

My 2-Mile Particle Accelerator X-ray Laser Runs Linux

SLAC National Accelerator Laboratory

Simon Elmir / Department Head
Scientific Computing Systems - Core Services and Experimental Support

Date

The Stanford Two-Mile Accelerator

The Stanford Two-Mile Accelerator

Menlo Park, CA

Southeast of San Francisco

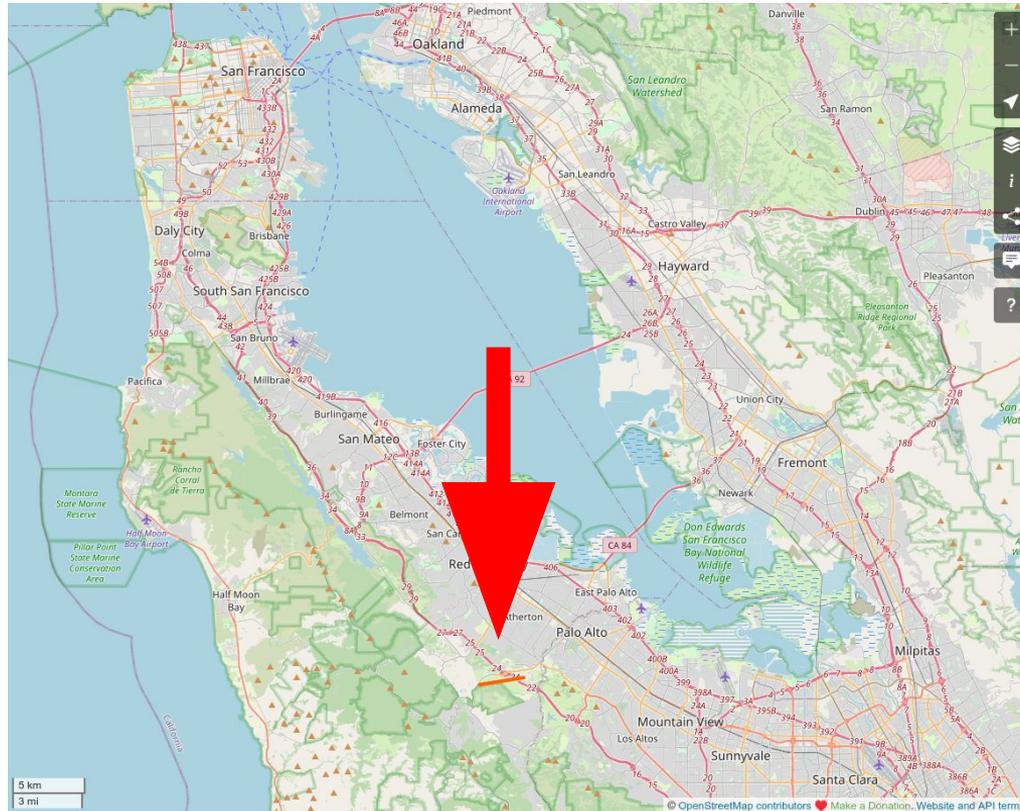




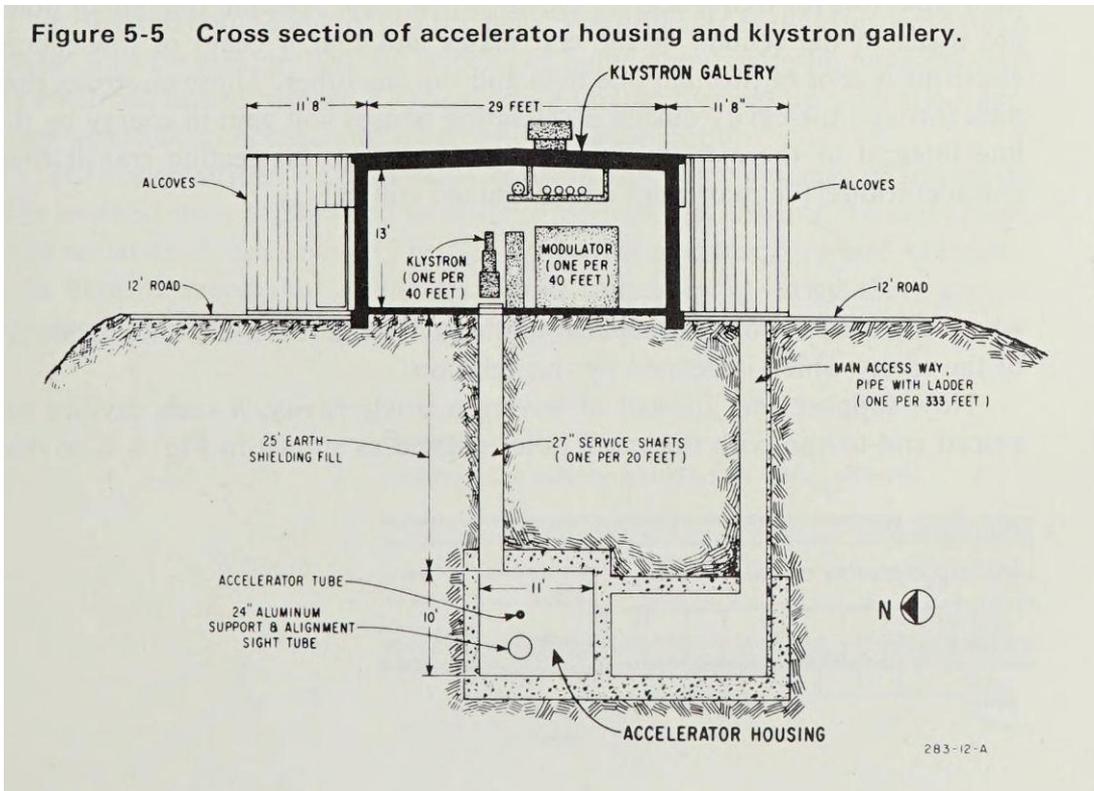
Photo: Olivier Bonin/SLAC National Accelerator Laboratory



Photo: Olivier Bonin/SLAC National Accelerator Laboratory

Building and Tunnel

Figure 5-5 Cross section of accelerator housing and klystron gallery.



Cross-section

Ground-level building

Accelerator tunnel

Klystrons



Microwave Amplifiers

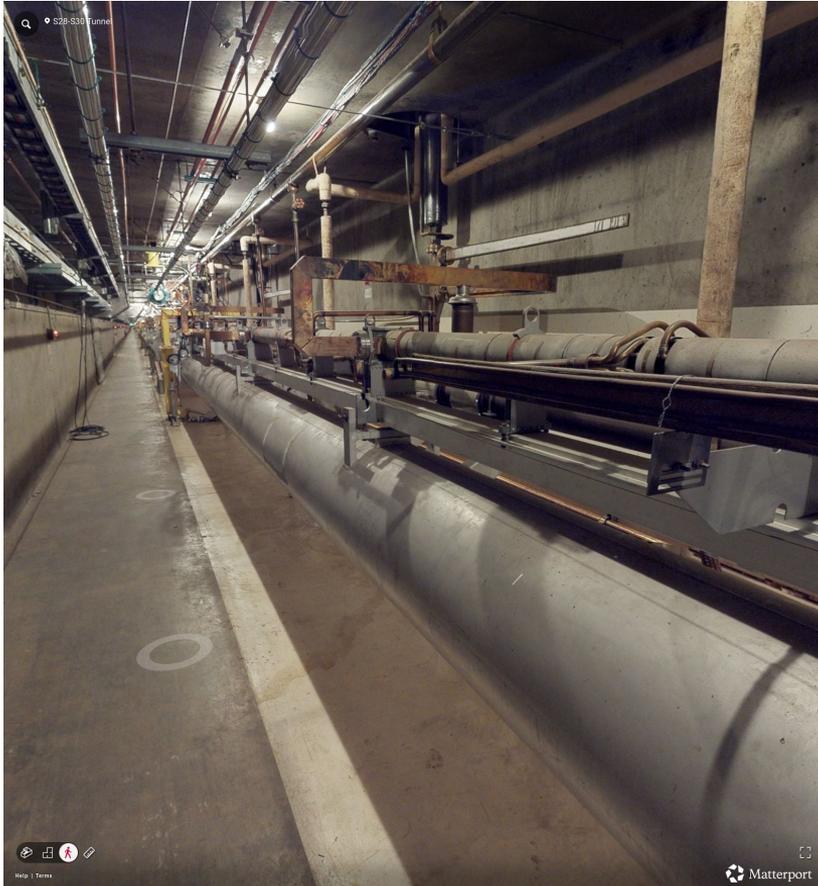
Microwaves 'push' electrons to travel faster through the accelerator

2.854 GHz

60 MW

The original accelerator had about 240 klystrons

Copper Accelerator



1960's Hardware used today

Light Pipe

Strongback

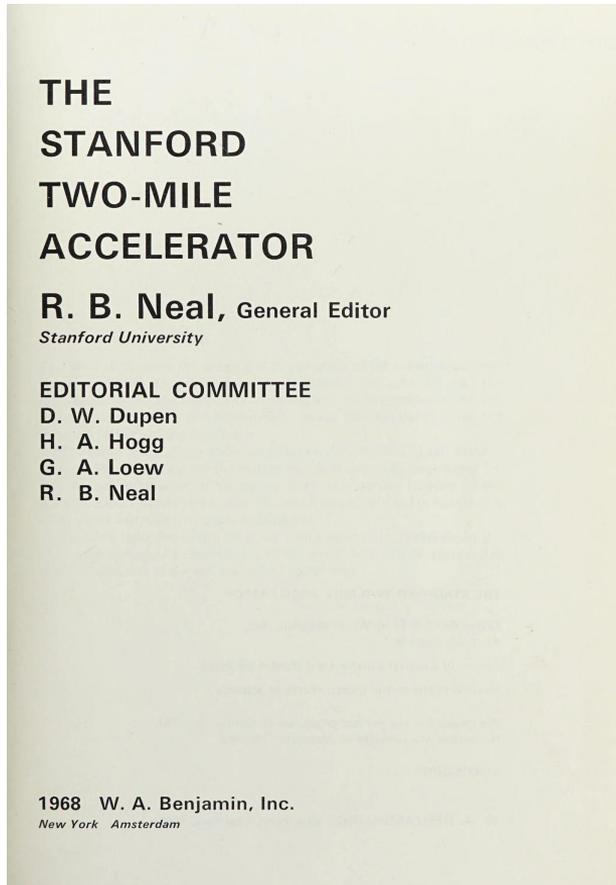
Waveguides

Copper Accelerator

Water cooling

Vacuum system

The 'Blue Book'



In the spirit of open source,

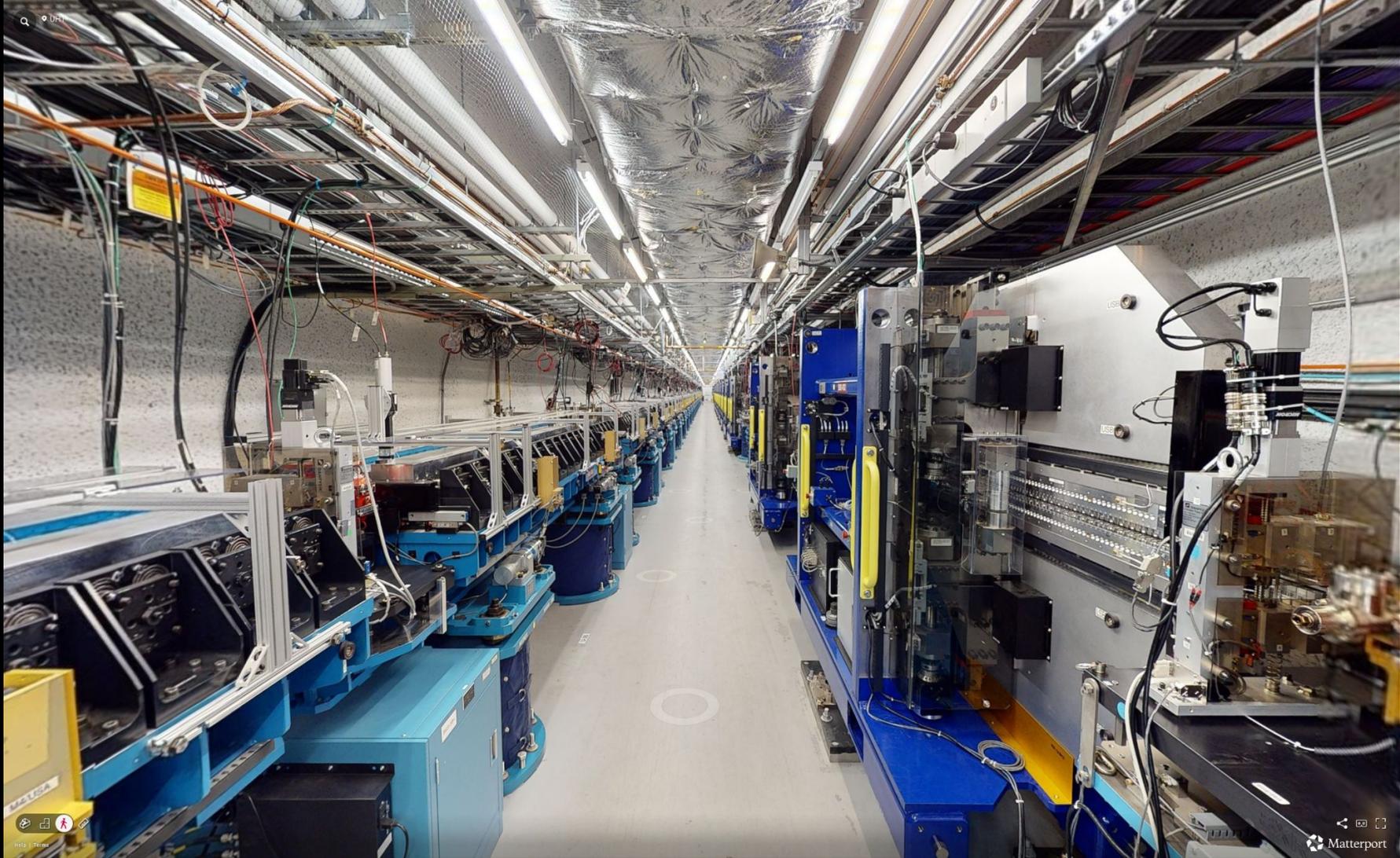
Documentation from on everything involved in bringing
SLAC online

<https://ahro.slac.stanford.edu/resources/slac-blue-book>



LCLS

The Linac Coherent Light Source



LCLS: Linac Coherent Light Source

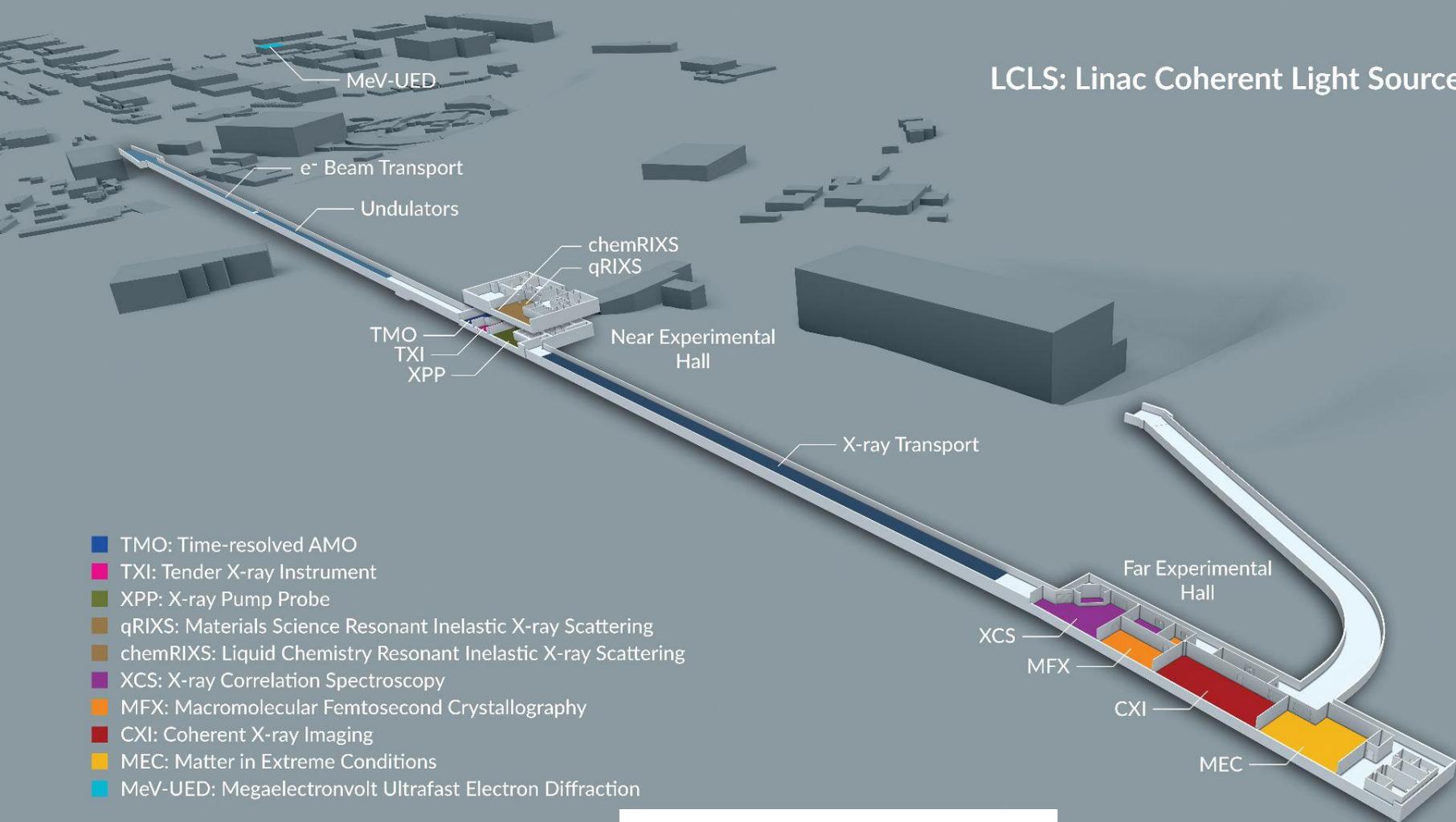


Image: <https://lcls.slac.stanford.edu/instruments/maps>

Recent media coverage



What Happens If You Keep Slowing
Down? ⋮

8.4M views • 1 month ago



What happens if you keep slowing down time? Sponsored by ...

4K CC

<https://www.youtube.com/watch?v=P-4pbFcERnk>

The world's most powerful X-ray lasers

The SLAC National Accelerator Laboratory in Silicon Valley is home to one of the world's most powerful X-ray lasers. Reporting for BBC Tech Now, Ben Derico heads behind the scenes to find out how scientists hope it will allow them to see and understand the movement of electrons like never before.

This video is from Tech Now, the BBC's flagship technology programme.

30 January 2026

<https://www.bbc.com/reel/video/p0mn7qhp/>

LCLS Control Rooms



Photo: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory



Photo: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory



Photo: Matt Beardsley/SLAC National Accelerator Laboratory

Workstations

OS

Enterprise Linux

- Red Hat Enterprise Linux
- Rocky Linux

Deployment

- Custom netboot & kickstart files
- Foreman

Configuration management

- Puppet
- Ansible

Hardware

Desktop chassis

8-core 16-thread AMD Epyc

64GiB RAM

2x 500GB SSD

2-4x 10Gbps Ethernet

1-2x GPUs

- AMD Radeon RX 6600
- Nvidia GeForce GTX 1660

Assorted TVs & monitors (Mostly 4K)

HDMI Streaming cards

LCLS Experimental Areas

‘Hutches’

Calendar

OS

Raspberry Pi OS

- Debian

Deployment

- Disk image

Configuration management

- Ansible

Hardware

Raspberry 4B or 5

PoE hat

Assorted TVs, typically portrait mode

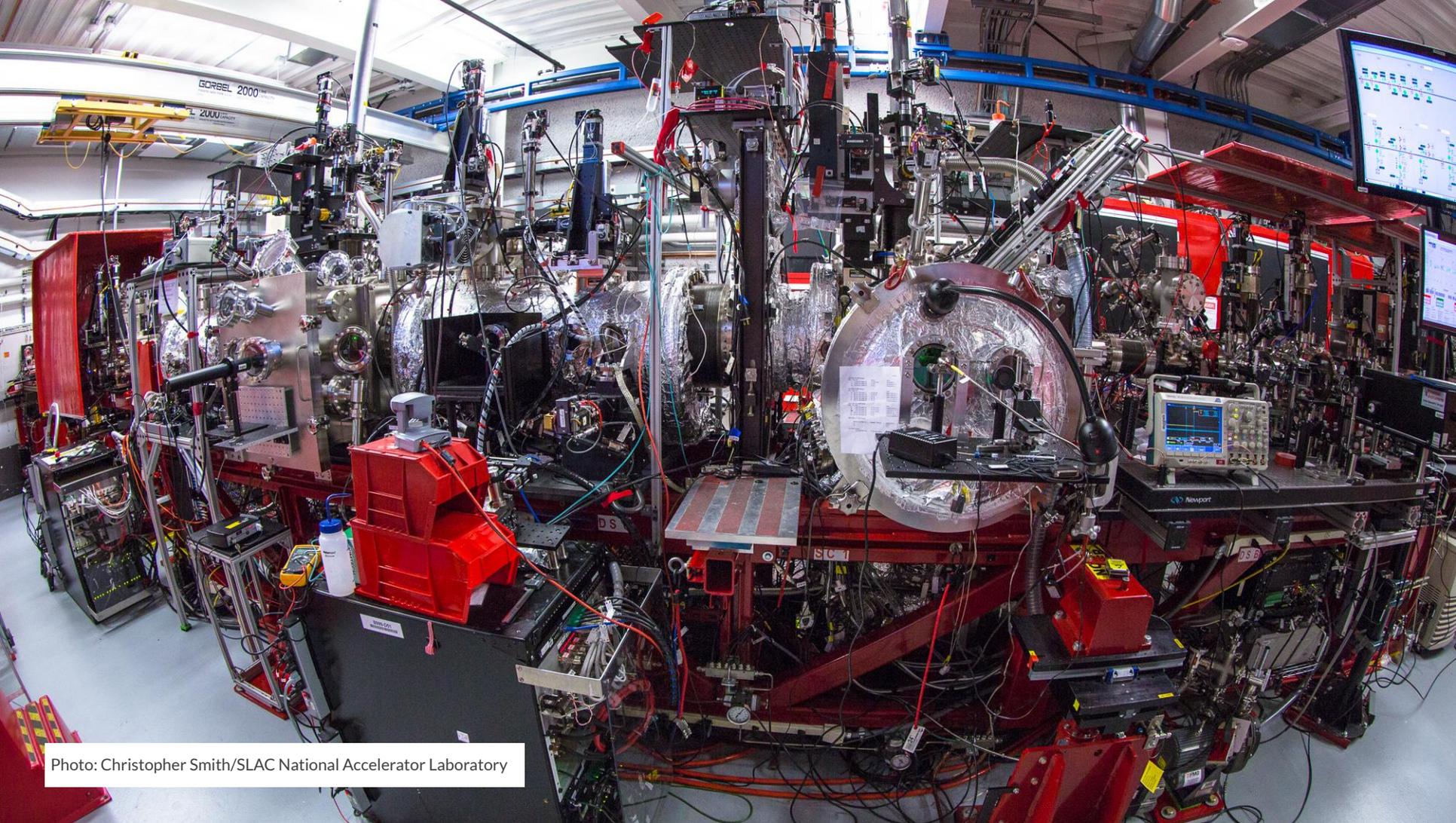


Photo: Christopher Smith/SLAC National Accelerator Laboratory

Servers

OS

Enterprise Linux

- Red Hat Enterprise Linux
- Rocky Linux

Deployment

- Custom netboot & kickstart files
- Foreman

Configuration management

- Puppet
- Ansible

Hardware

1U rackmount chassis

8-core 16-thread AMD Epyc

64GiB RAM

No local storage

2x 10Gbps Ethernet

Up to 4x FHFL PCIe cards

Assorted add-in cards

- Timing, image capture, other custom hardware

Netboot / Netinstall

```
SeaBIOS (version 1.17.0-debian-1.17.0-1build1)
Machine UUID 6a50f5af-2e14-4635-b550-61dda505f012

ipXE (https://ipxe.org) 01:00:0 CA00 PCI2.10 PnP PMM+7EFC7660+7EF07660 CA00

Booting from Hard Disk...
Boot failed: could not read the boot disk

Booting from ROM...
ipXE (PCI 01:00:0) starting execution...ok
ipXE initialising devices...

ipXE 1.21.1+git-20250829.969ce2c55+dfsg-3ubuntu2 -- Open Source Network Boot Fir
mware -- https://ipxe.org
Features: ULAN DNS HTTP HTTPS iSCSI NFS TFTP AoE ELF MBOOT PXE bzImage Menu PXEX
T

net0: 52:54:00:b0:60:71 using virtio-net on 0000:01:00.0 (Ethernet) [open]
Link:up, TX:0 TXE:0 RX:0 RXE:01
Configuring (net0 52:54:00:b0:60:71)..._
```

Boot from the network

Configured by DHCP

The DHCP server can provide a next-server & filename for the client to fetch via TFTP (or HTTP)

BIOS/UEFI

GRUB -> kernel & initramfs

Diskless-boot



No local drives needed

NFS mounts

Shared read-only root mount

Only server-specific differences are stored

readonly-root Subpackage of [initscripts](#)

Service for configuring read-only root support



Builds



Updates



Bugs



Sources

This package provides script & configuration file for setting up read-only root support. Additional configuration is required after installation.

Please note that readonly-root package is considered deprecated with limited support. Please use systemd-volatile-root functionality instead, if possible.



THE EXPERIMENTAL PHYSICS AND INDUSTRIAL CONTROL SYSTEM



FREE AND OPEN SOURCE

EPICS is developed as a public open source project. The source code is freely available according to the [EPICS Open License](#).



DEVELOPED COLLABORATIVELY

EPICS was created through collaborative contributions from scientific facilities since a long time. It is the preferred choice for complex, large scale distributed control system applications.



POWERFUL AND RELIABLE

The launch of EPICS 7 marks the biggest change of the EPICS code base for over 10 years. The new, feature-rich pvAccess protocol enables many new applications with unprecedented performance and capacity. [Read more](#)

Embedded Systems and one-offs

← Files v1.1.0 diod / README.md

 **garlick** update README.md for 1.1.0 3d6b0a5 · 4 months ago

99 lines (80 loc) · 2.5 KB

Preview Code Blame Raw Copy Download

diod

diod is a file server that speaks [9P2000.L protocol](#).

Building and Installing

The basic installation instructions are:

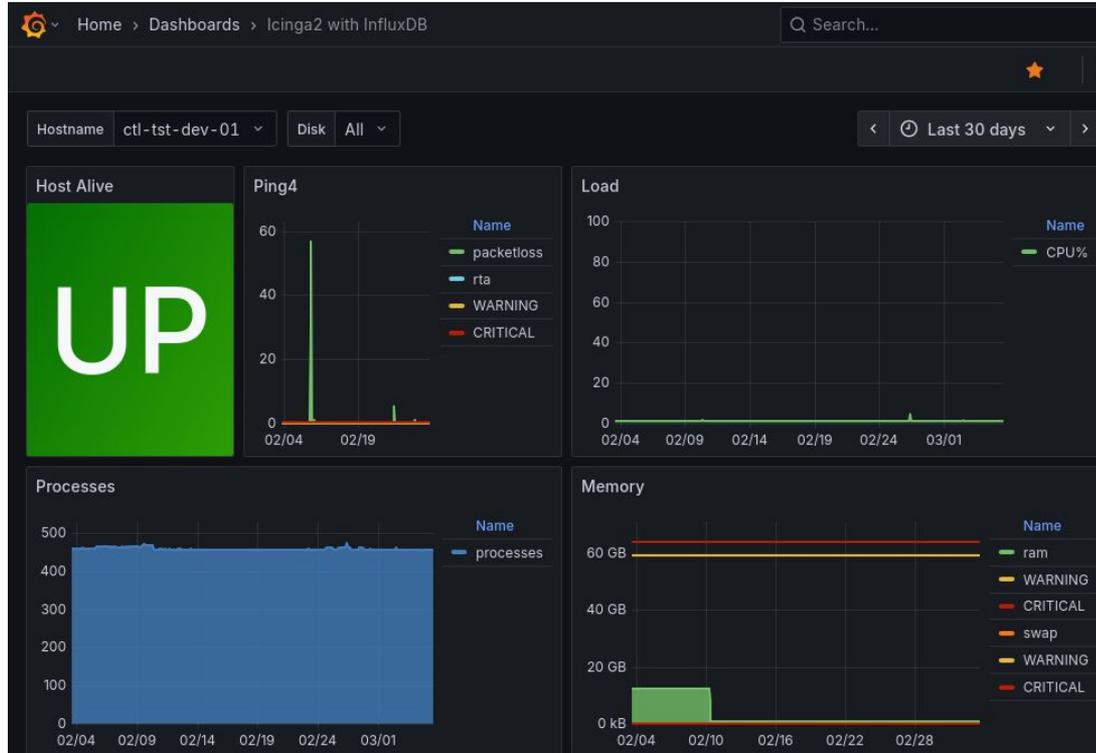
Extra-long-term support

Embedded systems with NFSv2

Plan 9 9p remote filesystem protocol

Monitoring

Icinga, Grafana



LCLS-II

Upgrading the Laser



Photo: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory

LCLS-II



Superconducting Accelerator

Runs in parallel with LCLS-I

Brighter, and faster

Cooled to 2 Kelvins

Pulse rate

- LCLS-I: 120 Hz
- LCLS-II (achieved): 96 kHz (96,000 Hz)
- LCLS-II (planned): 1 MHz (1,000,000 Hz)

Vera C. Rubin Observatory



Photo: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory

LSST Camera



World's Largest Digital Camera

3.2 Gigapixels per image

~30s exposure time

6 color filters, ranging from infrared to ultraviolet

~10TiB of images per night

10-year campaign will create ~30PB of raw images

And we need to process those images

By the end of its first year, will have generated more data than all other optical observatories combined

<https://www.guinnessworldrecords.com/world-records/728927-largest-digital-camera>

Skyviewer & Orbitviewer

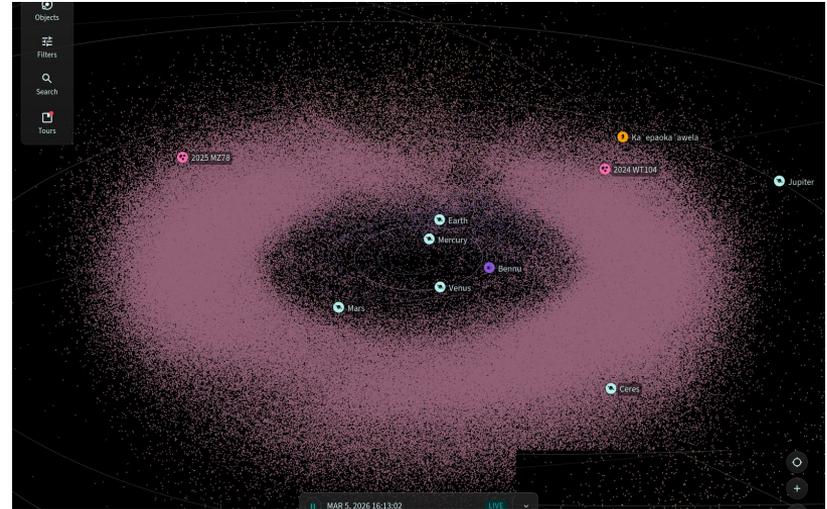


<https://skyviewer.app/>

Powered by Aladin Lite

<https://aladin.cds.unistra.fr/>

<https://github.com/cds-astro/aladin-lite>



<https://orbitviewer.app/>

Source code:

<https://github.com/fil-studio/Vera-Rubin>



<https://rubinobservatory.org/>

Photo: Olivier Bonin/SLAC National Accelerator Laboratory



S3DF

SLAC Shared Science Data Facility



SRCF

Stanford Research Compute Facility

Photo: Olivier Bonin/SLAC National Accelerator Laboratory



Photo: Jim Gensheimer/SLAC National Accelerator Laboratory

Foreman

The screenshot displays the Foreman web interface for a host named 'ctl-tst-dev-01.pcdsn'. The top navigation bar includes the Foreman logo, a hamburger menu, and filters for 'Any organization' and 'Any location'. The breadcrumb trail shows 'Hosts > ctl-tst-dev-01.pcdsn'. The host name is followed by a green checkmark, 'Rocky Linux 9.4', and 'x86_64'. It was created 5 months ago by John B and updated 1 minute ago. The 'Overview' tab is selected, showing a 'Host status' section with a 'No status' icon and the text 'All statuses cleared'. The 'Details' section shows 'IPv6 address' as 'Not available', 'IPv4 address' as '172.21.148.76', and 'MAC address' as blank. The 'Host group' is 'PCDSN/Diskless x86_64-rocky94'. The 'Recent jobs' section shows 'Finished', 'Running', and 'Scheduled' tabs, with 'No rest' displayed. The 'Recent audits' section shows 'All audits'.

Server Lifecycle Management

Provisioning via Netboot
Bare metal & VMs

DNS, DHCP, BMC (IPMI), TFTP, ...

Integration with configuration
management, e.g. Puppet, Ansible

Extensible via plugins

Slurm & Kubernetes

Slurm Workload Manager

<https://slurm.schedmd.com/>

Batch processing

Parallel execution

Resource-based allocation

Kubernetes

<https://kubernetes.io/>

Long-running Services

Container-based deployment

Handles complex dependencies

- Academia often has *specific* dependencies

Ceph

Clustered Storage

Large-scale distributed storage

Multiple interfaces

- Object Storage (S3)
- Block (RADOS Block Device)
- POSIX filesystems (CephFS)

```
[ceph: root@sdfceph001 /]# ceph df
--- RAW STORAGE ---
CLASS      SIZE      AVAIL      USED      RAW USED  %RAW USED
hdd        96 PiB    24 PiB     72 PiB     72 PiB    74.80
TOTAL     96 PiB    24 PiB     72 PiB     72 PiB    74.80
```

SLAC

Open Source

SLAC Open Source

Many repos on GitHub

<https://github.com/slaclab>

<https://github.com/slac-epics>

<https://github.com/pcdshub>



 **SLAC Lab**
A home for research-facilitating software developed at SLAC. For access requests: #comp-general / #github-slaclab in SLAC Slack

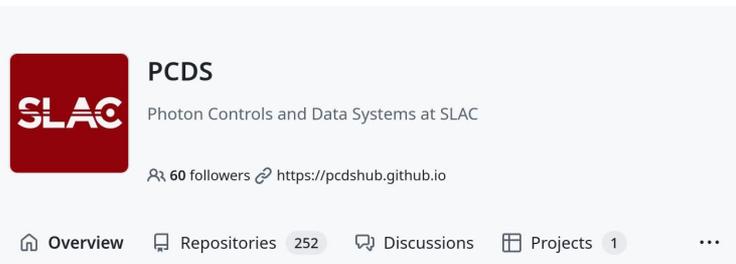
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 **SLAC EPICS development**
SLAC's EPICS software (modules, base, etc.)

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 **PCDS**
Photon Controls and Data Systems at SLAC

🔍 60 followers 🔗 <https://pcdshub.github.io>

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These Slides

<https://www.socallinuxexpo.org/scale/23x/presentations/my-2-mile-particle-accelerator-x-ray-laser-runs-linux>



SLAC Linear Accelerator Center

<https://slac.stanford.edu/>

<https://www6.slac.stanford.edu/news-and-events/connect-with-us>

Tours

Public Tours typically two days each month

<https://www6.slac.stanford.edu/news-and-events/events/public-tours>

Careers & Internships

<https://careers.slac.stanford.edu/>