used as a domestic peering fabric, as well.

CENIC's Charter Associates govern CENIC through their representatives on the CENIC Board of Directors. These leaders donate their time and expertise to participate in Board activities and Board committees designed to ensure that CENIC is managed effectively and efficiently, for the best interest of CENIC's member institutions and their communities.

CENIC operates as a 501(c)3 tax-exempt nonprofit but it constitutes a $100-120 million annual budget enterprise. It employs 67 full-time staff, plus part-time interns and a small number of contractors. Its operations are member-supported, along with several entrepreneurial activities. Operations are headquartered in Southern California in La Mirada, and there is also a satellite office in Northern California in Berkeley.

CENIC MEMBERSHIP LEVELS AND BENEFITS

CENIC's California Research and Education Network (CalREN) is a multi-tiered, high-performance network serving the majority of research and education institutions in the state. Each year 20 million Californians use CalREN but go unaware due to the seamless integration with our member institutions. By using CalREN broadband, CENIC members enjoy supremely reliable, efficient, and cost-effective access, as well as these benefits:

- **All-you-can-eat broadband usage.** CENIC does not charge users on per-bit terms and CENIC Charter Associates have access to the entire portfolio of networks that CENIC manages, including access to CENIC member institutions (through CalREN), access to Internet2, access to other R&E peer networks, access to the commodity Internet, Layer 1 (wave) services, and Layer 2 (VLAN) services.
- **Entry into a participatory, membership organization.** Users are offered collaboration resources, access to the Technical Advisory Councils where users can give input into how the network evolves, training sessions such as for IPV6 and perfSONAR, and an annual conference where users can share knowledge.
- **Network design expertise**. CENIC engineers design, configure, and deploy all layers of the network infrastructure, and implement agreed-upon connectivity solutions.
- **Discounts on equipment.** CENIC's extensive relationships with dozens of commercial services and equipment providers and vast buying power provides members with circuits and other telecommunications equipment at the best possible price.
- **Cloud connectivity and content services**. Use of CalREN's settlement-free peering services (to nearly 100 peers) provides high-speed access to many data-intensive sites frequented by researchers, students, and educators, such as Amazon, Google, and Microsoft.
- **24/7 Network Operation Center.** CENIC's NOC monitors CalREN and connections into CalREN around the clock. Members can contact the NOC at any time, and CENIC's team of experienced, highly trained network engineers will respond.
- **Scaling services to the need.** CENIC consults with each member and assists staff in choosing the right level of service that both meets present needs and enables cost-efficient scalability in the future.
- **Federal and state subsidy assistance.** CENIC obtains federal E-rate discounts, ranging from 20% to 90%, on both one-time and recurring costs for Internet access and upgrades for libraries and K–12 schools. CENIC also applies for the California Teleconnect Fund discount for monthly recurring costs, which is 50% after applicable E-rate discounts.
- **A community of thousands of research and education institutions.** By connecting to CalREN, members can connect directly to other education institutions around the globe.

Charter Associates

These founding and governing research and education members have full access to CENIC's portfolio of networks and services. Charter Associates' representatives comprise the CENIC Board of Directors, setting policy and guiding the organization.

- California Community Colleges
- California Institute of Technology
- California K–12 Schools
- California Public Libraries
- California State University
- Naval Postgraduate School
- Stanford University
- University of California
- University of Southern California

Associate

These independent research, educational, medical, and technology institutions and organizations engage with and connect directly to the broader CENIC community. Associates have direct access to CENIC's portfolio of networks and services, but they do not serve in governance roles.

- Carnegie-Mellon University West
- Montage Health (Community Hospital of the Monterey Peninsula)
- Monterey Bay Aquarium Research Institute
- NASA Ames Research Center
- Salinas Valley Memorial Healthcare System

Sponsored Associates

These are cultural, scientific, or artistic institutions or organizations with a close tie to a Charter Associate that serves as a sponsor. Sponsored associates have direct access to an abbreviated portfolio of CENIC's networks and services, which include access to CENIC member institutions (the CalREN Network), access to the commodity Internet, and access to Internet2.

- California Academy of Sciences
- Exploratorium
- Internet Archive
- Jackson Labs
- SFJAZZ Center
- United States Geological Survey (USGS), Menlo Park Campus

Auxiliary Associates

Auxiliary Associates are smaller institutions and organizations that engage with the CENIC community and have direct access to an abbreviated portfolio of networks and services, which include access to CENIC member institutions (the CalREN Network), access to the commodity Internet, and access to Internet2.

- Chapman University
- City of Hope National Medical Center
- J. Paul Getty Trust
- Pepperdine University
- University of San Diego

Affiliates

These educational and research institutions and organizations make use of CalREN indirectly through a Charter Associate that serves as an Affiliate's connection to the network.

- ArtCenter College of Design
- Broad Art Foundation
- Charles Drew University
- Claremont College
- Colburn School
- East Bay Community Law Center
- International Computer Science Institute
- Loyola Marymount University
- National Marine Fisheries Service
- Occidental College
- Pac-12 Enterprises
- The Scripps Research Institute
- Venter Institute

2 | CENIC Governance

CENIC Board of Directors
Technical Advisory Councils

CENIC BOARD OF DIRECTORS

CENIC is governed by its member institutions through the CENIC Board of Directors. Positions on the CENIC Board of Directors are held by representatives of the CENIC Charter Associate community, the segments of the California research and education community for and by which CENIC was created. The CENIC Charter Associates are comprised of the following segments:

- The California K–12 System
- The California Community College System
- The California State University
- The University of California
- Independent Universities
    - California Institute of Technology
    - Stanford University
    - The University of Southern California
    - The Naval Postgraduate School
- California Public Libraries

Each segment has three seats on the CENIC Board of Directors with the exception of the private universities, which each have one seat. Each segment typically appoints its representative Board members for two-year terms (which can be renewed), although Board members have occasionally been appointed to complete the term of another Board member who has retired.

Three Outside Directors are on the CENIC Board of Directors as voting members representing the research community, other regional networks, and private sector technology companies.

CENIC Board of Directors, as of September 2020

Segment	Role	Firstname	Lastname	Since	Through
California Commuity Colleges	Charter Director	Tim	Calhoon	06/08/11	06/30/21
California Commuity Colleges	Charter Director	Barney	Gomez	10/23/18	06/30/21
California Commuity Colleges	Charter Director	Deborah	Ludford	08/25/09	06/30/21
California State University	Charter Director	Michael	Berman	06/08/11	06/30/21
California State University	Charter Director	Kendra	Ard	11/05/19	06/30/21
California State University	Charter Director	Sam	Sudhakar	08/21/17	06/30/21
California K-12 System	Charter Director	Terry	Loftus	07/28/20	06/30/22
California K-12 System	Charter Director	Michelle	Murphy	07/01/19	06/30/21
California K-12 System	Charter Director	Jerry	Winkler	09/23/15	06/30/22
California Public Library	Charter Director	Michael	Liang	06/21/18	06/30/21
California Public Library	Charter Director	Anne	Neville-Bonilla	07/01/17	06/30/21
California Public Library	Charter Director	Patty	Wong	07/01/15	06/30/21
California Institute of Technology	Charter Director	Jin	Chang	07/01/17	06/30/21
Naval Postgraduate School	Charter Director	Vacant		N/A	
Stanford University	Charter Director	Sylvie	Cosgrove	07/01/19	06/30/21
University of Southern California	Charter Director	Doug	Shook	07/01/19	06/30/21
University of California	Charter Director (Chair)	Tom	Andriola	09/23/13	09/30/20
University of California	Charter Director	Larry	Conrad	07/01/17	09/30/20
University of California	Charter Director	Pramod	Khargonekar	07/01/19	06/30/21
CENIC	President, CEO; Ex Officio	Louis	Fox	N/A	
CENIC	Treasurer, CFO; Ex Officio	Bill	Paik	N/A	
Outside	Outside Director	Ron	Johnson	01/01/99	06/30/21
Outside	Outside Director	Larry	Smarr	06/06/01	06/30/21

STANDING COMMITTEES OF THE CENIC BOARD OF DIRECTORS

There are four standing committees appointed by the CENIC Board of Directors: the Governance and Board Development Committee, the Executive Review and Compensation Committee, and the Audit Committee. Committees are comprised of voting directors of the corporation, with the exception of the Finance Committee, which is comprised of a majority of voting directors but may include financial experts from CENIC Charter Associate institutions. All CENIC Board members serve on at least one committee. Ex Officio directors participate as non-voting members of these committees.

Governance and Board Development Committee

The Governance and Board Development Committee is charged with the following priorities:

(a) Assessing the board's current composition and identifying missing qualities and characteristics;

(b) Orienting new board members and continuing to educate all members on their responsibilities;
(c) Ensuring that the board regularly engages in self-assessment;
(d) Ongoing and continuous focus on identifying, preparing, and recruiting future governance leaders;
(e) Training and education of the Board related to governance roles and responsibilities (and with respect to bridging Board knowledge gaps);
(f) Assessment/evaluation of the Board, the Chair, individual directors;
(g) Evaluation of Board meetings/sessions; and
(h) Monitoring of governance structures and processes.

Audit Committee

The Audit Committee plans and supports audits of CENIC and its major projects or programs. Members of the Audit Committee meet on an as-needed basis. Specifically, the Audit Committee is responsible for recommending to the Board the retention and termination of the corporation's independent auditor and may negotiate the independent auditor's compensation on behalf of the Board. The Audit Committee confers with the auditor to satisfy its members that the financial affairs of the corporation are in order, reviews and determines whether to accept the audit, assures that any non-audit services performed by the auditing firm conform with standards for auditor independence referred to in Section 12586, subdivision (e) (1) of the California Government Code, and approves the performance of non-audit services by the auditing firm.

Finance Committee

The Finance Committee oversees development of the annual operating budget for CENIC. The committee is responsible for oversight of financial matters of the corporation, which includes review of quarterly and annual financial statements, proposed budgets and business and financial plans, matters pertaining to the corporation's fiscal and financial affairs, and business operations. In addition, the Finance Committee is responsible for review of the corporation's investments and investment policy, and recommending any changes to the Board.

Executive Review and Compensation Committee

The Executive Review and Compensation Committee, subject to the supervision of the Board, conducts a formal assessment of executive and compensation annually for (1) the President and Chief Executive Officer; (2) the Treasurer and Chief Financial Officer; and (3) any key executives of the corporation as the Board may deem appropriate.

Meetings

Board members are expected to prepare for and participate in three Board meetings per year, one Annual Meeting, and a Board Retreat. Between face-to-face meetings, there are monthly one-hour teleconferences, called "Lunch with Louis," each of which highlights a timely topic of interest.
Board meeting locations rotate between Northern and Southern California. Chairs of Technical Advisory Councils (TACs) typically participate via teleconference in Board meetings to provide quarterly TAC reports.

TECHNICAL ADVISORY COUNCILS

CENIC has three Technical Advisory Councils with members drawn from its Charter Associate community. Any interested individual from a Charter Associate institution can participate in the TACs.

DC Technical Advisory Council (DC TAC)

The CalREN-DC Technical Advisory Council (DC TAC) serves to provide technical analysis, review, and recommendations on the design, installation, operation, and performance of the CalREN-DC network and the related fiber infrastructure. The DC TAC also provides guidance on technical issues relating to CENIC infrastructure and to other areas as requested by the Board. The DC TAC is advisory to the CENIC Board of Directors and CEO.

HPR Technical Advisory Council (HPR TAC)

The CalREN-HPR Technical Advisory Council (HPR TAC) serves to provide technical analysis, review, and recommendations on the design, installation, operation, and performance of the CalREN-HPR network and the related fiber infrastructure. The HPR TAC also provides guidance on technical issues relating to CENIC infrastructure and to other areas as requested by the Board. The HPR TAC is advisory to the CENIC Board of Directors and CEO.

Security and Privacy Technical Advisory Council (SEC TAC)

The Security and Privacy Technical Advisory Council (SEC TAC) serves to provide technical analysis, review and recommendations on the design, installation, operation and performance of network security systems, tools, and techniques as part of the CalREN networks and their related infrastructure. The SEC TAC provides analysis, review, and recommendations on network and data privacy issues related to CalREN and common to CENIC Associates. The SEC TAC also provides guidance on technical issues relating to CENIC infrastructure and to other areas as requested by the Board. The SEC TAC is advisory to the CENIC Board of Directors and CEO.

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3 | CENIC Staffing & Operations

Executive Leadership
Department Organization & Functions
CENIC Events & Awards

EXECUTIVE LEADERSHIP

CENIC's executive staff brings decades of experience in a variety of fields that have prepared them to lead this unique nonprofit organization in its daily operations with an eye to the future.

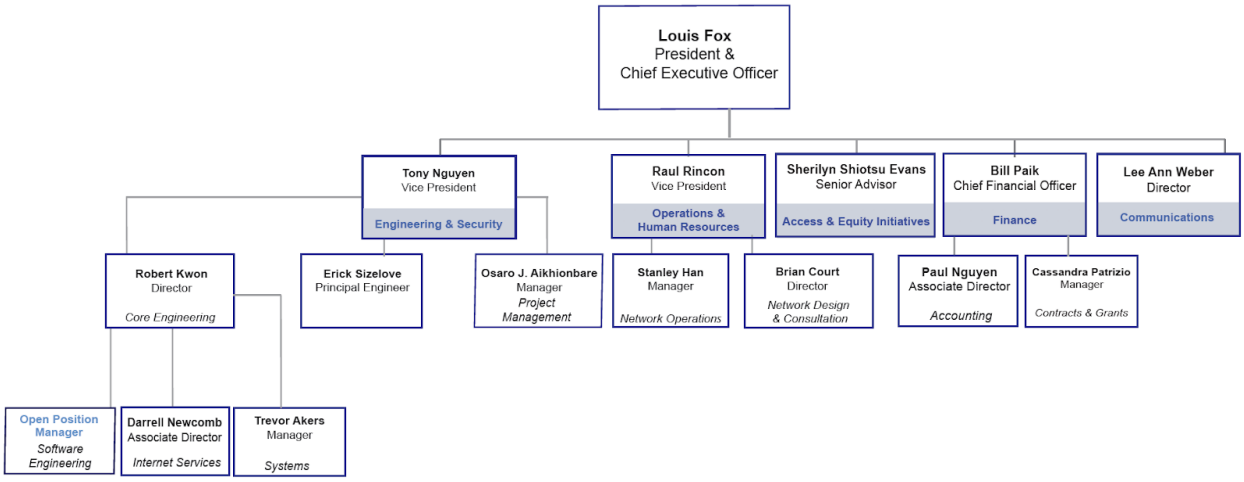
Louis B. Fox is President & Chief Executive Officer of CENIC, where he is responsible for the strategic direction and overall management of this nonprofit that operates the California Research and Education Network (CalREN). Prior to joining CENIC in 2012, Louis served for nearly three decades as a researcher, faculty member, and administrator at the University of Washington and Duke University. He has been an active leader in national and international R&E networking efforts for 30 years, with a particular focus on broadband and social equity in the US and abroad.

Tony Nguyen is Vice President of Engineering and Security at CENIC, where he is responsible for the systems, software, and network engineering departments. He also oversees the Program Management Office and Security Information Office. Tony joined CENIC in 2003 as part of a team that engineered, implemented, and operated CENIC's first-generation statewide optical and packet infrastructure. Prior to joining CENIC, Tony was the senior network architect at Ameriquest Mortgage, and lead systems engineer at the regional Internet Service Provider Digilink, where he oversaw the day-to-day technical operations as well as research and development of new technologies that would create growth for the company.

Raul Rincon is Vice President of Operations and Human Resources at CENIC, where he is responsible for technical operations and personnel. Raul started at CENIC 17 years ago as a network engineer and has advanced through several roles. Prior to joining CENIC, Raul was a network engineer at a startup in the late 90s that was acquired by Verio and then NTT, one of the largest telecoms in the world. He worked on the core team responsible for datacenter network engineering in the dedicated and enterprise hosting environments.

Bill Paik is Treasurer and Chief Financial Officer at CENIC, where he oversees and is responsible for accounting and human resources roles. Prior to joining CENIC, Bill was the accounting manager in two private companies, NI&D and American Fish, where he was responsible and performed the day-to-day accounting functions, as well as the monthly and annual financial closings. Bill earned his bachelor of science degree in finance at the University of Southern California and attained his Certified Public Accountant license in 2001.

CENIC ORGANIZATION CHART | June 2020



DEPARTMENT ORGANIZATION & FUNCTIONS

CENIC's greatest asset is its staff. There are 67 full-time employees working in the two offices in La MIrada and Berkeley, California. Our workgroups, whether technical or non-technical, are dedicated to CENIC's mission and work tirelessly to realize the highest possible quality of service for our members. These groups collaborate closely with each other, with our providers, with our members, and with the broader community to achieve CENIC's goals.

Network Operations

The Network Operations group runs the NOC (Network Operations Center) and keeps CalREN (California Research and Education Network) running seamlessly for thousands of organizations throughout the state. Its primary responsibilities are to address outages and disruptions on the network; perform maintenance tasks (e.g., replace and/or update software and equipment); and support Core Engineering on new and upgrade service implementations.

CENIC's Network Operations Center is available to assist CENIC members 24x7x365 (24 hours per day, 7 days per week, 365 days per year). Contact information (phone: 714-220-FIXIT and email: noc@cenic.org) is published on CENIC's website and disseminated widely to members through meetings, presentations, and publications.

Statistics from the fall of 2018 provide a snapshot of a typical quarter of activities in the NOC: Engineers triaged approximately 24,000 alarms, addressed more than 3,600 service requests, handled 136 requests related to circuit deployments, and completed 289 maintenances.

Alarms and requests: Alarms from any of CENIC's network monitoring systems (NMS) and requests for assistance (generated via phone call, email, or entries in CENIC's ticketing system) trigger a standardized triage process. Network triage alarms and service requests span a broad range of events, such as circuit bounces, single-site outages, multi-site outages, performance issues, and major issues or outages on the backbone. Engineers are required to troubleshoot and resolve issues with CENIC equipment, as well as work with commercial service providers to resolve issues on leased circuits, and work with members to resolve local site issues. CENIC has established a triage process to create a predictable environment for handling incoming requests, thereby increasing productivity by reducing interruptions for the majority of engineers on shift. One or two engineers per shift are designated to be responsible for triage on a rotating schedule, and they assess all incoming requests and assign tickets to themselves or other staff.

Escalations: Ticket escalations to Lead Engineers or Core Engineers are available 24x7x365 whenever needed. However, CENIC's culture encourages professional development of network engineers and sets an expectation that engineers continually enhance their technical skills. As a result, less than 1% of the requests that NOC receives require escalation. For our member institutions CENIC has defined an escalation path to provide members a method to raise visibility on any issue to the attention of CENIC management. Contact information for escalation is published on CENIC's website and distributed to authorized contacts at every member institution and service provider.

Level 1: CENIC Network Operations Center at 714-220-3494 and noc@cenic.org.
Level 2: Stanley Han, Manager, Network Operations at office 714-220-3468 and cell 626-533-1686.
Level 3: Sherilyn Evans, Sr. Vice President & COO at office 714-220-3438 and cell 714-465-7753.

Service implementation: NOC supports Core Engineering in the implementation of both new and upgraded services. For major deployments and maintenances, the Core Engineering team develops a "method of procedures" (MOP) for NOC engineers to follow. An example of a major deployment would be installing a new backbone router at a hubsite. NOC engineers ship the necessary equipment, which may include chassis, line cards, optics, and fiber jumpers, to the site. Typically, NOC engineers do not travel to backbone sites around the state; they coordinate work with field technicians who work for our colocation facilities. To minimize disruption to users, CENIC's NOC schedules the majority of maintenance work to occur between midnight and 5:00 AM, and issues maintenance notices at least four business days in advance, as well as posting notices publicly in CENIC's online maintenance calendar. Engineers capture pre-maintenance and post-maintenance snapshots to ensure affected services restore within operating specifications.

Staffing: To ensure 24x7x365 coverage, the NOC has three shifts: day, swing, and grave. These are designed as rolling shifts, with a range of start and end times to facilitate smooth transition between shifts. Day shift starts between 5:30 and 8:30 AM. Swing shift starts between 9:30 AM and 1:30 PM. Grave shift starts between 8:30 and 9:30 PM. Engineers work four 10-hour days per week to provide optimal coverage. Each shift has a lead engineer with supervisory responsibility for five to seven engineers. Total staffing of the NOC includes one manager, three shift leads, 17 network engineers, and two interns.

Core Engineering

The Core Engineering team is instrumental in connecting millions of Californians with reliable and forward-thinking solutions, from basic broadband to advanced services for experimental networks. This team architects and designs the various networks that CENIC manages and supports, and is responsible for identifying new technologies and planning future directions in network infrastructure and services.

Its main functions are to:

1. Deploy hundreds of new circuits each year.
2. Identify, assess, design, and implement upgrades on the network backbone.
3. Provide expertise for escalation of requests from the NOC.
4. Identify, assess, and employ new and emerging technologies.
5. Furnish technical expertise for a broad range of community projects.

In performing this work, Core Engineering interacts with every team within CENIC, with members across California, with providers of goods and services, and with colleagues, both nationally and internationally.

Examples of work undertaken by Core Engineering include:

- Analysis of how members connect, how they use the various networks, overall utilization, growth projections, and capacity planning, including for LEARN and GPN.
- Design and implementation of network services to connect member institutions to CalREN.
- "Future WAN Working Group": Forward-looking to plan for how to change the network to better support members now and in the future while reducing costs. This group coordinates with the New Network Group.
- Broadly scoped projects (beyond the boundaries of CalREN), such as NSF International Networking (IRNC), Pacific Wave, WRN, and GRP.
- Virtual Customer Equipment (VCE) pilot.
- Initiatives to use more automated processes on the network, such as network monitoring; explore use of non-native (alien) transponders; and collapsing the HPR and DC hardware into a single platform. (For details on future planning, see the Strategic Plan in Chapter 8.)
- Participation on CENIC's Technical Advisory Councils.

The team is made up of a director, a principal network architect, three senior-level network engineers, and six mid-level "associate core" network engineers.

Network Consultation & Design

This functional area provides technical consultation, both for prospective customers and existing member institutions. For prospective new members, this effort may include explaining the benefits of connecting to CalREN. For both prospective and existing members, this effort entails technical consultation on network design requirements for connectivity, including design changes and enhancements. In this capacity, the staff must coordinate closely with other CENIC teams: Core Engineering to identify equipment cost, Project Management Office to obtain circuit costs, and Contract Management to develop and execute contracts with new customers. The tools most often used by the

Network Consultation & Design staff include Cricket data utilization graphs, the Jira ticketing system, and two of CENIC's homegrown systems: Asset Management System (AMS) for inventory information and PARC for contract information.

Though not a frequent activity, there is also a consultative role this staff offers to charter members requiring an outside perspective on their local (i.e., enterprise-level) network planning, such as upgrading a campus network.

This area is currently staffed by a single employee with back-up provided through coordination with other teams at CENIC.

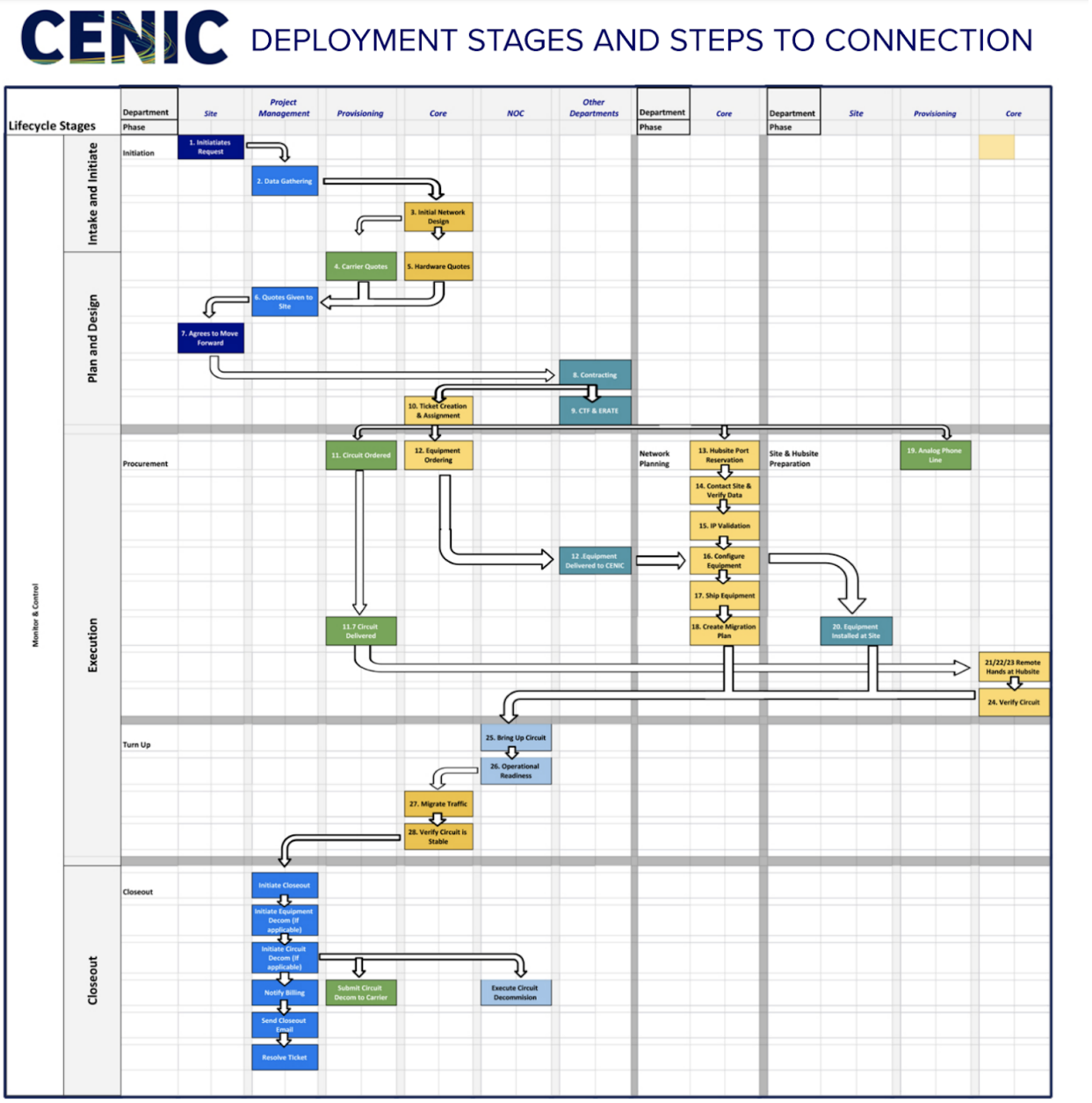
Project Management Office

The Project Management Office provides a centralized role that oversees project activities and ensures that projects are completed as efficiently as possible by coordinating tasks internally and externally throughout numerous project stages.

For example, this team is responsible for oversight of the entire lifecycle of network service deployment milestones, managing processes which span initiation, procurement, planning, site prep, and turn-up of service, through active production use of the service. While the majority of projects focus on service deployment, the PMO also handles major internal projects, such as the software project to transition from a legacy ticketing system (RT) to Jira.

The PMO is staffed by a manager, three project managers (PMs), two associate PMs, and two interns (an apprenticeship role). The genesis of this department began in September 2015, when two statewide initiatives dramatically increased the number of new circuit deployments: funding for libraries to join CENIC as the fifth public segment; and funding ($75M) to provide last-mile broadband connectivity to K–12 schools in historically underserved areas. This expansion caused a surge in activity that CENIC needed to manage effectively, and creation of a PMO was integral to addressing this need.

The workflow diagram below of a new circuit deployment provides an example of the many tasks PMs track, including their interactions with other CENIC departments.



Internet Services

The Internet Services team oversees and manages our network peering and exchange relationships with key Internet service providers, content providers, and cloud service companies.

The staff work with network peers such as ESnet, AMLIGHT, Google, Amazon, and Microsoft to build and maintain high-quality and high-capacity settlement-free interconnection (SFI) points between their networks and CENIC's. Exchanging traffic with other large networks this way supports routes and connection points to enhance network performance, offers caching strategies that bring content closer to users, and expands collaboration opportunities for CENIC members.

Most importantly, this long-standing SFI strategy means that CENIC is able to address the astronomical growth in commodity traffic without increasing ISP costs. CENIC peers 90% of its non-research traffic, which means only 10% of our current traffic traverses paid commodity links. Given the scale of CENIC's network, this is still a significant amount of network traffic.

Peering requires physical interconnection of the networks, an exchange of routing information, and is accompanied by peering agreements. CENIC works with hundreds of peers from both research and commodity networks, and has built out some of the highest-quality direct connectivity available across all R&E networks to all major cloud providers. This "built-in" connectivity generally obviates the need for CENIC members to pay for expensive direct connections to those cloud providers. CENIC's peering infrastructure supports researchers moving their computing to the cloud, campus administrators storing data off-site, and students using online and interactive resources.

The work also involves analyzing historical data and keeping close tabs on industry trends to anticipate and stay ahead of network demand.

Internet Services is staffed by the Associate Director of Internet Services and one network engineer.

Security

The Security group leads strategy on enterprise and network security and privacy issues as well as develops enterprise policies and operates a Security Incident Event Management (SIEM) system.

In January 2016, the CENIC security group spent the bulk of their first year cataloging the people, processes, computational, networked, and data (both online and offline) assets underlying CENIC's operations, including ancillary physical resources (buildings, physical plant operations, physical maps) to understand and prioritize the security risks. In November 2016, the team begin implementation of key security efforts.

CENIC's core security team strategizes high-level issues and manages day-to-day cybersecurity operations. Another team, the "Virtual Security Team," was assembled with representatives from each of CENIC's business units, as a means to collect and disseminate security-related info among all staff, and to propagate a wider culture in the organization in support of more hardened cybersecurity practices. Additionally, the CENIC Security & Privacy Technical Activities Committee (SEC-TAC) was created in July 2017 to convene discussions around security and privacy concerns within CENIC's constituency. CENIC and ESnet established a joint cybersecurity initiative in 2016, meeting on a periodic basis to exchange tactical and strategic information as well as to provide mutual review of internal security approaches.

Over the past three years, the security team has accomplished the following milestones:

- With the help of the Security Working Group (a predecessor to the SEC TAC), the CENIC Network Data Privacy Policy was developed, and adopted by the Board as CAPP 16 in June 2016.

- Compiled a risk-ordered audit list of computational assets.
- Implemented a mandatory security training program (SANS) for all staff to increase security awareness and exposure, and reduce phishing and other attack risks.
- Installed a network intrusion detection system on the CENIC office and server networks (Zeek/Bro).
- Implemented a Security Incident and Event Monitoring System (SIEM) to assess logged data for potential intrusions.
- Completed external access to WAN network devices.
- Implemented a password manager (LastPass) for staff to harden and manage passwords.
- Executed a volumetric DDoS mitigation pilot program to evaluate the benefits of such a service and examine internal processes and procedures.
- Enabled Multi-Factor Authentication (MFA) on all Layer 2 and Layer 3 network devices.
- Enabled TACACS+ on all capable Layer 1 network devices.

Additionally, the following projects have been initiated but are incomplete at this time:

- Implementing internal network redesign.
- Implementing BCP 38 anti-spoofing filtering on both CalREN and corporate networks.
- Enabling multi-factor authentication on other critical services.
- Contracting with Internet2 for a volumetric DDoS mitigation service.
- Implementing MANRS/RPKI.

Systems and Tools

This functional area is composed of two teams: Systems and Tools. Systems and Tools is staffed by a manager, five systems engineers, two software engineers, a network tools engineer, and is supplemented by temporary interns as needed.

The Systems team handles operational support and maintenance of the hardware and software systems and platforms that support CENIC's business needs. Their charge involves management of current systems, whether developed in-house or purchased, as well as support for new requirements as changes in technologies and tools may require.

The Tools team is responsible for supporting legacy systems, as well as developing new software tools. This team is currently endeavoring a complete overhaul of CENIC's suite of tools. Historically, CENIC has relied heavily on open-source "freeware" and "homegrown" applications, which have met CENIC's basic operational needs. However, as the size and complexity of CENIC's infrastructure have grown, so has the need for a more sophisticated set of tools. MOSAIC (Management of Security and Infrastructure at CENIC) is CENIC's multi-year project to port our tools and software services to a single platform based on the Atlassian suite of products.

Business, Finance, and Human Resources

As a nonprofit, CENIC relies on our accounting and human resources team to be excellent stewards of our finances, track our expenditures, and help us pass savings on to our members. The four department members are: Chief Financial Officer, Accounting Manager, Staff Accountant, and Human Resources Coordinator.

The department contracts with various vendors to support its work. TIAA administers the 403(b) retirement savings plan. KPMG has been performing annual certified financial audits for about 10 years. The accounting firm HKG LLP is contracted to: cut vendor checks, receive checks, assist with quarterly financial statements, and prepare tax returns. (AP checks are not cut in house for greater security.) QuickBooks is our accounting software. When CENIC receives federal grant funds in excess of $750,000 we are subject to an additional oversight audit.

The accounting staff rely on the Asset Management System (AMS) database to track and depreciate the inventory of network equipment such as devices, routers, and switches.

HR supports recruitment efforts by managers, issues employment offer letters, manages staff enrollment in benefit plans, negotiates for group coverage benefits, and coordinates annual employee performance reviews. The vendor Paychex provides a payroll platform and contracts with our carriers for benefits. Payroll is processed in house and approved by the CEO. (Recruitment for most technical and engineering positions is managed by Raul Rincon.)

Administrative Services and Facilities

The Administrative Services team encompasses a wide range of administrative functions: general administrative support, contract management, asset management and inventory control, executive and Board support, meeting coordination and logistics, purchasing, shipping and receiving, expense reimbursement, and the procurement and maintenance of office supplies, services, furniture, and equipment.

There are six full-time staff members with various titles and reporting relationships who staff these efforts, along with two part-time student interns. The tools used by this staff include: Jira ticketing system, PARC (contract management and purchase order system), and AMS (asset management and inventory control system).

Communications

This team is responsible for external communications for the following brands: CENIC, Pacific Wave, Pacific Research Platform, and National Research Platform. A broad spectrum of deliverables is produced against an annual schedule for both a general and segmented set of audiences.

The in-house team produces CENIC events, promotes network news, progress, and uses, and develops partnering initiatives. The team consists of three full-time staff and one contractor for assistance with producing the annual conference.

All of the audience touchpoints are integrated and include the websites, blog articles, social media (LinkedIn, Facebook, and Twitter), and press releases, for each brand. Content is created, managed, and updated regularly across all.

Other materials that are produced and continually refreshed include the Annual and Biennial reports for Pacific Wave and CENIC respectively, as well as illustrated maps of network footprints, media kits, presentations, branded design collateral and logo marks, the annual conference and Innovation Awards, workshops, and other CENIC-sponsored events.

Communications staff also handle a considerable number of internal communications needs, such as design and formatting of data, reports, and special presentations for the executives, staff and Board at meetings and conferences.

Refreshing the Talent Pool

Finding talented individuals in the technology field has always been difficult, but the ever-tightening job market for technically proficient workers in the last several years, has been even more challenging. One way we've taken on that challenge is by developing an internship program. We began with a modest effort: hiring interns into the Network Operations group in 2011. Initially, we brought in two, part-time interns referred by the faculty at a local community college. As we developed the program, we were able to create a great pipeline of network engineers. As an added benefit, we found talented interns who were able to fit into other areas of the organization as well. Interns that began in Network Operations have gone on to full-time positions in Systems Engineering, Software Engineering, and Project Management. We've expanded the program and created similar intern positions in other departments to develop multiple talent-specific pipelines. To date, we've made 13 full-time hires through our internship program; with as many as seven interns working in four different departments at any given time.

CENIC EVENTS & AWARDS

CENIC's position in California affords us a unique perspective on advanced networking and on the needs of the communities that depend on it, as well as the responsibility to ensure that innovations and best practices are disseminated throughout those communities.

CENIC Annual Conference

CENIC has, since its inception, held annual conferences, bringing together researchers and educators throughout California, along with their colleagues from around the nation and the world. Attendees come together for presentations, demonstrations, keynote addresses, the annual Innovations in

Networking Awards, latest news from networking vendors, and, of course, the ad hoc human networking at the conference.

The CENIC Annual Conference themed “The Right Connection” typically is a three-day event alternating each year between locations in northern and southern California in order to enable Associate researchers and educators from all over the state to attend. Conferences taking place during odd years are located in southern California at the Estancia La Jolla, while even-year conferences take place in northern California at the Hyatt Regency Monterey. Previously, conferences have taken place at Associate campus locations, including UC Davis (2016), UC Irvine (2015), Sonoma State University (2014), and UC San Diego (2013).

CENIC works to maintain a reasonable registration fee for attendees, as we understand the travel and other budget challenges facing Associate researchers and educators. CENIC does however understand that many researchers and educators in California who may wish to attend may still not be able to justify the expenditure, and hence a portion of the Annual Conference programming is streamed live via YouTube and and archived there for remote viewing within the CENICNews channel.

The Conference Committee and Program Committee that typically organize the conference and plan the programming are comprised of members of the CENIC research and education community who generously donate their time and expertise to ensure that the event is useful and enlightening and features a wide spectrum of innovations.

CENIC Innovations in Networking Awards

Each year, CENIC seeks to discover and recognize exemplary innovations that leverage CalREN and have the potential to improve the way instruction and research is conducted. We request nominations from the community of applications and projects that represent innovative uses of the network. Each year’s awards are presented during the CENIC Annual Conference. Award winners are invited to give presentations on their projects.

CENIC Innovations in Networking Awards are presented annually in some or all of the following categories:

- Educational Applications
- Research Applications
- Experimental/Developmental Applications
- Gigabit/Broadband Applications
- Individual Contributions
- Technical Contributions
- Corporate Contributions

CENIC encourages nominations of applications and projects focused on research, teaching, and learning activities involving collaboration across multiple segments of the K–20 community, and/or international collaborations that have been developed within the fiscal year prior to the conference.

More recently, CENIC created the Christine Haska Distinguished Service Award to recognize extraordinary individual service to the CENIC community and its partners — local, regional, national, and international. The award is named in honor of Dr. Christine Haska (1951-2017). After a long career in higher education, Dr. Haska joined the Naval Postgraduate School (NPS) in Monterey, California, in 2002, where she served as Vice President of Information Resources and Chief Information Officer, and she served on the CENIC Board of Directors.

CENIC Research Workshops

Aside from the CENIC Annual Conference, other topic-specific research workshops are occasionally sponsored by CENIC and other advanced networking organizations and held at various locations. For example, in February 2013, a research workshop focused on 100-plus-gigabit networking, sponsored by CENIC, the California Institute for Telecommunications and Information Technology (Calit2), and the Energy Sciences Network (ESnet), was held at UC San Diego. A series of workshops focused on promoting network utilization and cross-border research between the United States and Mexico was also held in Ensenada (October 2013) and UC San Diego (February 2014), organized by CENIC, Calit2, CICESE, CUDI, and Florida International University.

In its second year, the National Research Platform Workshop brought together representatives from interested institutions to discuss implementation strategies for deployment of interoperable Science DMZs at a national, and potentially international, scale. The viewpoints of researchers, cyberinfrastructure experts, CIOs, as well as perspectives from regional and national networks, helps to shape the program. Recent experiences from projects such as the National Science Foundation-funded Pacific Research Program, along with analogous national and international projects, are essential features of the workshop, as well.

Sessions at the NRP Workshop are devoted to science-driver application researchers, who describe their needs for high-speed data transfer, including their successes and frustrations. Discussions focus on requirements from the domain scientists and the networking architecture, policies, tools, and security necessary to deploy a National Research Platform. The NRP Workshop is co-sponsored by Calit2/PRP, Internet2, ESnet, Montana State University, and CENIC.

Through these and other more targeted events, CENIC seeks to maintain its position of leadership and collaboration with other advanced networking organizations while ensuring that future networking developments within California are informed, found useful, and adopted by the communities that CENIC was created to serve.

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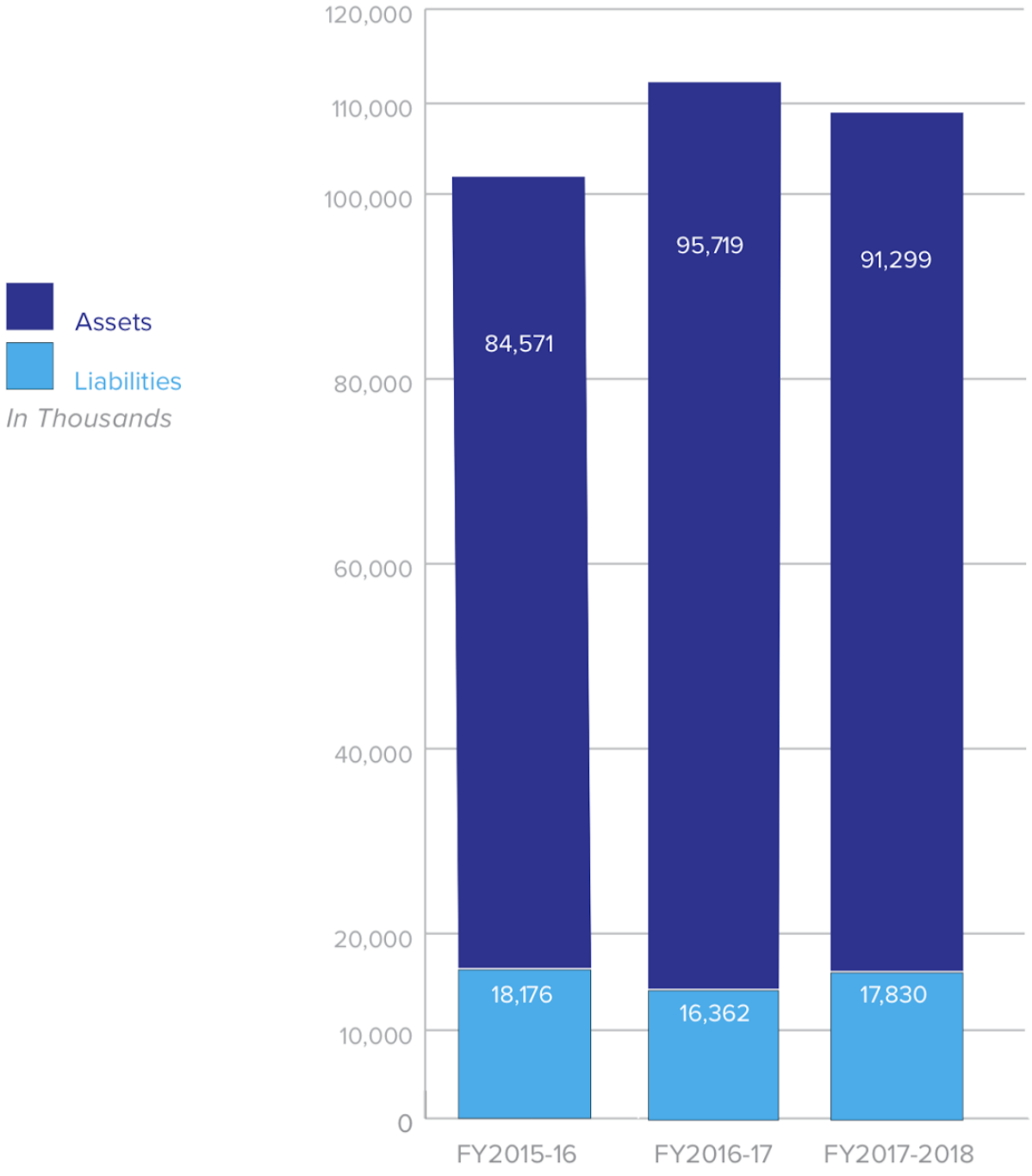
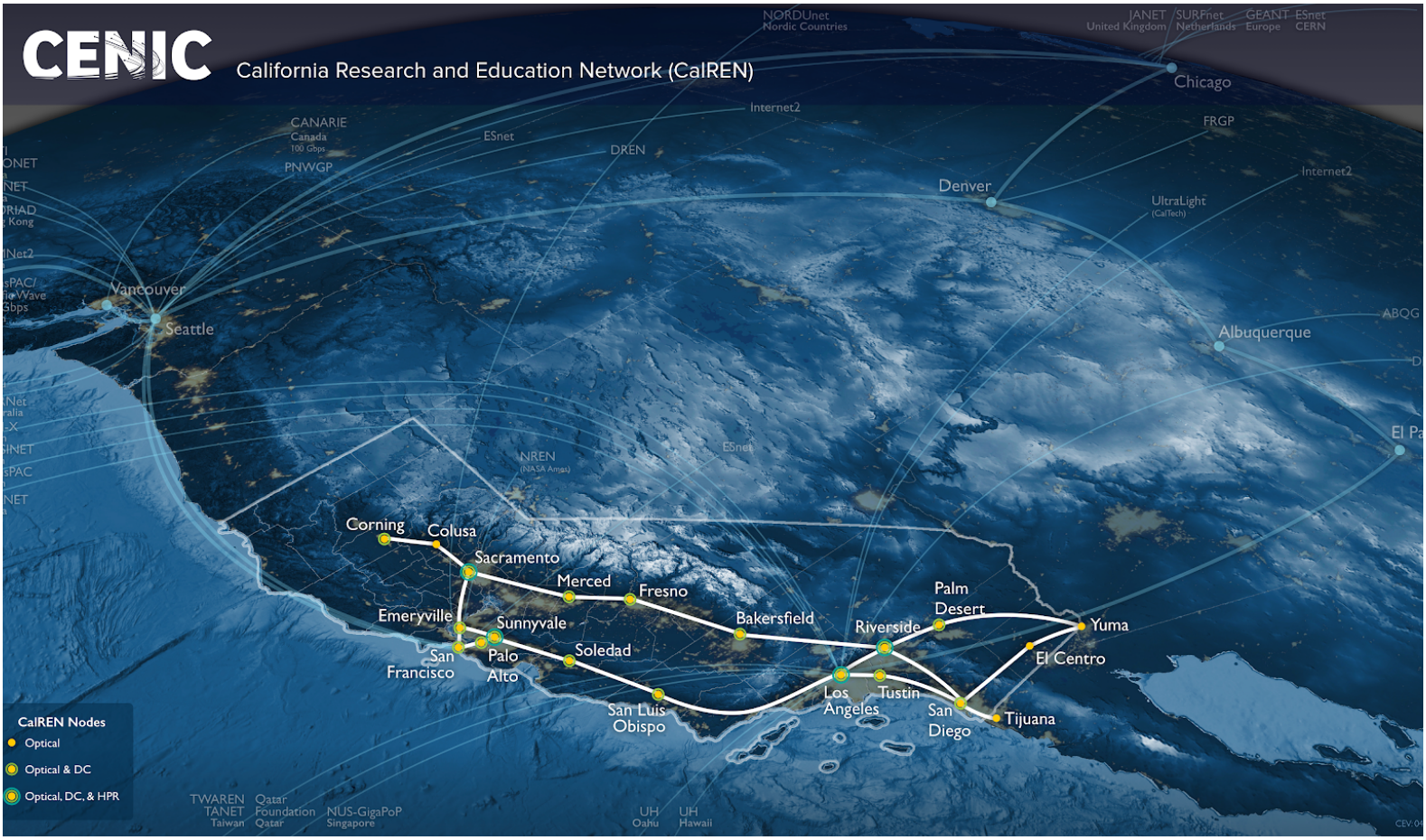
4 | Financial Statement

CENIC Financial Statement 2015 - 2018

	FY2015-16	FY2016-17	FY2017-18
Liabilities	18,176	16,362	17,830
Assets	84,571	95,719	91,299
Total Assets	102,747	112,081	109,129





5 | CENIC Networks

Network Infrastructure Overview
Connecting to CalREN
Future Technology Strategies
Addressing Growth Demands & Evolving Requirements

NETWORK INFRASTRUCTURE OVERVIEW

CENIC's tagline is "CENIC connects California to the world," and we've accomplished this largely through the development and management of the California Research and Education Network (CalREN). However, this implies much more than is obvious to the casual observer. CalREN is a multi-tiered network, offering differentiated services in each tier. The foundation that underpins this advanced network is CENIC's statewide fiber backbone. One of the first R&E networks to own and operate their own dark fiber, CENIC has engineered an 8-terabit (Tb) Layer 1, dense wavelength division multiplexing (DWDM) optical platform. Overlaid on top of this bedrock are CalREN's three independent networks serving the vast majority of research and education institutions in the state.

CalREN-DC. CENIC's Digital California network provides high-quality, predominantly Layer 3, network services for students, faculty, researchers, and staff at educational institutions, libraries, and other member organizations. Connectivity to the commercial Internet through ISPs and commodity peering is handled at this tier for all CENIC members.

CalREN-HPR. CENIC's High-Performance Research network provides leading-edge Layer 2 and 3 services for large-application users, predominantly at research institutions. Connectivity to other researchers internationally, through interconnection with Internet2, ESnet, and Pacific Wave/WRN, is handled at this network tier.

CalREN-XD. CENIC's eXperimental/Developmental network comprises built-to-order resources to support bleeding-edge services for network researchers at sites such as the San Diego Supercomputer Center, the University of California Institutes for Science and Innovation, High Energy Physics researchers at Caltech and the Jet Propulsion Laboratory, the University of Southern California and its Information Sciences Institute, Stanford University and the Stanford Linear Accelerator Center, national laboratories, and other major network research entities that collaborate with these researchers in California.

In addition to providing the entire California research and education community with the most cost-effective advanced services network available, the multi-tiered CalREN infrastructure includes network tools, such as the Pacific Research Platform (PRP), necessary to conduct high-performance research activities.

Network Layers 1-3

CENIC was one of the first research and education networks in the US to purchase Indefeasible Rights of Use (IRUs) for dark fiber and currently manages more than 8,000 miles of CENIC-operated fiber, lighting this fiber with hundreds of optical components. CENIC's Layer 1 optical backbone consists of three linear routes (Inland, Coastal, and Southern) that provide network on-ramps at 27 key point-of-presence (PoP) sites throughout California.

Where practical, dark fiber is also the preferred method for connectivity from member institutions into CalREN, and is used to connect every member research institution. CENIC engineers identify dark fiber options between these institutions and various CalREN Point of Presence (PoP) sites to determine the best option in each case, using DWDM optical systems to light the fiber. While this design requires higher upfront capital expenditures, the lower operating expenditures, as compared to the monthly recurring costs for leased circuits, results in a lower net costs. Moreover, this model yields lower incremental upgrade costs, faster circuit provisioning times, and allows greater flexibility to satisfy specialized network requirements, such as dedicated Layer 2 connections to other institutions. These benefits have caused this model to gain adoption at a number of CSU and K–12 member sites.

At Layer 3, network capacity on the CalREN backbone is 3x100G in a routed-ring topology. This design allows failover to a secondary route during outage events, which ensures a robust and resilient network. Aggregation is performed throughout the state at 18 PoP sites that are strategically identified to support both densely populated and rural regions. This large number of entry points into the network enables greater flexibility for CENIC members and facilitates diverse connection options for sites with dual connections.

Peering Infrastructure

The benefits of exchange points have long been recognized within the R&E networking community. CENIC has given this area particular focus, establishing a robust peering fabric with immense fiscal and technical benefit to our community. CENIC has more than 100 active peers and interconnects with six peering exchanges: San Diego NAP, PacificWave, CIIX, NYIIX LA, Equinix Los Angeles, and Palo Alto (formerly referred to as PAIX). Most recently, a number of our settlement-free interconnections (SFIs) have been upgraded to 100 Gigabit Ethernet (GbE) or multiple 100 GbE. Through Pacific Wave, CENIC member institutions are able to connect to universities in Asia, Australia, New Zealand, Canada, Mexico, and South America.

Beyond traditional peering, CENIC leverages use of content caches that began with Akamai and have expanded to include content from large providers such as Netflix, improving performance and decreasing off-net traffic. Similarly, CENIC engineers have worked with providers of major cloud-based services, such as Microsoft, Facebook, Apple, Amazon, and Google, to enhance peering connections for performance that rivals “direct” connection services offered by many of these companies.

The effectiveness of these efforts is illustrated by two data points. Firstly, although we’ve seen a dramatic rise in commodity traffic year over year for more than a decade, there has been no increase in usage of our ISP drains. Secondly, while the quantity of traffic traversing our ISP drains has remained constant, the percent of traffic traversing our ISP drains has decreased to 10% of total traffic. That is, 90% of our commodity traffic to and from CalREN now takes place through our peering infrastructure.

CONNECTING TO CALREN

There are over 600 connections from member sites into the CalREN backbone, and this number continues to grow. CENIC manages this constantly expanding service in several ways. Rather than the typical service provider/customer relationship, we create working partnerships with our members by establishing a specific demarcation point, typically a CENIC-managed device at the customer site (Customer Premise Equipment [CPE]), with clearly defined roles and responsibilities. Member institutions are responsible for setting up CPE and working closely with CENIC engineers to turn up services. CENIC engineers are responsible for configuring CPE, monitoring the link from CPE to the CalREN backbone, and coordinating efforts to resolve any network issues as quickly as possible.

CENIC also takes the time to understand the needs of each member institution and actively seeks ways to assist in addressing these needs. Recently, CENIC implemented an annual planning process with our member institutions to forecast future connectivity needs. This enables improved financial and resource planning for everyone involved. CENIC also works collaboratively with technical leadership from each segment through ongoing engagement with the various Technical Advisory Councils (TACs). These councils facilitate in-depth conversations on technical topics, give rise to new ideas and services, and distinguish CENIC from commercial network providers.

Finally, CENIC encourages member involvement in the broader community. Through the annual CENIC conference and Innovations in Networking awards program, CENIC fosters a sense of community by supporting greater exposure to and communication with peers. CENIC is not merely an organization that provides a set of services; rather, it is the core of an ecosystem that adds value to all those involved.

Benefits of Connecting to CalREN

In addition to the numerous benefits discussed in Chapter 1, CalREN access provides CENIC members with a unique level of service: customized solutions to address the unique needs of each member institution. This is best illustrated through the following example.

When the state of California transitioned standardized testing of K–12 students from paper-and-pencil to an online format, CENIC assisted the California Department of Education by designing and implementing a connection from CalREN through Internet2 directly to the testing service's data center that bypassed the commodity Internet. This design avoids the bottlenecks that congest the commercial Internet.

More importantly, it enables CENIC engineers to monitor end-to-end performance for California schools during the months when testing occurs. Because CENIC manages the connections from the schools through CalREN, we can work with our colleagues at Internet2 to isolate connectivity issues from the edge of CalREN through Internet2's network to the testing service's data center. Each time a problem has arisen, CENIC engineers have successfully identified the cause and provided consultation to the other parties on resolution. This level of coordination and assistance would be impossible across the commercial Internet.

FUTURE TECHNOLOGY STRATEGIES

In the years since CENIC created the first iteration of CalREN, the technologies available and requirements of our members have advanced dramatically. The first CalREN implementation was a pair of leased OC-48 SONET rings (Los Angeles Metro and San Francisco Bay Area) that were eventually connected by OC-12 SONET links traversing the state. Designed to link the California universities with the national research fabrics of the vBNS (very high-speed Backbone Network Service) and Abilene, the network supported both Packet over SONET and ATM protocols. No commodity ISP or commercial peering services were supported.

DWDM Provides the Foundation

After the turn of the century, as financial and technological conditions began changing ever more rapidly, it became both practical and cost effective for CENIC to acquire dark fiber and replace the SONET rings with a DWDM optical system over owned infrastructure. The capabilities and specific design details of the network have evolved over the years, particularly as new member segments were incorporated, while the fundamental building blocks of a routed network over a premise-based DWDM system have remained.

Operating a DWDM optical system has provided CENIC the ability to expand the network several orders of magnitude to accommodate the growing needs of California's research and educational institutions. In addition, this infrastructure provides a foundation that is flexible and scalable enough to support numerous, simultaneous, independent networks, including:

- DC
- HPR
- Connectivity with the national RENs (Internet2, ESnet)
- Commodity ISP connectivity
- Commercial private peering
- Commercial content caches
- Both transient and continuous dedicated research (such as Pacific Wave, Pacific Research Platform, and others)
- Connectivity with international RENs
- UC Health
- Remote sensor networks (e.g., UC ANR, USGS, WIFIRE)

ADDRESSING GROWTH DEMANDS & EVOLVING REQUIREMENTS

Recently, the dramatic expansion of capability and user base, as well as the insatiable appetite of bandwidth-intensive applications and higher use patterns, have resulted in a 46% annual growth in utilization of backbone capacity since 2003. This experience mirrors reports by other R&E networks, as well as many of our member institutions. There is no reason to expect that future demand will subside; rather, there are strong indicators that demand for bandwidth will continue to increase given the evolutions in mobile networks (both cellular and Wi-Fi), sensor networks, data intensive instruments and science, and wired/optical networks.

The challenge for CENIC is to manage the expected and necessary growth of the backbone infrastructure ahead of customer demand in a cost-neutral approach. CENIC's strategy in facing this challenge is to use approaches that balance resilience against cost, and that balance risk against reward. Under the leadership of CENIC's CTO, John Dundas, an internal working group was established in late 2017 to continuously re-assess, re-design, and deploy our next-generation network. Because this group makes decisions that may affect Pacific Wave and the Western Regional Network and related partners, representatives from partner organizations serve as a Council of Expert Advisors: ESnet (Inder Monga), Internet2 (Rob Vietzke), PNWGP (Ron Johnson), and WRN (Marla Meehl).

The group considers future requirements in terms of hardware and software system design and implementation with these central objectives: to ensure that current efforts across all of our CENIC networks (CalREN, Pacific Wave, WRN) are coordinated with our future plans, to ensure that our plans and those of our closest partners are convergent, and to ensure we remain cognizant of the needs of the research community, which is the defining community for exploring new technologies that will extend, over time, to all of our segments.

Further principles the group abides by as it formulates and refines both current and future requirements are:

- **Capacity:** anticipate demand through continuous measurement and projection, developing cost-effective capacity prior to actual demand.
- **Flexibility:** support increasingly complex workflows and open standards, supporting legacy technology as necessary while adapting to technology innovations.
- **Scalability:** force multiplication of human capacity through extensive automation; support "one button" repair, analyze, install, deploy, and orchestration.
- **Resilience:** the networks have varying levels of tolerance for service impacting events and must be designed accordingly.
- **Security:** visibility, granular control, and role-based access are foundations for secure networks.
- **External factors:** service alignment with partner RENs, taking advantage of unplanned opportunities, leveraging technology advancement.

Base Services by Layer

Clearly defined requirements and capabilities structured in a layered service model support transparent management of the complex interrelationships that exist among components of the CalREN system. This model is well aligned with Internet2, ESnet, and other RENs. At each layer, there exist base services forming the foundation of that particular layer. Optional services are defined to augment the capabilities of the base service. Each upper layer builds upon the mandatory base services of the subordinate layers without relying on optional services.

Layer 1	Layer 2	Layer 3
Managed circuits	Ethernet edge access	R&E transit
Alien waves		Commodity transit
		Virtual private networks

Embracing the Software-Defined Network

In addition to reconsidering CENIC's networks, engineering emphasis going forward must shift from an almost purely network focus to one where software development is balanced with network design and operations. Software to perform orchestration, anomaly detection, process automation, security analysis, address equipment heterogeneity, etc., is critical to expanding the capacity of the existing workforce to deal with the scope and complexity of future networks and user demand.

To address this strategic shift, CENIC has embraced a software-intensive future through several initiatives including:

- Define an overall software architecture sufficiently robust to address issues in: development, testing, deployment, automation, operations, security integration, and business continuity.
- Grow staff skills through professional development and targeted hiring.
- Acquire software tools to support a robust development environment.

With a highly adaptable, software-driven network, other opportunities arise that require further exploration. One opportunity is to determine what data needs to be collected for an artificial intelligence/machine learning system to run the majority of the network operations in autopilot. Another opportunity considers where to put distributed compute and storage intelligently throughout the network.

Partnership Opportunities

Complementary to our internal deliberations, CENIC has and continues to look for practical opportunities to partner with other RENs to extend the value and reach of CalREN. These opportunities also shape how we think about future CalREN architecture and services. Our ongoing collaboration with ESnet has provided the opportunity to participate in requirements, architecture, and design reviews for ESnet6, gaining valuable knowledge of their approach and they have similarly reviewed and provided feedback on technical approaches to our engineers. Internet2 is collaborating with us in several areas of strategic significance.

- Fiber network and equipment sharing (Layer 1) on the West Coast; in part, supports the Pacific Wave infrastructure.
- Spectrum agreement and equipment sharing for WRN.
- Extending PRP to NRP over the Internet2 footprint.
- Asia-Pacific R&E exchange (AP-REX).
- Possible sharing of Northern Tier fiber, a joint PNWGP and a Pacific Wave project, to support our initiative to provide direct connectivity to Epic Systems for our medical center members.

Related Documents:

CENIC's approved network and network-related policies https://cenic.org/network/policies
CENIC Settlement-Free Interconnection (SFI) https://cenic.org/network/settlement-free-interconnection
CENIC Peering Relationships https://cenic.org/network/peering

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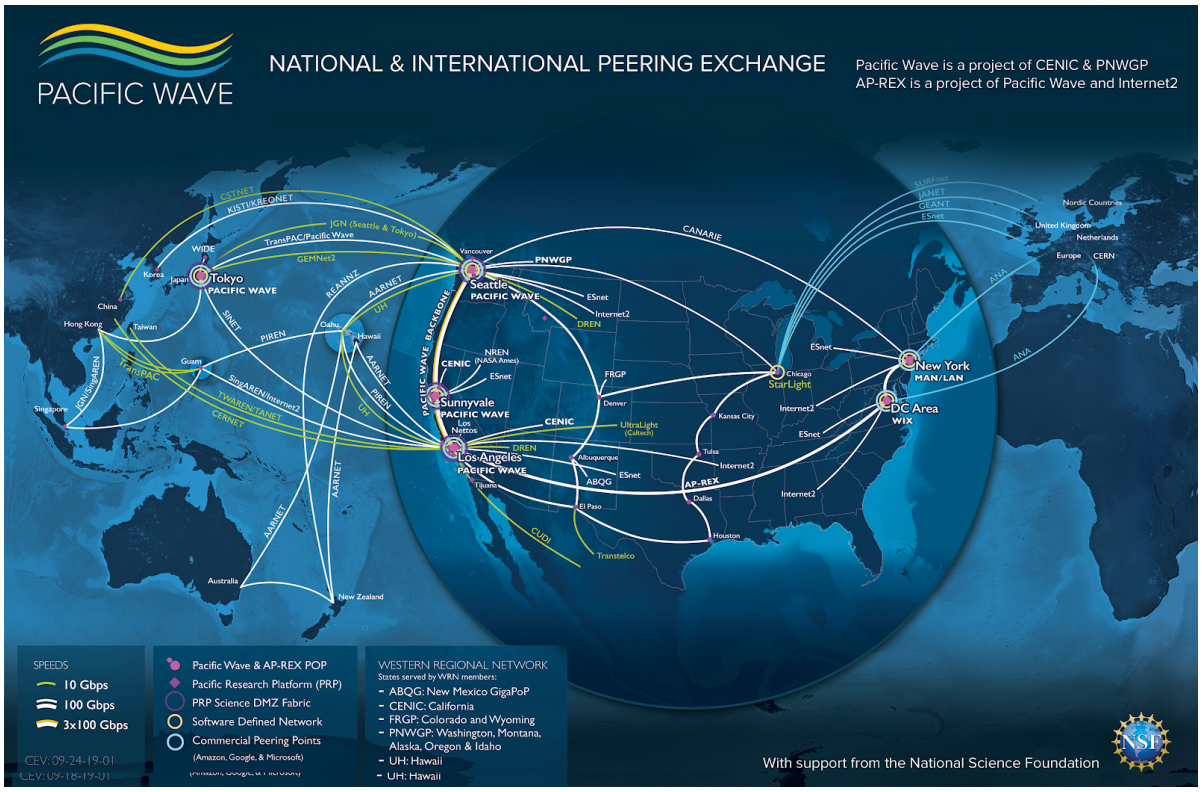
6 | Examples of Projects in Support of Research

Pacific Wave International Exchange
Western Regional Network
Pacific Research Platform
MANRS Routing Security Initiative
CHASE-CI
WIFIRE & HPWREN

Pacific Wave International Exchange

Every day, researchers in California use Pacific Wave to collaborate with international colleagues and to collect data from remote sensors. Pacific Wave supports collaborative research in astronomy, digital media and cinematic arts, biology and medicine, computation sciences, earth sciences, grid computing, high-energy physics, and oceanography.

Pacific Wave is a joint project of CENIC and Pacific Northwest Gigapop (PNWGP), and is operated in collaboration with the University of Hawaii and the University of Washington. Western Regional Network, a collaboration of US western R&E networks, is an extension of Pacific Wave.



The Pacific Wave & AP-REX Map

Pacific Wave is a wide-area advanced networking facility that is designed to provide R&E networks throughout the Pacific Rim with access to separate but interrelated state-of-the-art peering and exchange, Science DMZ, Software Defined Exchange (SDX) and Software Defined Networking (SDN) capabilities. Pacific Wave includes the following services on their own dedicated but interconnected wavelengths:

- A distributed, fully open, peering and exchange fabric with access points on a 100 Gbps backbone that spans Seattle, Sunnyvale, and Los Angeles to which nearly all Pacific Rim R&E networks connect and which is in turn interconnected with all US R&E backbones including Internet2 and ESnet (each with multiple 100 Gbps connections) as well as the major cloud providers and international ISPs.

- A wide-area Research DMZ platform with a dedicated 100 Gbps backbone among Los Angeles, Sunnyvale, and Seattle and also access in Tokyo (at WIDE/T-REX and Tata pops), Denver, Albuquerque, El Paso, and Chicago (at StarLight) via shared 100 Gbps wavelengths.
- A parallel, dedicated SDN/SDX testbed with access points in Seattle, Sunnyvale, and Los Angeles, enabling collaborative efforts with StarLight, WIDE/T-REX, and others to explore regional and international interoperability of next-generation network and exchange capabilities.

Pacific Wave is the official USA NSF-funded peering facility and SDX exchange for Pacific Rim networks. The five-year NSF International Research Network Connections (IRNC) RXP grant enables Pacific Wave to expand its infrastructure to facilitate growth, increase backbone capacity to meet peak science needs, and to deploy and test SDX capability. This award funds infrastructure to support multiple 100 Gbps connections among US R&E networks and international counterparts from countries including Australia, Canada, Japan, Mexico, New Zealand, Singapore, South Korea, and Taiwan.

Additional enhancement of the Pacific Wave infrastructure will be provided by a collaboration between Pacific Wave and Internet2. The Atlantic Pacific Research and Education Exchange (AP-REX) pilot includes a 100 Gbps interconnection between US East and West Coast exchange points. Internet2 operates the MANLAN international exchange in New York City and the Washington Internet Exchange (WIX) in McClean, Virginia. AP-REX will create a high-capacity interconnection between Pacific Wave and Internet2's key exchange points where global research networks from Africa, Asia, Australia, Europe, the Pacific Islands, and South America connect to North American networks such as CANARIE in Canada, CUDI in Mexico, ESnet and Internet2 in the US, as well as to each other.

PACIFIC WAVE PARTICIPANT LIST

- AARNet
- Albuquerque Gigapop
- Allen Institute for Brain Science
- Amazon
- Asia Pacific Advanced Network
- A*STAR
- BCNET
- Broad Art Foundation
- California Academy of Sciences
- California Community Colleges
- California Institute of Technology
- California K–12 System
- California Public Libraries
- California State University
- California Telehealth Network
- Canadian Network for the Advancement of Research, Industry and Education (CANARIE)
- Carnegie-Mellon University West
- CENIC

- CenturyLink
- CERNET
- Chapman University
- Charles R. Drew University
- CineGrid
- City of Hope
- Cisco
- City of Seattle
- Claremont College
- Colburn School
- China Science and Technology Network (CSTNet)
- The University Corporation for Internet Development (CUDI-Mexico)
- Defense Research and Engineering Network 4 (DREN)IV
- East Bay Community Law Center
- Energy Sciences Network (ESnet)
- Exploratorium
- Front Range Gigapop
- Fred Hutchinson Cancer Research Center
- Global Enhanced Multifunctional Network 2 (GEMnet2-Japan)
- Global Network Advancement Group (GNA-G)
- Gonzaga University
- Google
- Guam Open Research & Education Exchange (GOREX)
- GPN
- Fred Hutchinson Cancer Research Center
- Heritage University
- HPWREN
- Idaho Regional Optical Network
- Indiana University International Networks
- Internet2
- International Computer Science Institute
- JGN (Japan)
- Korea Institute of Science and Technology Information (KISTI)
- Korea Research Environment Open NETwork (KREONet)
- LEARN
- Link Oregon
- Los Nettos
- Loyola Marymount University
- Microsoft
- Montana State University
- Monterey Bay Aquarium Research Institute
- NTT Research
- NASA Ames Research Center
- NASA Research and Education Network
- National Institute of Informatics (NII Japan)
- National Marine Fisheries Service
- Naval Postgraduate School
- New Mexico GigaPop

- Nevada System of Higher Education
- National Institute of Information and Communications Technology (NICT-Japan)
- NOAA N-Wave
- NOAA Pacific Marine Environmental Laboratory
- North Dakota State University
- Northwest Access Exchange
- NSF International Research Network Connections
- National University of Singapore Gigapop (NUS-GP)
- Occidental College
- ONEnet
- Pac-12 Enterprises
- Pacific Northwest Gigapop
- Pacific Northwest National Laboratory
- Pepperdine University
- PIREN
- PRAGMA
- Research and Education Advanced Network New Zealand (REANNZ)
- Salinas Valley Memorial Healthcare System
- Seattle Cancer Care Alliance
- Seattle Children's Hospital
- Seattle Internet Exchange
- SF Jazz
- Singapore Advanced Research and Education Network (SingAREN)
- Science Information NETwork 5 (Japan)
- Stanford University
- StarLight

Western Regional Network

Western Region Network (WRN) is a collaboration among the leading regional research and education network providers in the western United States. This multi-state partnership includes CENIC, Pacific Northwest Gigapop (PNWGP), the Front Range Gigapop (FRGP), Albuquerque Gigapop (ABQGP), and the University of Hawai'i. WRN serves Alaska, California, Colorado, Hawai'i, Idaho, Montana, New Mexico, Washington, and Wyoming.

WRN spans the West, employing a dedicated 100 Gbps network infrastructure, including optical channels provisioned on Internet2. WRN reaches Pacific Wave's international peering exchange point at the StarLight exchange in Chicago, providing a direct connection to European R&E networks.

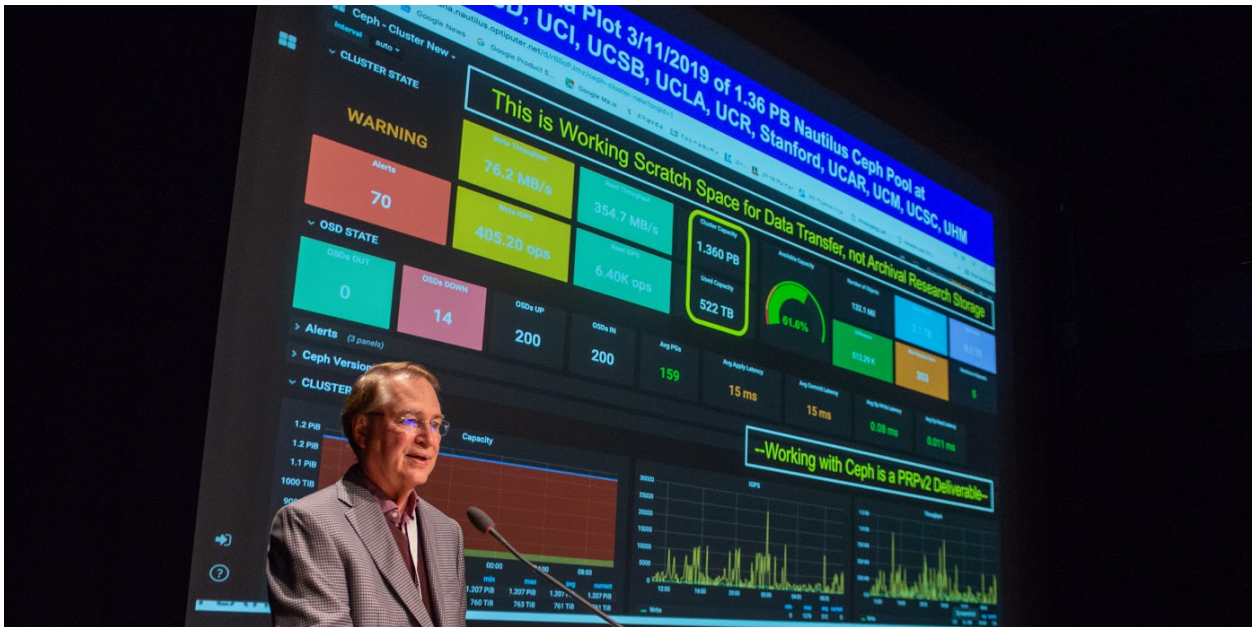
WRN enables research and scientific projects, supports the sharing of scientific and network resources, and provides access to instruments and services. The CENIC community, particularly climate and atmospheric researchers, are dependent on this infrastructure to reach important resources like the National Center for Atmospheric Research (NCAR) and related supercomputing facilities.
At last count, over 325 climate and atmosphere researchers and 950 projects at California research institutions rely on WRN's infrastructure

Pacific Research Platform

Pacific Research Platform builds on the optical backbone of Pacific Wave to create a seamless research platform that encourages collaboration on a broad range of data-intensive fields and projects. PRP is a partnership of more than 50 institutions, led by researchers at UC San Diego and UC Berkeley, and including the NSF, US Department of Energy, and multiple research universities in the US and around the world. PRP has been funded by a five-year $5 million NSF grant since 2015.

PRP extends the campus Science DMZ model to a regional, national, and, eventually, a global scale. Developed by ESnet, a Science DMZ is implemented at the border of a campus or institution's computer network, and consists of equipment and security policies distinct from those supporting general-purpose networking and specifically designed and configured to optimize data-intensive, high-performance research applications.

PRP researchers are routinely achieving high-performance end-to-end networking from their labs to their collaborators' labs and data centers, traversing multiple, heterogeneous Science DMZs and wide-area networks connecting multiple campus gateways, enabling researchers across the partnership to transfer data over dedicated optical lightpaths at speeds from 10 to 100 Gbps. PRP, and its evolution to a National Research Platform (NRP) and Global Research Platform (GRP), aims to achieve transparent and rapid data access among collaborating scientists at multiple institutions throughout the US and the world.



MANRS Routing Security Initiative

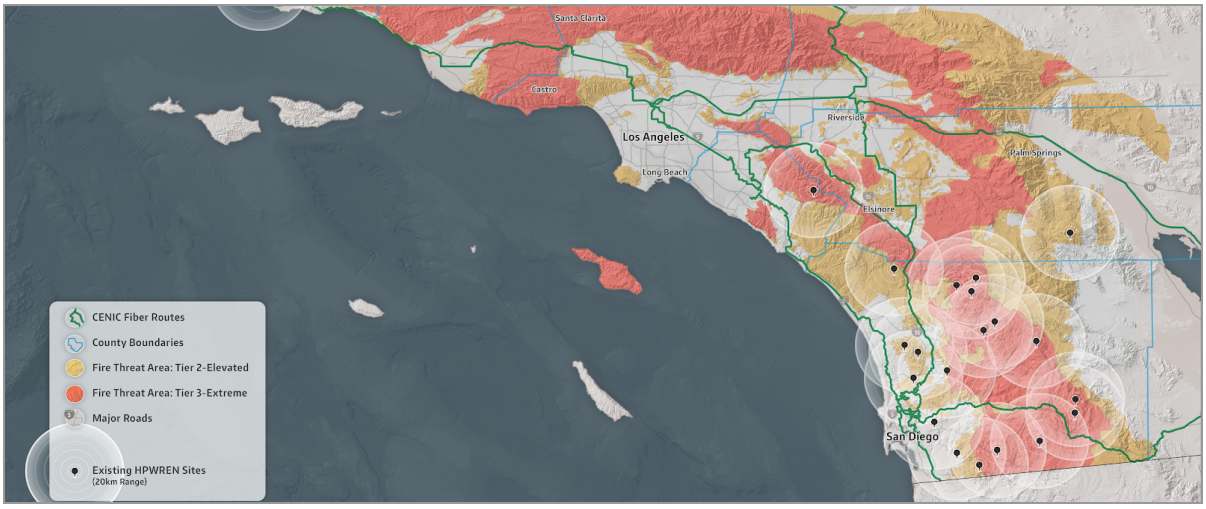
CENIC is leading a pilot to facilitate Mutually Agreed Norms for Routing Security (MANRS) adoption and to implement Resource Public Key Infrastructure (RPKI) deployment on a regional scale among CENIC and Pacific Wave research universities.

MANRS is an initiative, supported by the Internet Society, focused on reducing the most common threats to the global routing ecosystem through a variety of localized implementation methods. RPKI is a technology that enables network operators to verify the integrity of routing information. The MANRS-RPKI pilot is a collaborative effort involving contributors from CENIC, NSRC, ESnet, and ARIN, as well as from the research university community.

More than 30 research and education networks worldwide have already adopted MANRS, including Internet2. Industry giants such as Google and Microsoft also participate. CENIC, however, would be the first R&E network to adopt the initiative on such a large scale.

CHASE-CI

This project, called the Cognitive Hardware And Software Ecosystem Community Infrastructure (CHASE-CI), will build a cloud of hundreds of affordable Graphics Processing Units (GPUs), networked together with a variety of neural network machines to facilitate development of next-generation cognitive computing. This cloud will be accessible by 30 researchers assembled from 10 universities via the NSF-funded Pacific Research Platform. These researchers will investigate a range of problems from image and video recognition, computer vision, contextual robotics to cognitive neurosciences using the cloud to be purpose-built in this project. Training of neural networks with large data-sets is best performed on GPUs. Lack of availability of affordable GPUs and lack of easy access to the new generation of Non-von Neumann (NvN) machines with embedded neural networks impede research in cognitive computing. The purpose-built cloud will be available over the network to address this bottleneck. PIs will study various Deep Neural Network, Recurrent Neural Network, and Reinforcement Learning Algorithms on this platform.



WIFIRE and HPWREN

WIFIRE is an NSF-funded project led by UC San Diego that has developed real-time and data-driven simulation, prediction, and visualization of wildfire behavior. During the 2018 fires, WIFIRE's publicly

available fire map was viewed more than 8 million times, while the WIFIRE team was in close communication with fire response agencies. WIFIRE also provided predictive maps for fires in Southern California and created simulations of the spread of specific wildfires.

The collection of this crucial data is made possible by the High Performance Wireless Research and Education Network (HPWREN), which started in 2000 under NSF funding. HPWREN has built high-speed wireless networks in San Diego, Imperial, Orange, and Riverside Counties, enabling hundreds of cameras and meteorological stations to stream data to servers connected with each other by the CENIC backbone, and providing wide-area wireless Internet access throughout southernmost California. HPWREN's remote sensor network collects data from wildfire cameras, seismic networks, hydrological sensors, oceanographic sensors, meteorological sensors, and coastal radar and GPS, providing information that is shared via the CENIC network.

Along with these two projects, and GeoLinks, a fixed wireless telecommunications partner with whom we have over 100 projects, CENIC has responded to a Request for Innovative Ideas (RFII) from the Governor's Office and CAL FIRE to scale up the HPWREN/WIFIRE wireless sensor network infrastructure statewide, an infrastructure now called "CALinks," which can be extended as a multi-hazard scientific and first responder platform. We have also engaged the leadership of FirstNet to see how CALinks can collaborate with the California FirstNet deployment. The RFII received nearly 100 responses; CALinks is in the remaining 10 proposals that may receive funding.

7 | Examples of Projects in Support of Broadband Equity

Broadband Infrastructure Improvement Grants
Public Libraries Initiative
Broadband Consortia Tour
Middle-Mile Broadband Expansion Projects
CENIC, Pacific Wave, and Tribal Communities

Broadband Infrastructure Improvement Grants

California public K–12 schools began connecting to the Internet through CENIC in 2001. By 2014, most K–12 school sites in California were connected to CalREN, but some schools were unable to connect due to financial and geographic constraints. In recognition of these constraints, the State of California allocated funding for Broadband Infrastructure Improvement Grants (BIIG). Through public-private partnerships, CENIC has established broadband connectivity for hundreds of schools in historically underserved areas.

CalREN now provides broadband connectivity to 100% of county offices of education, 85% of school districts (897), 80% of schools (8,594), and 5.1 million students. More than half of these K–12 schools are connected at speeds of 1 gigabit or higher.

On May 7, 2019, California set a record when 683,673 students simultaneously took the online Smarter Balanced state tests. Before connecting to CalREN, some schools had to limit the number of students testing at the same time and had to spread test dates over the course of a month or more. Other schools were previously unable to perform online testing at all. Equally important, students, teachers, and administrators are now able to take advantage of the increased capacity for day-to-day teaching and learning, as indicated by the doubling of K–12 traffic on CalREN in 2018 (up 117%).

CENIC continues to collaborate with the California Department of Education, the California Legislature, the California Public Utility Commission, the K–12 High Speed Network, school sites, and commercial service providers to connect the schools that remain unserved or underserved in California.

In the State budget for 2019-20, the Governor's Office and the Legislature committed $7.5 million directly to CENIC to pilot innovative approaches for provisioning broadband to the hardest-to-reach schools. We are to develop prospective new models for serving these hardest-to-serve constituents, and they will require novel approaches to partnerships across our segments and other communities such as local and county government, health care, tribes, and the private sector. As such, it is an opportunity to break new ground. If we do this well, significant additional funding may follow. No one has cracked this code on the scale we need to in California. We believe we can.

Public Libraries Initiative

In 2013, the California State Legislature and Governor charged the California State Librarian to prepare a needs assessment and spending plan to connect local public libraries to a statewide high-speed Internet network. According to the resulting report, which was conducted by CENIC, the state of connectivity in California's public libraries (nearly 1,200 libraries, in 180 library "jurisdictions") was dire. Most libraries had slower Internet than is found in most homes and most were overpaying for inadequate service. California subsequently undertook a historic initiative to help all of California's public libraries receive broadband service through CalREN.

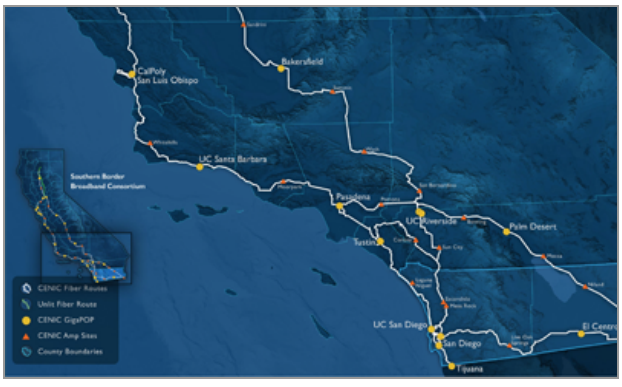
When California libraries began connecting to CalREN, they received faster and more reliable Internet at a cost savings of up to 95%. Now, more than 80% of libraries are connected with increased speeds of 10 to 100 times their earlier capacity. The Los Angeles Public Library became the first public library in the world with a 100 Gbps connection.

This transition to CalREN has improved administrative functions and made possible new services. Because bandwidth is no longer a limitation, patrons can work remotely, take online training programs and certification testing, experience new technology such as virtual reality and 3D printing, and more. In times of crisis, such as recent wildfires, libraries serve as community resource centers and communication hubs. In areas without adequate Internet access, libraries are loaning hotspots and providing remote access points in parks and other community centers. Connecting libraries to CalREN provides California's residents with access to the myriad of resources that constitute 21st-century digital citizenship.

Broadband Consortia Tour

To find ways that CENIC can help expand Internet access in underserved communities, President and CEO Louis Fox is visiting all 17 regional broadband consortia in California in partnership with California Emerging Technology Fund (CETF) leaders.

Broadband consortia are local efforts organized to improve and expand Internet access and are funded by the California Public Utilities Commission. Getting the Internet to the most remote areas necessitates public-private partnerships and hybrid strategies that combine broadband technologies.
Through this statewide tour, CENIC and CETF are identifying connectivity gaps, funding sources, ways CENIC's network might be used, and relationships with broadband providers that might be leveraged.



Working collaboratively, CENIC now has many projects in production that stitch together two or more broadband technologies to extend last-mile symmetrical gigabit connections to schools, libraries, community colleges, and research sites in rural communities that previously had little or no bandwidth.

Middle-Mile Broadband Expansion Projects

CENIC has partnered with many organizations to bring critical middle-mile fiber optic infrastructure to underserved areas in the Coachella Valley, Central Valley, and Central Coast regions in California. Projects have enabled last-mile connections from the new backbones into California colleges, universities, K–12 schools, homes, and businesses.

In 2004, the H. N. and Frances C. Berger Foundation made a $3.4 million grant to CENIC for the initial phase of the Connecting Coachella Valley to the World project, representing a new 400-mile, dark-fiber build-out to the greater Coachella Valley area from Riverside and south from Palm Desert into Imperial County. In 2006, the second phase of this project was completed, and the CalREN backbone now extends from Palm Desert through Yuma, AZ, and El Centro, CA, returning to San Diego. CalREN now features a fully diverse gigabit network from Riverside to San Diego to provide services to the fast-growing Coachella Valley region.

In 2014, CENIC and the Central Valley Independent Network (CVIN), now Vast Networks, completed the Central Valley Next Generation Broadband Infrastructure Project (CVNGBIP), designed to improve the availability of broadband networking infrastructure for 18 counties within the California Central Valley area: Amador, Calaveras, Colusa, El Dorado, Fresno, Kings, Kern, Mariposa, Merced, Madera, Nevada, Placer, Tuolumne, Tulare, San Joaquin, Stanislaus, Sutter, and Yuba.

The CVNGBIP project involved building, operating, and maintaining a fiber-optic network infrastructure that traverses 1,371 miles of California's Central Valley in addition to last-mile wireless capability. The network serves an agricultural heartland of the US, and an area consisting of 40,000 square miles and more than 4 million people. The project received $46 million in broadband stimulus grants as part of the American Recovery and Reinvestment Act (ARRA), plus $6 million from the California Public Utilities Commission’s California Advanced Services Fund, and $13 million from CVIN affiliates.

In 2017, the Central Coast Connect project helped bring broadband to underserved communities across 430 square miles through the Salinas Valley. Sunesys, now part of Crown Castle, a private sector partner of CENIC, built a 91-mile fiber-optic network from Santa Cruz to Soledad with $10.6 million in CASF grants and service commitments from CENIC.

CENIC, Pacific Wave, and Tribal Communities

Through a partnership with the Tribal Digital Village Network (TDVnet), which serves 20 tribes in Eastern San Diego County, with support from the Southern California Tribal Chairmen’s Association (SCTCA), CENIC and TDVnet have evolved a partnership that provides tribal community anchor institutions and scientific organizations access to Pacific Wave, which serves the R&E networks of sovereign nations around the Pacific Rim and their US academic partners. Pacific Wave now serves sovereign nations who are our domestic partners, as well. The CENIC-TDVnet partnership, which recently began passing traffic to

Pacific Wave, was done with support from AT&T and Google. The goal is to develop a model that can be extended to over 100 federally recognized tribes in California and, ultimately, throughout the Western US.

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8 | Strategic Plan

CENIC 5-Year Strategic Plan for CalREN 2019-2023

CENIC Board | July 23, 2019

CONFIDENTIAL

Part One: Investing in the Evolution of the CENIC Network 2019–2023

Vision Statement

To continue its history of responsiveness and relevance to the diverse communities it serves, and to perpetuate its leadership and successes, CENIC must to be able to (1) meet the exponential growth in traffic; (2) reach more un- and underserved sites among its charter associates and their partners, while continuously upgrading existing sites; (3) sustain network performance, reliability, and resiliency; and, (4) remain cost-effective, as it has for 20+ years.

The Crossroads

The legacy approach of R&E networks – that is, what got us here – may not be financially sustainable. Total cost of ownership of legacy hardware and software is not declining in price fast enough to meet our expected growth. Owned infrastructure requires space and power whose costs will continue to increase, likely in larger increments to date, given consolidation in the telecommunications industry. Security, in particular, resiliency, and reliability (for one of the world's most complex and diverse networks), are tremendous burdens to sustain, organizationally, operationally, and economically.

At the same time, the R&E community still can't get, or afford to buy, what we need from telecommunication companies. We remain in a "pre-commercial" space in order to support leading-edge research and the diverse needs of one of the largest R&E communities in the world. That's not likely to change. Other R&E networks are facing the same challenges - and we are all working together. And, the Clouds and leading-edge.coms are addressing many of the same problems. We are learning with and from them.

A Roadmap for CalREN

With input from the capacity planning process from each segment, discussions with the board and technical advisory committees, CENIC will prepare a multi-year, phased development and implementation plan. The plan for the future of CalREN should include the following elements: (1) the network must be cost-effective and manage/flatten the cost-curve; (2) the network must be reliable and resilient; (3) the network must meet the capability and capacity needs of all CENIC segments; and (4) it must be "facilities efficient," deploying cost-saving new technologies that decrease both capital and operating expenses, often in partnership with other networks.

Year One Goals (2019-20)

1. **Goal: Refine and articulate goals, gaps, priorities for capabilities and capacity needs among the CENIC segments, and ensure that funding is commensurate with network services that support all CENIC segments**.

    a. Using existing 95% percentile data, model future demands for each segment and the combined impact of segment demands on the CalREN network and related CENIC services.

    b. Meet with each segment to discuss 2018-23 capacity plan models and understand what new capability needs on the horizon for each of CENIC's segments.

    c. Share understandings of the above with CENIC Board and among CENIC constituencies.

    d. Working with the Board, the Finance Committee, and the Business Advisory Council, develop a revenue plan that will (1) enable CENIC to continue its incremental approach to network upgrades over the next five years and (2) ensure that there are operating funds that are adequate to support the network and network services.

2. **Goal: Explore resource development and cost-savings through new customer segments and automation technologies.**

    a. Explore new "customer" segments using existing and/or new LLC strategies.

    b. Explore and implement a new five-year "automation and security assessment" to look for potential areas for cost-savings.

    c. Implement any/all immediately accessible and affordable process automation approaches that lower operations costs.

3. **Goal: Work with, learn from, and develop prospective partnering strategies – with key R&E network partners and commercial/cloud partners – to share costs, facilities, and development.**

    a. Explore node-slicing technologies, shared optical layer (similar to the West Coast Agreement), and other prospective common cost-saving approaches with Internet2.

    b. Explore shared-spectrum agreements, dark channel, alien wave, and co-locations condo agreements with Internet2 (starting in 2019) and ESnet (starting in 2021, when ESnet 6 is operational).

    c. Explore the above with Pacific Northwest Gigapop.

d. Discuss possible leadership roles, in return for deep discounts, and co-development opportunities with industry leaders in commercial/cloud arenas: Ciena, Juniper, Cisco, Amazon, Google, Microsoft, etc.

4. **Goal: PRP-developed network transparency and measurement tools deployed among all CENIC segments.**

   a. Deploy pilot program at 24-50 institutions: CSU and CCC, initially.

   b. Develop workshop with PRP for CSU and CCCs in conjunction with CENIC Annual Conference.

   c. Evaluate and potentially engage other R&E partners involved in similar broad-scale measurement efforts.

CENIC 5-Year Strategic Plan for Access and Equity
Part Two: A Connected California 2019–2023

Vision Statement

CENIC connects California to the world—advancing education and research statewide by providing the world-class network essential for innovation, collaboration, and economic growth. This nonprofit organization operates the California Research & Education Network (CalREN), a high-capacity network designed to meet the unique requirements of over 20 million users, including the vast majority of K–20 students together with educators, researchers, and other vital public-serving institutions. CENIC's Charter Associates are part of the world's largest education system; they include the California K–12 system, California Community Colleges, the California State University system, California's Public Libraries, the University of California system, Stanford, Caltech, USC, and the Naval Postgraduate School. CENIC also provides connectivity to leading-edge institutions and industry research organizations around the world, **serving the public as a catalyst for a vibrant California**.

Over the past 20 years, CENIC has had many successes in evolving CalREN backbone capacity and services, while connecting our Charter Associates, removing bandwidth as a constraint whenever and wherever possible among our member institutions. Yet, some among our members remain either unconnected or poorly connected, and what constitutes "well-connected" is a moving target as our institutions and their needs and aspirations are dynamic, not static. **Our goals, then, are two-fold: (a) continue the work of enhancing connectivity among our already connected members, and (b) continue the work of connecting those institutions who are either unconnected or poorly connected.** The latter are often in communities that have little or no access to broadband capacity – in their community anchor

institutions, businesses, government offices, or homes. In order to serve our members, we must find common cause with our partners in the public, private, and governmental sectors. We have a history of engagement with these partners and we must deepen our ties to them, explore new strategies and resources for our common work and, together, achieve the goal of a "Connected California."

Year One Goals (2019-20)

1. **Goal: Enhance forecasting and deployment of new circuits and/or new fiber connections for CENIC Charter Associate institutions.**

    a. Work with each segment to develop better annual and multi-year forecasting of new sites and growth of existing sites.

    b. Develop new and better CENIC processes for the deployment for both commercial lit services and dark fiber – transparent, accelerated, automated (where possible).

    c. Develop segment strategies that can be implemented simultaneously – e.g., large institution (dark fiber), middle-sized institution (lit services), and rural/edge and small institutions (fixed wireless and other, related wireless technologies).

    d. Continue to develop compelling narratives about successful deployments and what they enable.

2. **Goal: Form a CENIC Rural Broadband Working Group comprised of CENIC associates and interested partners from the public (e.g., CETF, Broadband Consortia, CPUC, etc.) and private sector partners committed to innovations in rural connectivity (e.g., Spiral Communications, GeoLinks, SONIC, Crown Castle, etc.)**

    a. Work with CPUC and CETF to develop better data and mapping ("heat" and asset maps) including E-rate, CENIC data, subscription data, and local interest for rural communities to shape project priorities.

    b. Develop community narratives and profiles for visibility/motivation and, ultimately, funding – where CENIC and communities have partnered successfully, serving CENIC community anchor institutions and community priorities.

    c. Explore new partnerships – broadband consortia, local government, public safety, utilities, transportation, public housing, successful community-based efforts (e.g., EBS/LTE Spectrum Group in Imperial County, COEs and libraries, etc.), etc.

d. Develop a plan for working with priority communities and demonstration/pilot projects – rapid and action-oriented efforts.

3. **Goal: Assist, where possible, CETF in achieving its goal of 98% access in California, with CENIC's focus on its community anchor institutions.**

   a. Visit and engage broadband consortia, developing with CETF a priority list of consortia and prospective projects.

   b. Develop plans for working with priority communities and demonstration/pilot projects – rapid and action-oriented efforts.

   c. Continue to engage policy makers – local, state, and national around broadband deployment and adoption goals and funding.

4. **Goal: Develop the *Fighting Fire with Data initiative*, the first step in a California Fixed Wireless Consortium, and continue to explore the possibilities of a Pan-California Wireless Mesh Consortium to support emerging applications and underserved communities.**

   a. Support extensions of CalREN via HPWREN, AlertWildfire, WIFIRE, UC ANR and related projects coming from the university research community.

   b. Partner with GeoLinks, research leaders, utility companies, and first responder communities, to develop plans for phase one of the California-wide fixed wireless mesh, *Fighting Fire with Data*, that will provide wildfire detection, prevention, and situational awareness systems, with the research community providing the technology, GeoLinks the fixed wireless, and CalREN the backhaul to SDSC and other research sites.

   c. Develop a proposal and funding plan, and with the nascent Consortium engage the Governor's Office, the legislature, first responder communities, and others to support and fund this initiative (with R&D resources to the California researchers, equipment, and support for wireless and CalREN networks).

   d. Work with the CA Fixed Wireless Consortium to develop collaborative plans for policy and funding in support of local, regional, and statewide fixed wireless deployments in other areas including additional research arenas (earthquake monitoring and research, climate research, weather research, etc.), support for UC ANR (and partners) efforts in precision agriculture, and broadband connectivity for community anchor institutions, including CENIC's constituents.

CENIC 5-Year Strategic Plan for Security
Part Three: A Secure CENIC and a Resilient CalREN

Vision Statement

We aspire to a secure CENIC and resilient CalREN. We seek a CENIC enterprise in which all CENIC computing and networking and intellectual property assets are identified, activity involving those assets is visible, and industry best practices for security mitigations are applied to those assets, in accordance with the level of risk that a compromise of that asset would have to CENIC.

Simultaneously, we seek a CalREN that supports the research and education missions of CENIC's constituents, while being resilient to attacks against the network and other failures, and where possible and desired, provides CENIC's constituents with the appropriate visibility and security controls to help them enhance the security of their own enterprise, without interfering with the research and educational missions of their respective sites.

Year One Goals (2019-2020)

1. **Goal: A Resilient CalREN**

    a. An updated disaster recovery plan that includes security incident response and recovery procedures to large-scale security compromises of various systems such as network segments going down, the Tustin data center being physically compromised, key servers being subverted, etc.

    b. Annual disaster preparedness and recovery drills that test security compromises of various systems such as network segments failing, the Tustin data center being physically compromised, key servers being subverted, etc.

2. **Goal: Visibility of all CENIC-Operated Equipment:**

    a. Security and event logs for all CENIC network devices, servers, desktops, laptops, mobiles, printers, video conferencing, IoT, etc.

    b. Taps for network infrastructure at LAN and control plane ingress/egress points, including protocol level details.

c. Complete, automated, and up-to-date asset inventories of any networked equipment (e.g., including IoT, such as door badge readers, security cameras, environmental sensors, etc.).

3. **Goal: Strong Authentication Everywhere**

a. Two-factor authentication and strong passwords (through a password manager) for all CENIC devices, servers, and outsourced services that permit it. Alternative controls (e.g., bastion hosts) for systems that do not permit 2FA. Priority is devices with shared administration. Escrowed credentials for key services.

4. **Goal: Robust Internal Networks**

a. Highly segmented LANs.

b. Insulate LANs that don't require Internet access from exposure.

5. **Goal: Security Personnel Capacity Development**

a. Increase security operational resources, including incident response.

b. Increase software development capacity to support building tools to address evolving threats and responses.

6. **Goal: Ability to Aid CENIC's Constituents with Technical Security Mitigations**

a. Production DDoS detection and mitigation for CalREN-DC.

b. Pilot DDoS detection and mitigation tools for CalREN-HPR.

APPENDIX

- Biennial Report
- CENIC Publications
- CENIC News
- CENIC Events