# 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**

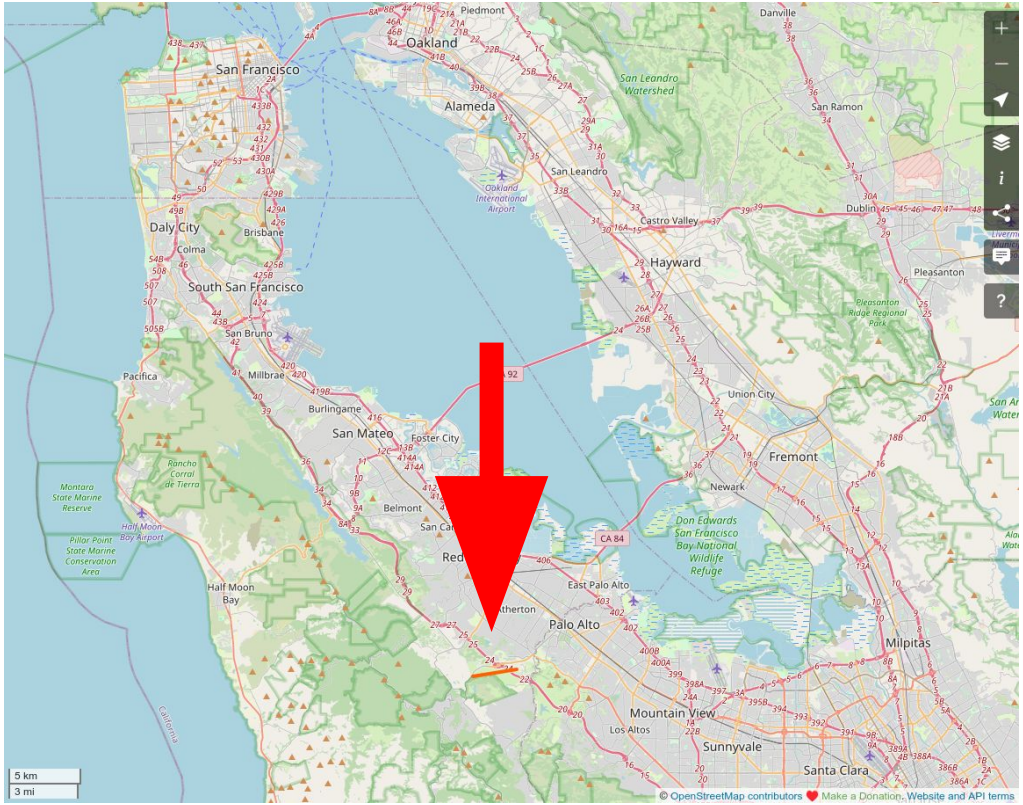
SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University

U.S. DEPARTMENT of ENERGY

# The Stanford Two-Mile Accelerator

# The Stanford Two-Mile Accelerator




## Menlo Park, CA

Southeast of San Francisco

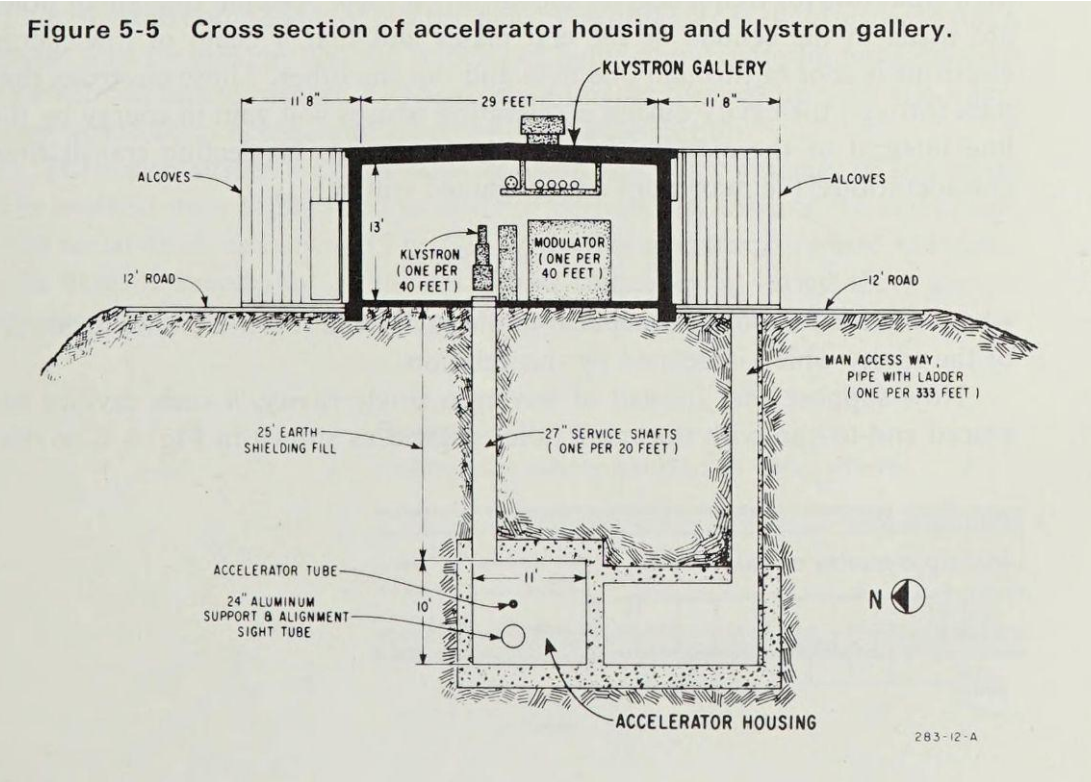


Photo: OpenStreetMap

Photo: Olivier Bonin/SLAC National Accelerator Laboratory

Photo: Olivier Bonin/SLAC National Accelerator Laboratory

# Building and Tunnel




## Cross-section

Ground-level building

Accelerator tunnel



Image: SLAC 'Blue Book,' p. 59 - https://ahro.slac.stanford.edu/resources/slac-blue-book

# Klystrons

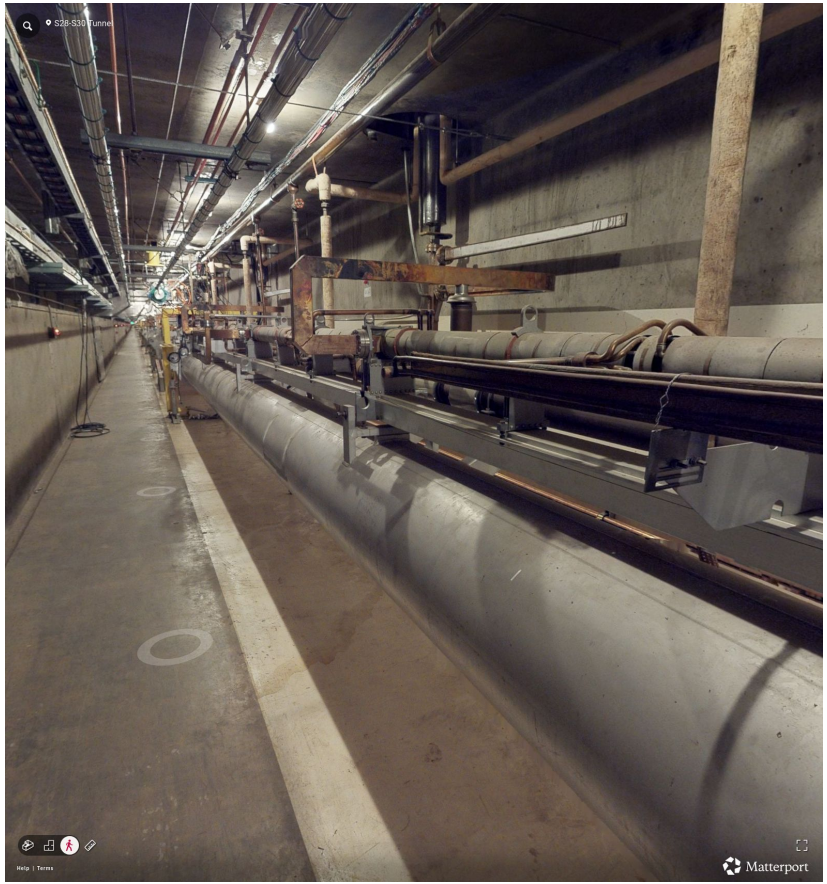
## Microwave Amplifiers

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

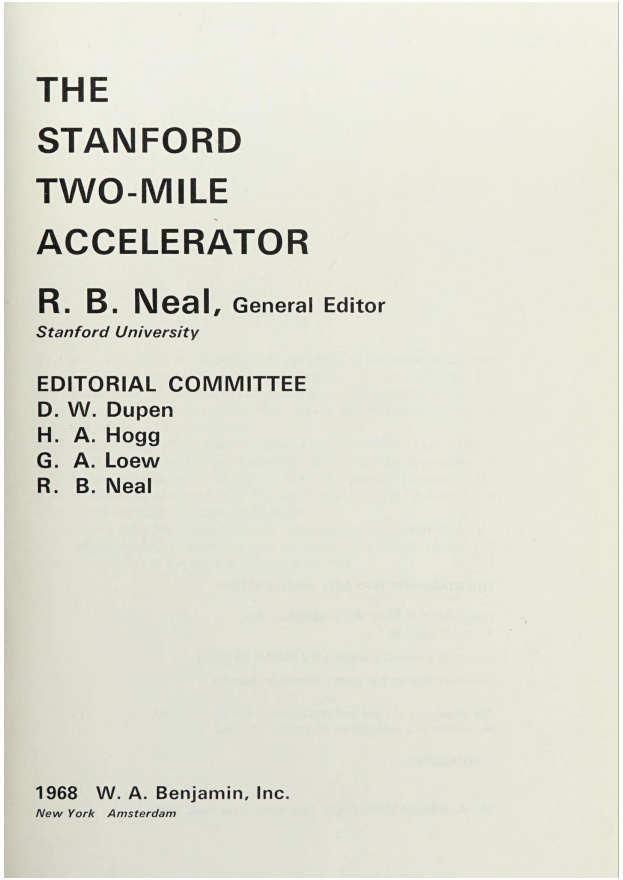
Waveguides

Copper Accelerator

Water cooling

Vacuum system

# The ‘Blue Book’


THE
STANFORD
TWO-MILE
ACCELERATOR

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*New York Amsterdam*

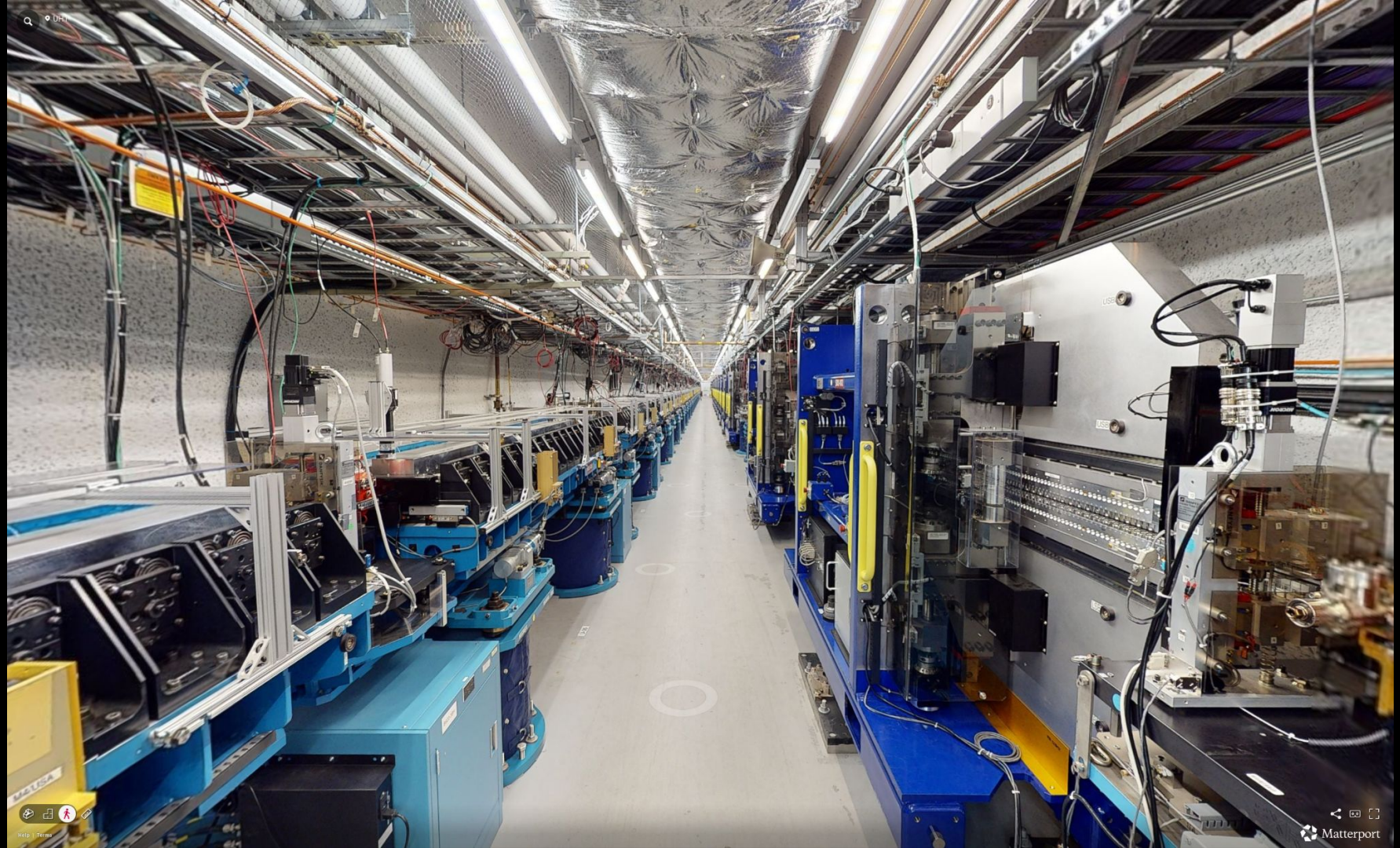
## In the spirit of open source,

Documentation from on everything involved in bringing SLAC online

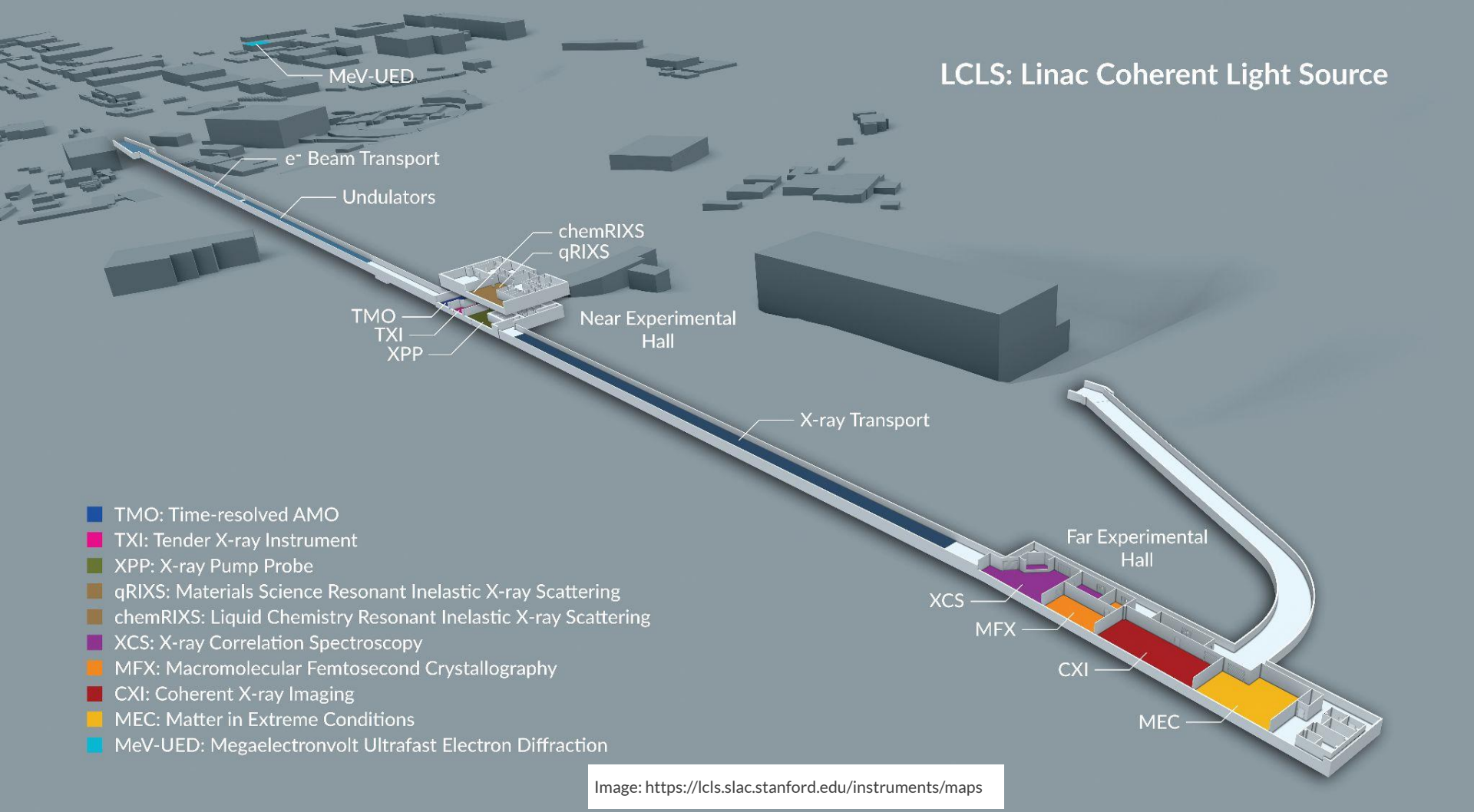
https://ahro.slac.stanford.edu/resources/slac-blue-book

# LCLS

## The Linac Coherent Light Source


MEUSA
Matterport

# LCLS: Linac Coherent Light Source




- TMO: Time-resolved AMO
- TXI: Tender X-ray Instrument
- XPP: X-ray Pump Probe
- qRIXS: Materials Science Resonant Inelastic X-ray Scattering
- chemRIXS: Liquid Chemistry Resonant Inelastic X-ray Scattering
- XCS: X-ray Correlation Spectroscopy
- MFX: Macromolecular Femtosecond Crystallography
- CXI: Coherent X-ray Imaging
- MEC: Matter in Extreme Conditions
- MeV-UED: Megaelectronvolt Ultrafast Electron Diffraction

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

# Recent media coverage

What Happens If You Keep Slowing Down?

8.4M views • 1 month ago

Veritasium

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

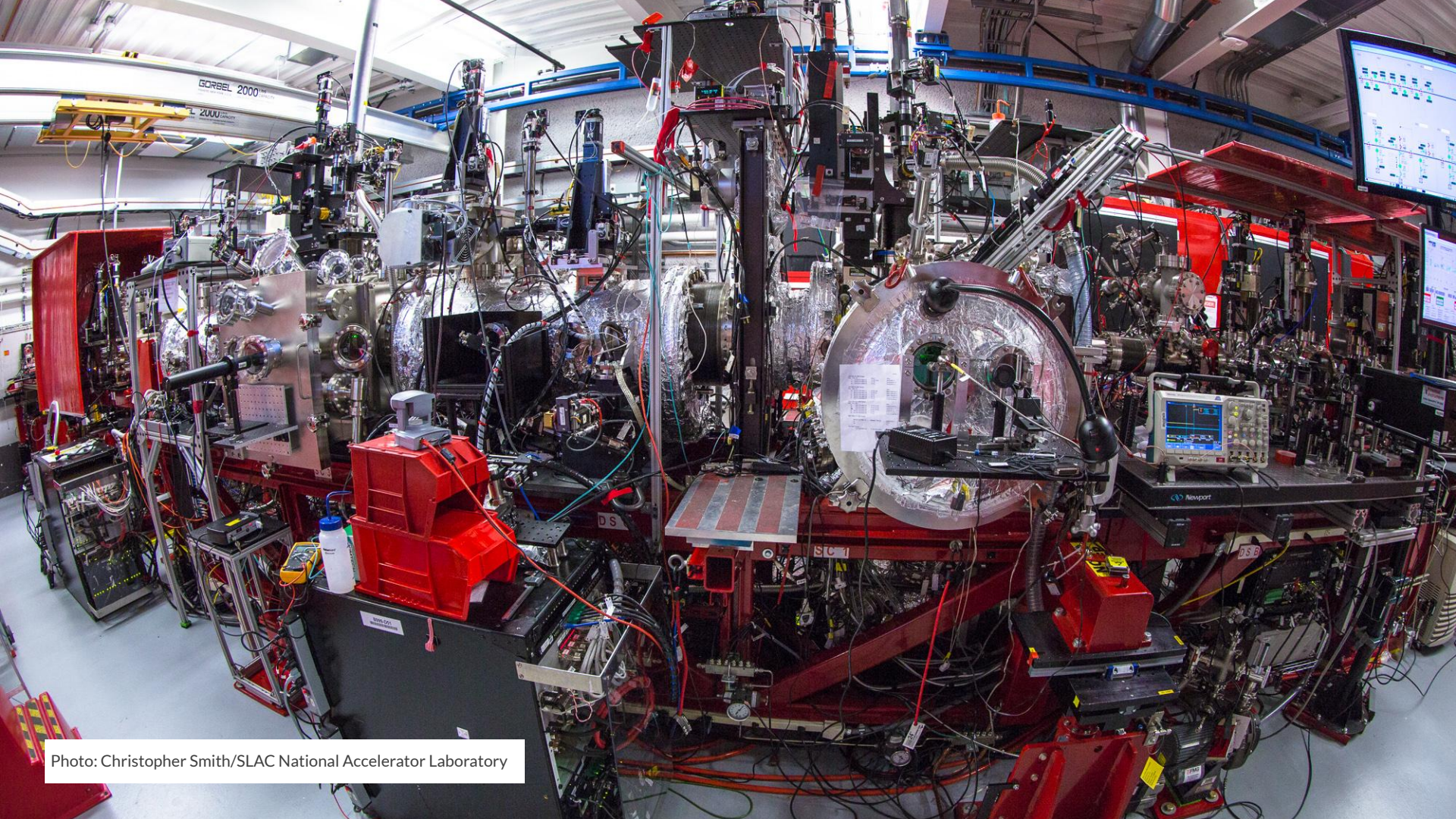


Photo: Christopher Smith/SLAC National Accelerator Laboratory

# 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**

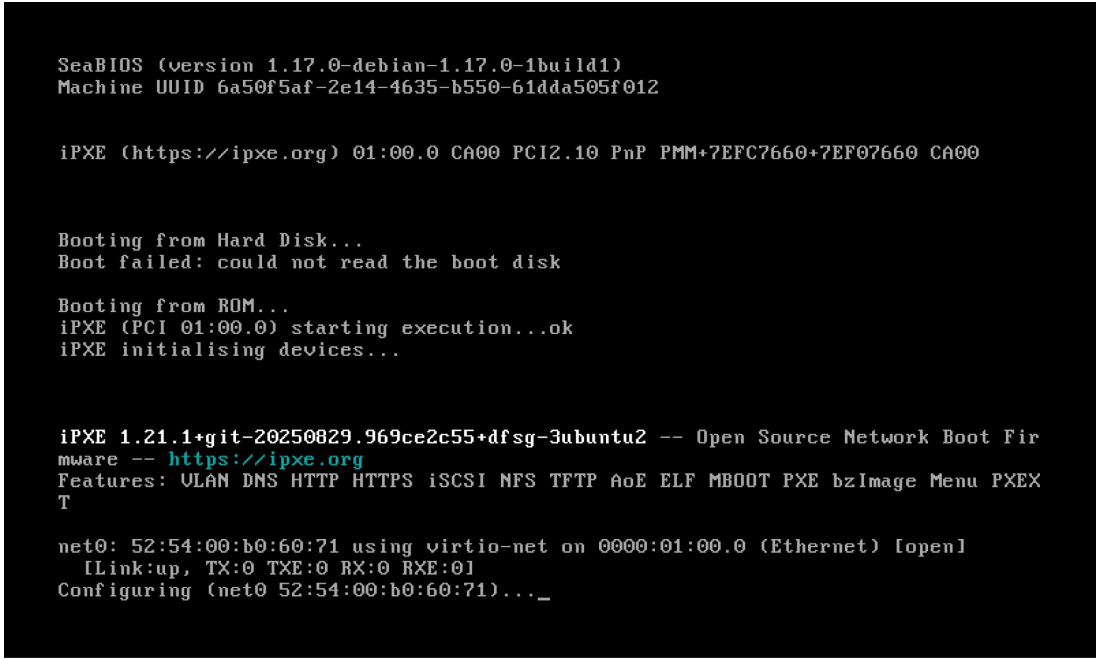
2x 10Gbps Ethernet

**Up to 4x FHFL PCIe cards**

Assorted add-in cards

- Timing, image capture, other custom hardware

# Netboot / Netinstall




## Boot from the network

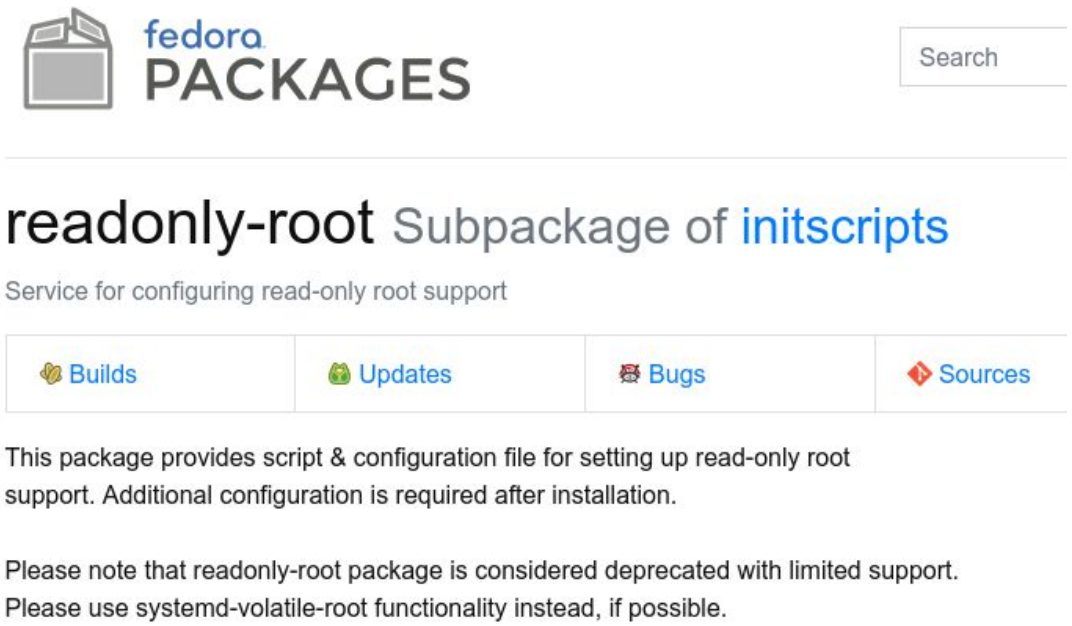
Configured by DHCP

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

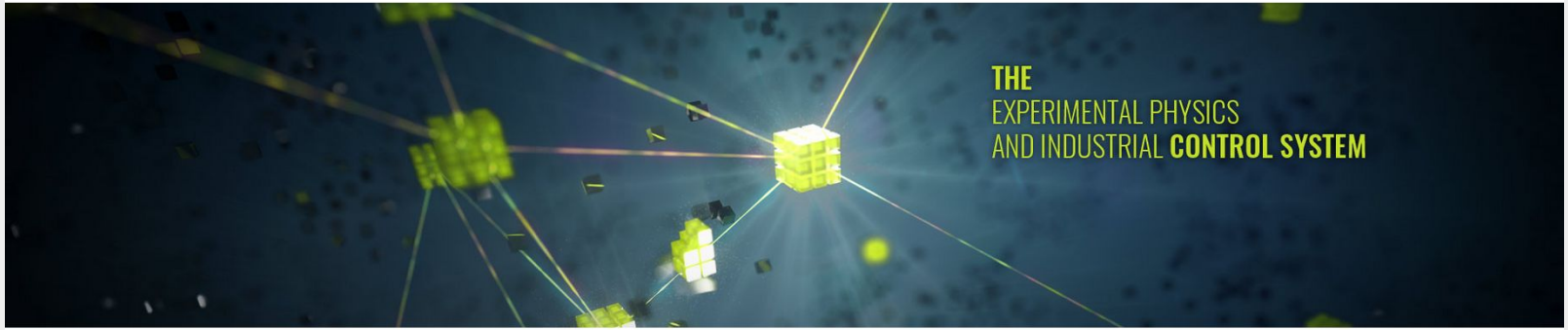
NFS mounts

Shared read-only root mount

Only server-specific differences are stored

EPICS

Home | About | News and Events | Software | Support | Community




## 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

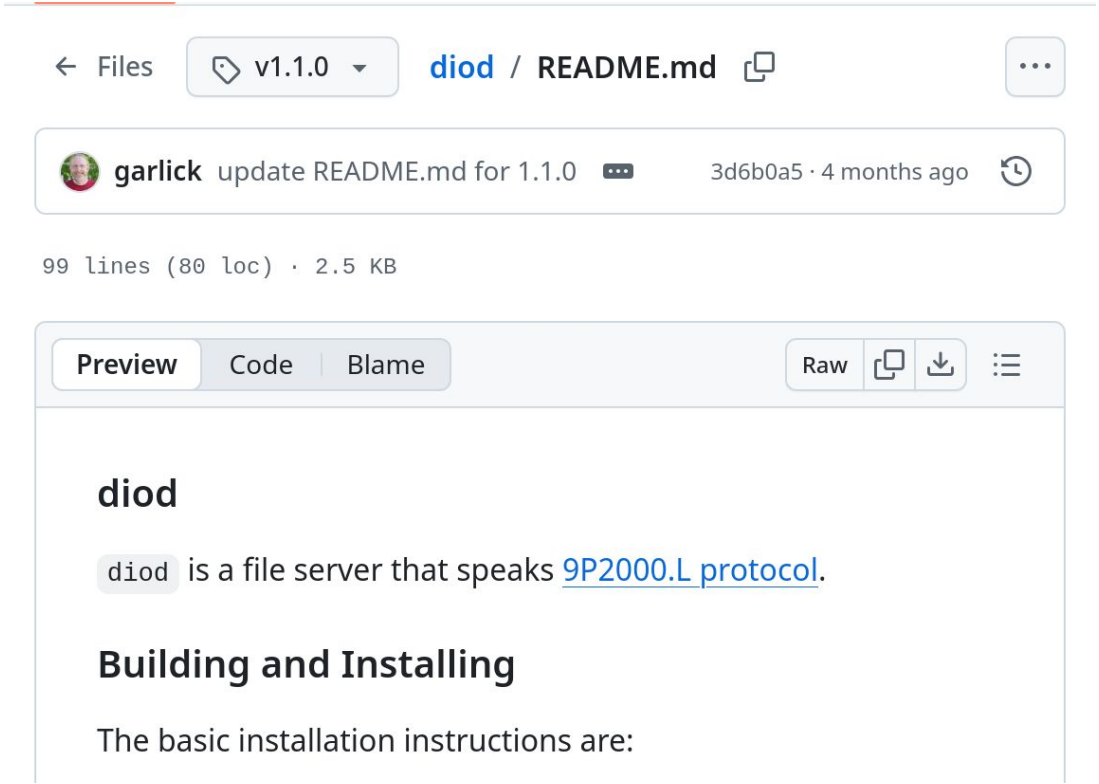
EPICS was created through collaborative contributions from scientific facilities since a long time. It is the preferred choice for complex, large scale distributed control system applications.

## 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

https://epics-controls.org/

# Embedded Systems and one-offs

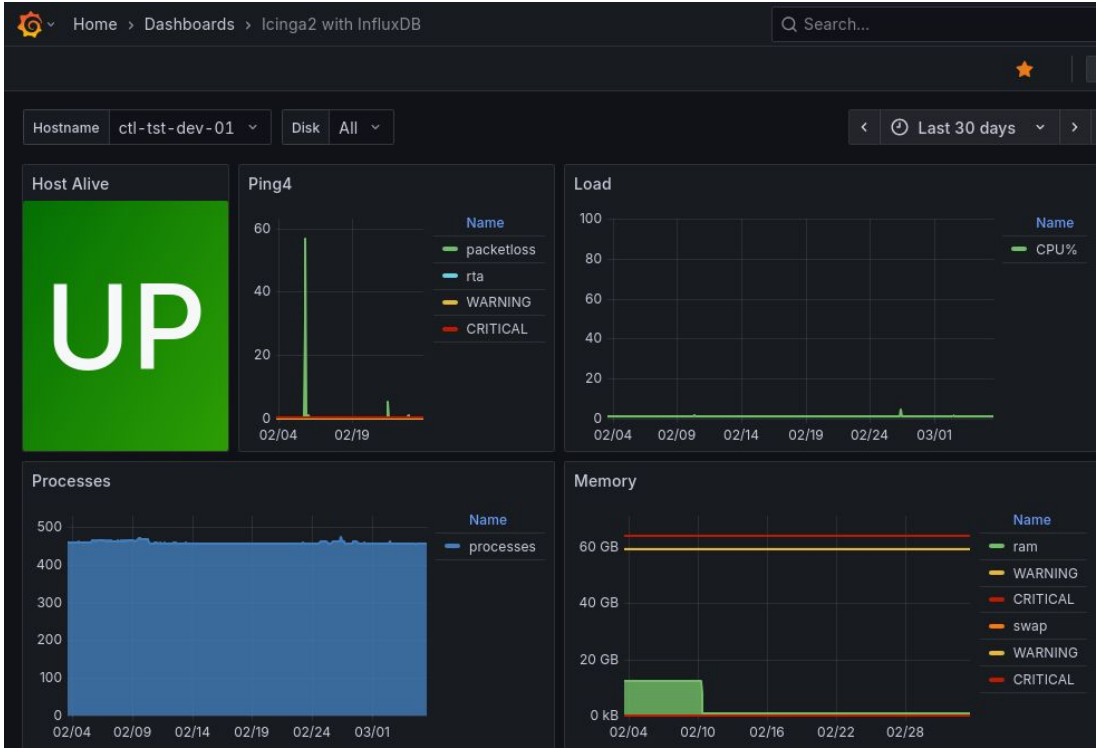



## Extra-long-term support

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

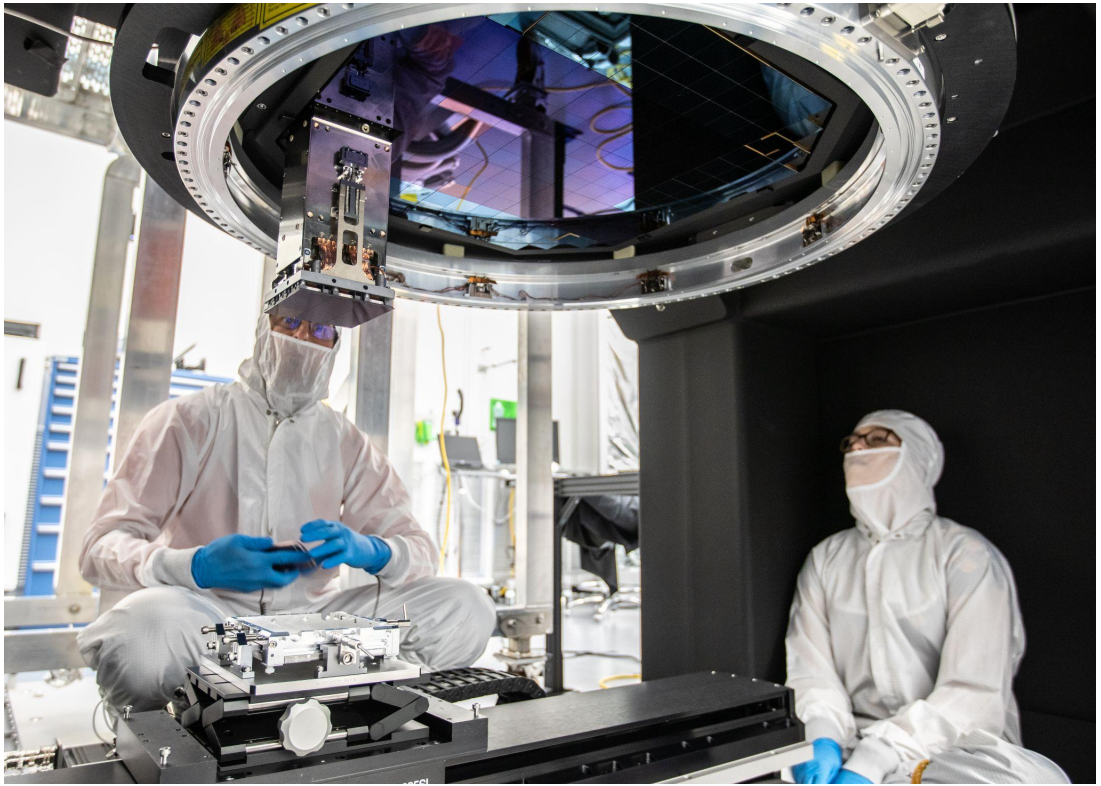
- LCLS-I: 120 Hz
- LCLS-II (achieved): 96 kHz (96,000 Hz)
- LCLS-II (planned): 1 MHz (1,000,000 Hz)

Photo: Greg Stewart/SLAC National Accelerator Laboratory

# 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

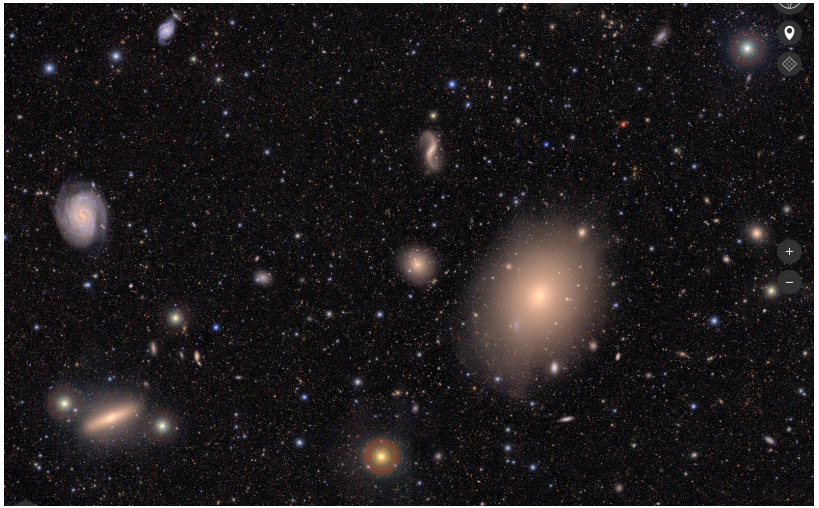
And we need to process those images

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

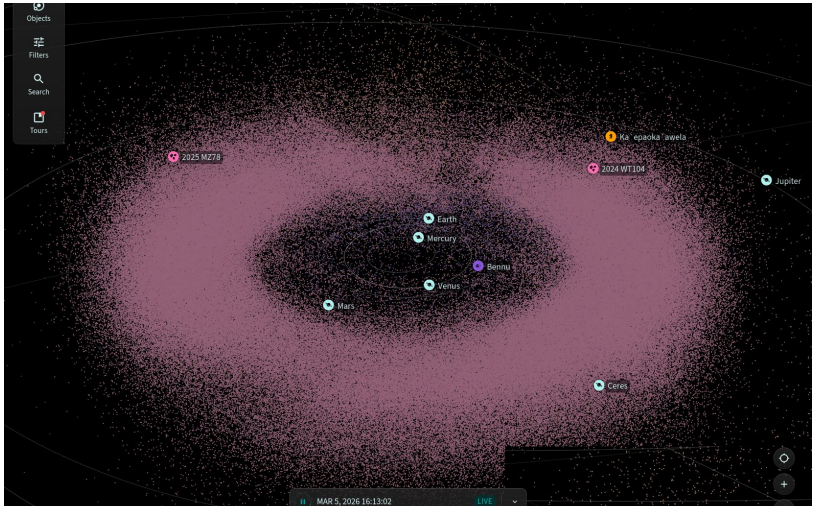
SLAC Photo: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory

# 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

Photo: Olivier Bonin/SLAC National Accelerator Laboratory

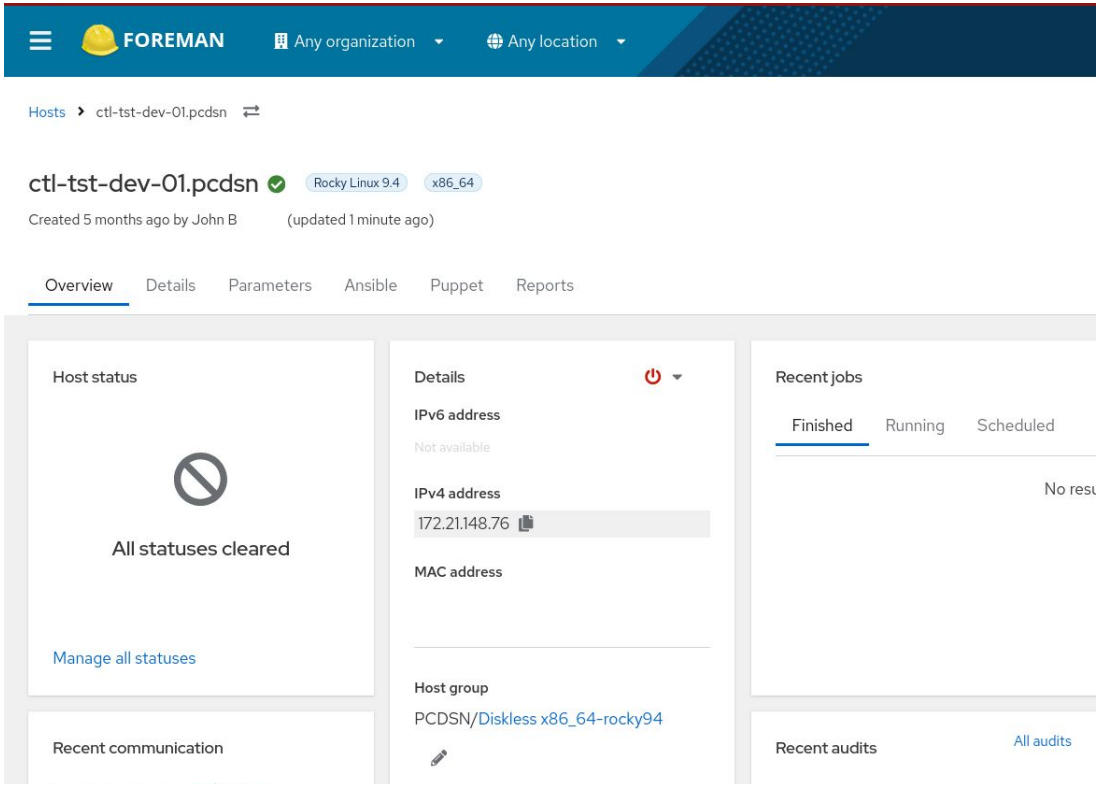
# S3DF

## 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




## 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

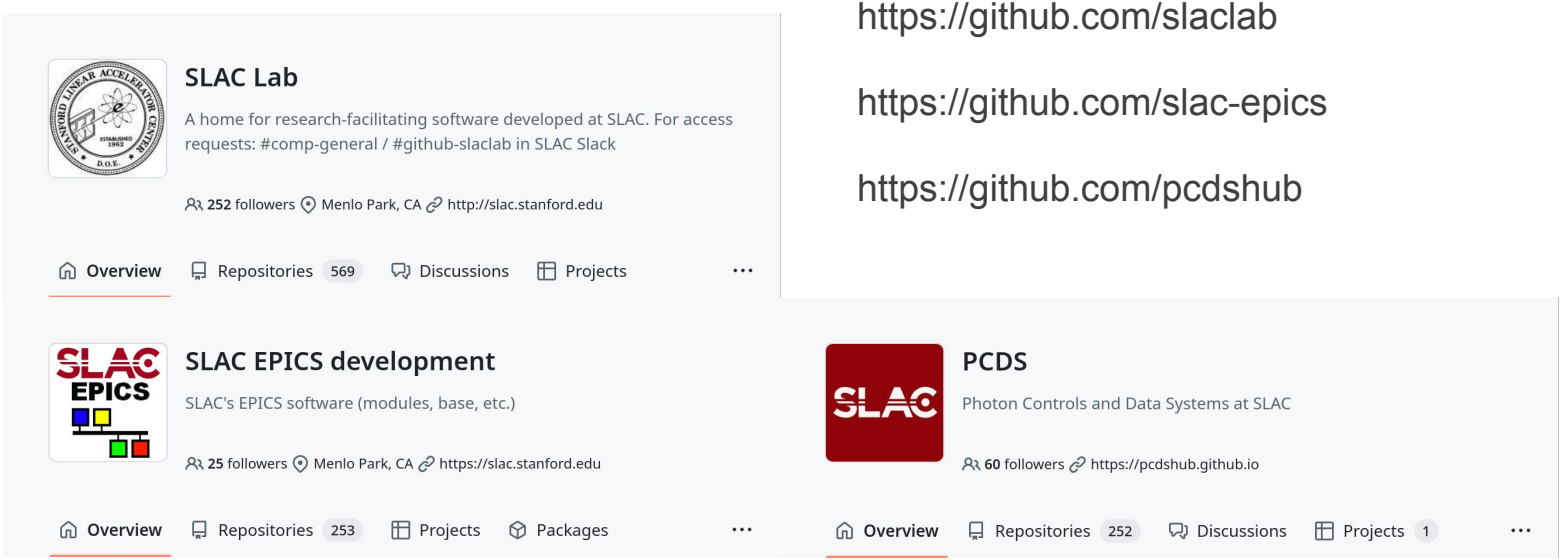
- Object Storage (S3)
- Block (RADOS Block Device)
- POSIX filesystems (CephFS)

```
[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

# 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/