# Hydra Infrastructure
# Complete Reference Manual

RKE2 Kubernetes Cluster
Student Container Platform
GPU Computing Infrastructure

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## Contents

# Part I
# System Overview

## 1 Introduction

Hydra is a containerized development platform providing persistent development environments for Computer Science students and faculty at SUNY New Paltz. The system runs on a 3-node RKE2 Kubernetes cluster with GPU acceleration for AI/ML workloads.

### 1.1 Key Features

- **SSO Authentication:** Azure AD SAML 2.0 with automatic user provisioning
- **Persistent Containers:** Per-student development environments with SSH, VS Code, and Jupyter
- **GPU Computing:** 5 GPUs across 2 nodes (3x RTX 3090 + 2x RTX 5090)
- **AI Chat:** OpenWebUI + Ollama LLM inference (gpt.hydra.newpaltz.edu)
- **Ray Cluster:** Distributed computing framework for ML training
- **Dynamic Routing:** Traefik reverse proxy with ForwardAuth
- **Workflow Automation:** n8n with integrated user management
- **21 TB Storage:** RAID-10 ZFS array with NFS exports

### 1.2 Access URLs

| Service | URL | Description |
|---|---|---|
| Dashboard | `https://hydra.newpaltz.edu/dashboard` | Main user interface |
| OpenWebUI | `https://gpt.hydra.newpaltz.edu/` | AI chat (Ollama) |
| CS Lab Site | `https://hydra.newpaltz.edu/` | Department homepage |
| Student Forms | `https://hydra.newpaltz.edu/student-forms` | Form hub |
| Hackathons | `https://hydra.newpaltz.edu/hackathons` | Hackathon voting |
| VS Code | `https://hydra.newpaltz.edu/students/{user}/vscode` | Browser IDE |
| Jupyter | `https://hydra.newpaltz.edu/students/{user}/jupyter` | Notebooks |
| n8n | `https://n8n.hydra.newpaltz.edu/` | Workflow automation |
| Servers | `https://hydra.newpaltz.edu/servers` | Cluster status |

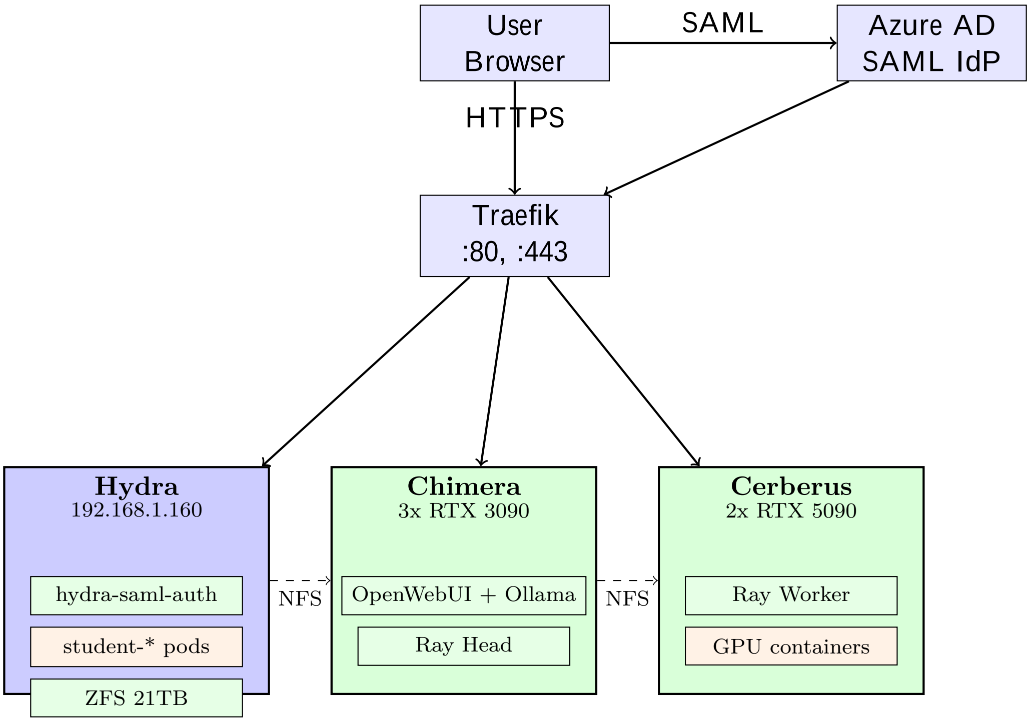
# 2 Cluster Architecture

## 2.1 Node Inventory

| Node | IP | Role | OS | Hardware |
|---|---|---|---|---|
| Hydra | 192.168.1.160 | Control plane, etcd | Ubuntu 22.04.5 | 64 cores, 256 GB RAM, 21 TB RAID-10 |
| Chimera | 192.168.1.150 | GPU inference | Ubuntu 24.04.2 | 48 cores, 256 GB RAM, 3x RTX 3090 (72 GB VRAM) |
| Cerberus | 192.168.1.233 | GPU training | Ubuntu 24.04.3 | 48 cores, 64 GB RAM, 2x RTX 5090 (64 GB VRAM) |

Table 1: All nodes run RKE2 v1.28.4+rke2r1 with containerd 1.7.7.

## 2.2 Architecture Diagram



## 2.3 Network Architecture

- All nodes on 192.168.1.0/24 LAN (gateway 192.168.1.1)
- Direct ethernet bridge between Chimera and Cerberus (reserved for RDMA/RoCE)
- WireGuard VPN: Chimera `wg0` = 10.8.0.2, Cerberus `wg0` = 10.8.0.3
- Flannel VXLAN (port 8472/udp) for K8s pod networking, restricted to LAN
- UFW firewall on all nodes — workers expose only SSH publicly

# 3 Storage

## 3.1 Hydra Storage Layout

| Device | Mount | Size | Purpose |
|---|---|---|---|
| `/dev/mapper/ubuntu-vg-*` | `/` | 1 TB | OS, applications |
| `/dev/md0` (RAID-10, 6 SSDs) | `/data` | 21 TB | Student volumes, K8s PVCs |
| `/dev/sdh4` | `/mnt/sdh4` | 1.1 TB | Daily backups |

```
# RAID-10 details
/dev/md0: 6 active devices (sda-sdf), Chunk 512K, Layout near=2
State: clean, ext4, 4096-byte blocks
```

## 3.2 Kubernetes Storage Classes

| Name | Provisioner | Usage |
|---|---|---|
| hydra-local | rancher.io/local-path | Student PVCs (default) |
| hydra-nfs | nfs.csi.k8s.io | Cross-node shared storage |

## 3.3 NFS Configuration

Hydra exports `/data/containers` to the cluster LAN:

```
# /etc/exports on Hydra
/data/containers 192.168.1.0/24(rw,sync,no_root_squash)
```

CSI-NFS runs as a DaemonSet on all 3 nodes for dynamic PV provisioning.

# Part II
# Kubernetes Services

## 4 Namespace Layout

| Namespace | Contents |
|---|---|
| `hydra-system` | Core platform: traefik, hydra-auth, cs-lab-backend, cs-lab-db |
| `hydra-infra` | Infrastructure services: ollama, open-webui, n8n, hackathons, java-executor, git-learning, sshpiper, ray-head, ray-worker |
| `hydra-students` | Student container pods (25+ active) |
| `gpu-operator` | NVIDIA GPU operator, device plugin, DCGM exporter |
| `kube-system` | RKE2 system: etcd, coredns, canal, metrics-server, CSI-NFS |
| `local-path-storage` | Local-path provisioner |

## 5 Core Services (hydra-system)

### 5.1 Traefik (Reverse Proxy)

**Traefik v2.11** serves as the cluster ingress controller. It runs on Hydra with `hostPort` binding on ports 80, 443, and 6969. The deployment uses `strategy: Recreate` to avoid hostPort conflicts during rolling updates.

| Port | Name | Purpose |
|---|---|---|
| 80 | web | HTTP (redirects to HTTPS) |
| 443 | websecure | HTTPS with Let's Encrypt |
| 6969 | hydra-auth | Direct auth service access |

**Manifests:** `k8s/components/traefik/`

### 5.2 Hydra Auth (SAML Gateway)

The main authentication and container management service. Handles:

- SAML 2.0 SSO via Azure AD
- JWT cookie issuance and JWKS endpoint
- Student container lifecycle (create, start, stop, delete)
- Dashboard UI, admin panel
- OpenWebUI and n8n account provisioning
- WebSocket terminal bridge

**Manifests:** `k8s/components/hydra-auth/`

### 5.3 CS Lab Website

React frontend + Express backend + MariaDB database. Serves the department homepage at `hydra.newpaltz.edu`.

| Component | Port | Image |
|---|---|---|
| cs-lab-backend | 5001 | newpaltz-cs-lab-website-backend:latest |
| cs-lab-db | 3306 | mariadb:10.11 |

**Database:** 15 tables including Admins, Events, Faculty, Courses, StudentHighlightBlog, TechBlog, etc.

**Manifests:** `k8s/components/cs-lab/`

### 5.4 IngressRoute Summary

| Name | Namespace | Match | Backend |
|---|---|---|---|
| hydra-main | hydra-system | hydra.newpaltz.edu catch-all | hydra-auth:6969 |
| cs-lab-website | hydra-system | /api/ prefix | cs-lab-backend:5001 |
| hydra-default | hydra-system | HTTP redirect | HTTPS redirect |
| hackathons | hydra-infra | /hackathons/ prefix | hackathons:45821 |
| java-executor | hydra-infra | /java/ prefix | java-executor:55392 |
| git-learning | hydra-infra | /git/ prefix | git-learning:8080 |
| n8n | hydra-infra | n8n.hydra.newpaltz.edu | n8n:5678 |
| openwebui | hydra-infra | gpt.hydra.newpaltz.edu | openwebui-chimera:3000 |

## 6 Infrastructure Services (hydra-infra)

### 6.1 Ollama (LLM Inference)

Runs on Chimera with all 3 RTX 3090 GPUs. Serves LLM models (gemma3:12b, etc.) via the Ollama API on port 11434.

**Manifests:** `k8s/components/ollama/`

Ollama requests all 3 GPUs on Chimera. Other GPU workloads on Chimera (like Ray head) must **not** request GPU resources, or they will conflict.

### 6.2 OpenWebUI

AI chat frontend at `gpt.hydra.newpaltz.edu`. Connects to Ollama for inference. Includes a **middleman sidecar** container for user account management.

**Middleman API (port 7070):**

- `POST /openwebui/api/check-user` — Check if user exists
- `POST /openwebui/api/create-account` — Create new user
- `POST /openwebui/api/change-password` — Update password

Authentication via `x-api-key` header with timing-safe comparison.

**Source:** `k8s/components/openwebui/middleman/index.js`

**Manifests:** `k8s/components/openwebui/`

### 6.3 n8n (Workflow Automation)

Workflow automation platform at `n8n.hydra.newpaltz.edu`. Uses PostgreSQL for data storage.

**Components:**

- n8n application (port 5678)
- PostgreSQL 16 (StatefulSet with PVC)
- n8n User Manager API (port 3000)

**n8n User Manager API:**

- `GET /health` — Health check (no auth)
- `GET /api/users` — List all users (auth required)
- `GET /api/users/:email` — Get user by email
- `POST /api/users/change-password` — Change password

Authentication via `x-api-key` header.

**Source:** `k8s/components/n8n/user-manager/`

**Manifests:** `k8s/components/n8n/`

### 6.4 Ray Cluster (Distributed Computing)

Ray provides distributed computing for ML training and inference.

| Component | Node | GPU | Purpose |
|---|---|---|---|
| ray-head | Chimera | None (coordinator) | Scheduling, dashboard |
| ray-worker | Cerberus | 2x RTX 5090 | Training compute |

**Manifests:** `k8s/components/ray/`

### 6.5 Other Services

| Service | Port | Description |
|---|---|---|
| hackathons | 45821 | Hackathon voting/judging app (Vue.js + Express) |
| java-executor | 55392 | Remote Java code execution service |
| git-learning | 8080 | Interactive Git learning environment |
| sshpiper | 2222 | SSH proxy routing to student containers |

**Manifests:** `k8s/components/{hackathons,java-executor,git-learning,sshpiper}/`

## 7 GPU Infrastructure

### 7.1 NVIDIA GPU Operator

The GPU Operator runs in the `gpu-operator` namespace and manages:

- Device plugin (exposes GPUs to K8s scheduler)
- Container toolkit (nvidia-container-runtime)
- GPU Feature Discovery (node labels)
- DCGM Exporter (GPU metrics)
- CUDA validator (verifies GPU access)

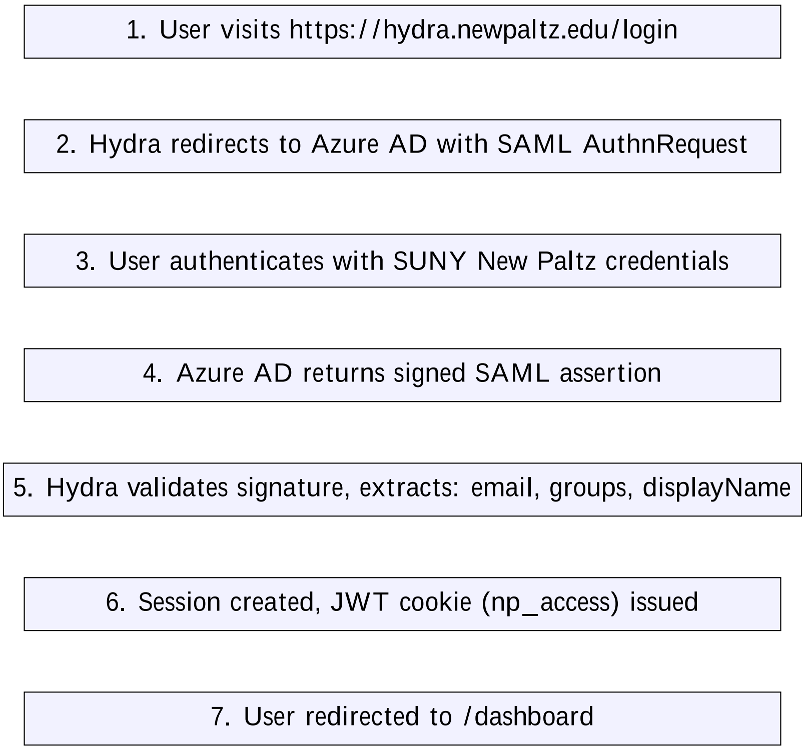
**Hydra Exclusion:** Hydra (control plane) has no GPUs. All `nvidia.com/gpu.deploy.*` labels are set to `false` on Hydra to prevent GPU operator pods from scheduling there.

## 7.2 GPU Allocation

| Node | GPUs | Model | VRAM | Primary Consumer |
|---|---|---|---|---|
| Chimera | 3 | RTX 3090 | 72 GB total | Ollama (all 3) |
| Cerberus | 2 | RTX 5090 | 64 GB total | Ray Worker / Student GPU containers |

# Part III
# Authentication System

## 8 SAML 2.0 SSO Flow



1. User visits https://hydra.newpaltz.edu/login

2. Hydra redirects to Azure AD with SAML AuthnRequest

3. User authenticates with SUNY New Paltz credentials

4. Azure AD returns signed SAML assertion

5. Hydra validates signature, extracts: email, groups, displayName

6. Session created, JWT cookie (np_access) issued

7. User redirected to /dashboard

## 9 Session and JWT Management

- **Express Session:** Server-side storage in SQLite
- **JWT Cookie** (np_access)**:** Site-wide SSO cookie
- **JWKS Endpoint:** `/.well-known/jwks.json` for public key distribution
- **Algorithm:** RS256
- **TTL:** Configurable via `JWT_TTL_SECONDS` (default: 86400)
- **Cookie Domain:** `.newpaltz.edu`

## 10 Cross-Service Authentication

### 10.1 OpenWebUI Account Provisioning

When a user logs in via SAML, Hydra automatically provisions an OpenWebUI account via the middleman API. The password is derived and set transparently.

### 10.2 n8n Account Provisioning

Similarly, n8n accounts are provisioned via the n8n User Manager API on first login.

## 10.3 CS Lab JWT Verification

The CS Lab backend verifies JWT tokens using the public key mounted via ConfigMap `cs-lab-jwt-key` at `/app/server/keys/jwt-public.pem`.

# Part IV
# Student Containers

## 11 Container Features

Each student receives a persistent container with:

| Feature | Details |
|---|---|
| Node.js | Latest LTS via nvm |
| Python | 3.11+ with pip, venv, Jupyter |
| Java | OpenJDK 21 |
| Docker | Docker-in-Docker support |
| VS Code | code-server browser IDE |
| Jupyter | Notebook and JupyterLab |
| SSH | Direct access via SSHPiper (port 2222) |
| Tools | Git, curl, wget, build-essential |

## 12 Container Presets

- **Jupyter:** `jupyter/minimal-notebook`, port 8888, ForwardAuth
- **Static:** `nginx:alpine`, port 80, no auth
- **Repo:** Cloned from GitHub, runtime varies (Node/Python/nginx)
- **VS Code:** `codercom/code-server`, mounts any project volume

## 13 Resource Presets

| Preset | RAM | CPU | Storage | GPU | Approval |
|---|---|---|---|---|---|
| Minimal | 256 MB | 0.5 | 5 GB | 0 | Auto |
| Conservative | 512 MB | 1 | 10 GB | 0 | Auto |
| Standard | 1 GB | 1 | 20 GB | 0 | Auto |
| Enhanced | 2 GB | 2 | 40 GB | 0 | Required |
| GPU Inference | 32 GB | 8 | 100 GB | 1 | Required |
| GPU Training | 48 GB | 16 | 200 GB | 2 | Required |

## 14 SSH Access via SSHPiper

Students access containers via SSH through the SSHPiper proxy:

```
# Connect to your container
ssh -p 2222 student@hydra.newpaltz.edu

# Port 2222 is forwarded through the router to the sshpiper K8s pod
```

- SSHPiper routes connections based on username to the correct student pod
- Passwords displayed in dashboard after container creation
- Key-based auth supported (`~/.ssh/authorized_keys`)

## 15 Container Labels and Routing

Common labels on student containers:

- `hydra.managed_by=hydra-saml-auth`
- `hydra.owner=<username>`
- `hydra.project=<project>`
- `hydra.basePath=/students/<user>/<project>`

Traefik routes requests at `/students/<user>/<project>` to the corresponding container using StripPrefix middleware (except Jupyter, which uses `base_url`).

# Part V
# Networking

## 16 Firewall Configuration (UFW)

### 16.1 Hydra (Control Plane)

```
22/tcp          ALLOW  Anywhere        # SSH
80/tcp          ALLOW  Anywhere        # HTTP
443             ALLOW  Anywhere        # HTTPS
6969            ALLOW  172.17.0.0/16, 172.24.0.0/16  # Auth (Docker)
51820/udp       ALLOW  Anywhere        # WireGuard
6443/tcp        ALLOW  192.168.1.0/24  # K8s API
9345/tcp        ALLOW  192.168.1.0/24  # RKE2 supervisor
10250/tcp       ALLOW  192.168.1.0/24  # Kubelet
2379:2380/tcp   ALLOW  192.168.1.0/24  # etcd
2222/tcp        ALLOW  Anywhere        # SSHPiper
2049/tcp        ALLOW  192.168.1.0/24  # NFS
111/tcp,udp     ALLOW  192.168.1.0/24  # portmapper
8472/udp        ALLOW  192.168.1.0/24  # Flannel VXLAN
```

### 16.2 Chimera (GPU Worker)

```
22/tcp          ALLOW  Anywhere        # SSH
7070/tcp        ALLOW  192.168.1.148   # OpenWebUI middleman
9100            ALLOW  192.168.1.0/24  # Metrics
8472/udp        ALLOW  192.168.1.0/24  # Flannel VXLAN
10250/tcp       ALLOW  192.168.1.0/24  # Kubelet
```

### 16.3 Cerberus (GPU Worker)

```
22/tcp          ALLOW  Anywhere        # SSH
9100            ALLOW  192.168.1.160   # Metrics from Hydra
2376            ALLOW  192.168.1.160   # Docker from Hydra
8472/udp        ALLOW  192.168.1.0/24  # Flannel VXLAN
10250/tcp       ALLOW  192.168.1.0/24  # Kubelet
```

## 17 Router Port Forwarding

| External Port | Internal IP | Internal Port | Service |
|---|---|---|---|
| 22 | 192.168.1.160 | 22 | Admin SSH |
| 80 | 192.168.1.160 | 80 | HTTP |
| 443 | 192.168.1.160 | 443 | HTTPS |
| 2222 | 192.168.1.160 | 2222 | Student SSH (SSHPiper) |

## 18 DNS

- `hydra.newpaltz.edu` — Main domain, points to campus public IP

- `gpt.hydra.newpaltz.edu` — OpenWebUI subdomain
- `n8n.hydra.newpaltz.edu` — n8n subdomain

TLS certificates managed by Let's Encrypt via Traefik ACME.

# Part VI
# Deployment and Operations

## 19 Ansible Playbooks

The cluster can be deployed from scratch using Ansible playbooks in `ansible/`:

```
cd /home/infra/hydra-saml-auth/ansible
ansible-playbook -i inventory.yml playbooks/site.yml
```

### 19.1 Playbook Execution Order

1. `00-preflight-backup.yml` — Create backups before changes
2. `01-prepare-nodes.yml` — Install packages, configure kernel
3. `02-rke2-server.yml` — Setup RKE2 control plane on Hydra
4. `03-rke2-agents.yml` — Join Chimera and Cerberus to cluster
5. `04-gpu-setup.yml` — Configure NVIDIA drivers and GPU Operator
6. `05-deploy-hydra.yml` — Deploy all K8s manifests

### 19.2 What 05-deploy-hydra.yml Deploys

In order:

1. Namespaces and RBAC
2. Storage classes
3. Traefik CRDs and deployment
4. Hydra Auth deployment
5. CS Lab website (backend + DB)
6. Hackathons, Java Executor, Git Learning
7. SSHPiper
8. n8n (app + Postgres + user manager)
9. Ollama
10. OpenWebUI (with middleman sidecar)
11. Ray cluster (head + worker)

## 20 CS Lab Website Deployment

```
# 1. Build the image
cd /home/infra/NewPaltz-CS-Lab-Website
docker build --no-cache -t newpaltz-cs-lab-website-backend:latest .

# 2. Export to tarball
docker save newpaltz-cs-lab-website-backend:latest \
  -o /data/containers/images/newpaltz-cs-lab-website-backend-latest.tar

# 3. Import into RKE2's containerd
sudo ctr --address /run/k3s/containerd/containerd.sock \
  -n k8s.io images import \
  /data/containers/images/newpaltz-cs-lab-website-backend-latest.tar
```

```
# 4. Restart the pod
kubectl delete pod -l app.kubernetes.io/component=backend -n hydra-system
```

**Docker vs RKE2 Containerd:** Docker and RKE2 use separate containerd instances with separate image stores. Docker builds go to Docker's containerd. You must explicitly import images into RKE2's containerd at `/run/k3s/containerd/containerd.sock`.

# 21 Image Management

- Image tarballs stored at `/data/containers/images/`
- Use `imagePullPolicy: Never` for locally-imported images
- Use unique tags (e.g., `v20260206144528`) to force pod recreation

# 22 Backup System

## 22.1 Daily Cluster Backups

| Setting | Value |
|---|---|
| Backup Location | `/mnt/sdh4/backups/` |
| Schedule | Daily at 1:00 AM (crontab) |
| Method | rsync with compression |
| Script | `/home/infra/backup-cluster.sh` |
| Log File | `/var/log/cluster-backup.log` |

## 22.2 etcd Snapshots

Automatic every 12 hours via RKE2. Stored in `/var/lib/rancher/rke2/server/db/snapshots/`.

## 22.3 Backup Exclusions

`/dev/*`, `/proc/*`, `/sys/*`, `/run/*`, `/tmp/*`, `/var/tmp/*`, `/var/cache/*`, `/mnt/*`, `/var/lib/docker/*`, `/var/lib/rancher/*`

# 23 Common Operations

## 23.1 Kubectl Shortcuts

Sourced from `~/.hydra-aliases`:

```
k           # kubectl
kgp         # kubectl get pods -A
kgs         # kubectl get svc -A
students    # list student pods
hydra-health  # quick cluster health check
gpu-check     # GPU availability per node
```

## 23.2 Service Management

```
# View all pods
kubectl get pods -A

# Restart a deployment
kubectl rollout restart deployment/<name> -n <namespace>

# View logs
kubectl logs -f deployment/<name> -n <namespace>

# Execute shell in pod
kubectl exec -it <pod-name> -n <namespace> -- /bin/bash
```

# Part VII
# OpenWebUI API Integration

## 24 Getting Started

1. Log in at `https://hydra.newpaltz.edu/dashboard`
2. Visit `https://gpt.hydra.newpaltz.edu`
3. Go to Settings → Account → Generate New API Key
4. Copy the key (format: `sk-...`) — shown only once

## 25 API Configuration

```
ENDPOINT=https://gpt.hydra.newpaltz.edu/api/chat/completions
MODEL=gemma3:12b
API_KEY=sk-your-api-key-here
```

## 26 cURL Example

```
curl https://gpt.hydra.newpaltz.edu/api/chat/completions \
  -H "Content-Type: application/json" \
  -H "Authorization: Bearer sk-your-api-key-here" \
  -d ’{
    "model": "gemma3:12b",
    "messages": [{"role": "user", "content": "Hello!"}]
  }’
```

## 27 Python Example

```
import openai, os
openai.api_base = "https://gpt.hydra.newpaltz.edu/api"
openai.api_key = os.getenv("HYDRA_API_KEY")

response = openai.ChatCompletion.create(
    model="gemma3:12b",
    messages=[{"role": "user", "content": "Hello!"}]
)
print(response.choices[0].message.content)
```

## 28 JavaScript Example

```
const response = await fetch(
  ’https://gpt.hydra.newpaltz.edu/api/chat/completions’,
  {
    method: ’POST’,
    headers: {
      ’Content-Type’: ’application/json’,
      ’Authorization’: ’Bearer ’ + API_KEY
    },
    body: JSON.stringify({
      model: ’gemma3:12b’,
      messages: [{role: ’user’, content: ’Hello!’}]
    })
  }
);
const data = await response.json();
console.log(data.choices[0].message.content);
```

Additional language examples (PHP, Java, C#, Ruby, Go, Rust) are available in the full API access guide at `docs/access.md`.

# Part VIII
# Security

## 29 Security Architecture Layers

1. **Network:** UFW firewall, TLS encryption, CORS policy
2. **Authentication:** SAML 2.0, JWT tokens, API keys
3. **Authorization:** Role-based access, container ownership labels
4. **Runtime:** Container isolation, resource limits, seccomp profiles

## 30 Known Vulnerabilities

**Critical:**

- **Privileged containers** in Docker mode grant full host access
- **Docker socket mount** in student containers is equivalent to root on host

**High:**

- Passwordless sudo for student user in container images
- Supervisor web interface (port 9001) without authentication
- Mining detection without automatic enforcement
- K8s pod security context missing `runAsNonRoot`, `allowPrivilegeEscalation: false`

**Medium:**

- No NetworkPolicy isolation between student pods
- No PID limits (fork bomb vulnerability)
- Jupyter/VS Code without application-level auth (relies on ForwardAuth)

See `docs/SECURITY_VULNERABILITIES.md` for full details and remediation steps.

## 31 Security Best Practices for Students

- Never share API keys publicly or commit to version control
- Use environment variables for sensitive configuration
- Rotate API keys regularly
- Use HTTPS only for all API communications
- Validate and sanitize user inputs before sending to API

# Part IX
# RDMA and GPUDirect

## 32 Overview

The cluster supports RDMA networking for high-performance GPU-to-GPU communication:

| Node | NIC | GPUs | RDMA |
|---|---|---|---|
| Hydra | Onboard | None | SoftRoCE (testing) |
| Chimera | ConnectX | 3x RTX 3090 | Hardware RoCE |
| Cerberus | ConnectX | 2x RTX 5090 | Hardware RoCE + GPUDirect |

## 33 Installation Order (Critical)

1. MLNX_OFED / DOCA (network drivers)
2. NVIDIA GPU Drivers (includes nvidia-peermem)
3. CUDA Toolkit
4. Load nvidia-peermem module

If the NVIDIA GPU driver is installed before MLNX_OFED, the driver must be reinstalled to compile nvidia-peermem with RDMA APIs.

## 34 SoftRoCE Setup

```
# Install prerequisites
sudo apt install rdma-core ibverbs-utils perftest

# Create SoftRoCE device
sudo rdma link add rxe0 type rxe netdev eth0

# Verify
rdma link && ibv_devices
```

## 35 GPUDirect RDMA Verification

```
# Load nvidia-peermem
sudo modprobe nvidia-peermem

# Make persistent
echo "nvidia-peermem" | sudo tee /etc/modules-load.d/nvidia-peermem.
    conf

# Test bandwidth (two nodes)
# Server: ib_write_bw -d mlx5_0 --use_cuda=0
# Client: ib_write_bw -d mlx5_0 --use_cuda=0 <server_ip>
```

See `docs/rdma-gpudirect-setup.md` for complete SR-IOV, DOCA, and KVM passthrough configuration.

# Part X
# Troubleshooting

## 36 Authentication Issues

| Symptom | Solution |
|---|---|
| SAML assertion invalid | Verify `METADATA_URL` and `SAML_SP_ENTITY_ID` match Azure config |
| Cookie not set | Check `COOKIE_DOMAIN`, ensure HTTPS |
| JWT verification fails | Check JWKS endpoint accessible, verify key rotation |

## 37 Container Issues

| Symptom | Solution |
|---|---|
| Container won't start | Verify student container image exists in RKE2 containerd |
| Container 404 | Check Traefik is running, container has correct labels |
| VS Code not loading | Check code-server process, ForwardAuth middleware |
| Jupyter issues | Verify `base_url` setting matches path |
| SSH not working | Check SSHPiper pod, verify port 2222 routing |
| Files not persisting | Only `/home/student/` is persisted via PVC |

## 38 GPU Issues

| Symptom | Solution |
|---|---|
| GPU not detected | Run `nvidia-smi` on host, check NVIDIA drivers |
| GPU pod pending | Check GPU operator pods in gpu-operator namespace |
| Ollama can't use GPU | Verify all 3 GPUs allocated to Ollama deployment |
| Ray worker can't use GPU | Check NVIDIA device plugin on Cerberus |

# 39 Networking Issues

| Symptom | Solution |
|---|---|
| Service unreachable | Check pod is Running, service exists, IngressRoute matches |
| 502 Bad Gateway | Backend pod crashed or port mismatch |
| TLS certificate error | Check Traefik ACME, run `certbot renew -dry-run` |
| NFS mount failed | Verify NFS server running on Hydra, firewall allows 2049 |
| Cross-node pod issue | Check Flannel VXLAN (8472/udp) allowed between nodes |

# 40 Traefik Deployment Issues

**Stuck Rolling Update:** Traefik uses `hostPort` which means only one pod can bind ports 80/443 at a time. The deployment MUST use `strategy: Recreate` (not `RollingUpdate`). If stuck:

```
kubectl rollout undo deployment/traefik -n hydra-system
```

# 41 CS Lab Website Catch-All Route

The Express server has a catch-all that serves `index.html` for SPA routes. Backend API paths are excluded:

```
# Paths excluded from SPA catch-all (served by backend):
/api/*, /faq, /faculty, /uploads, /scripts, /tech-blog,
/student-resources, /student-highlights, /admins, /auth,
/school-calendar, /sd-forms

# Paths explicitly allowed through for SPA routing:
/student-forms, /submit-*
```

If adding new frontend routes starting with `/student`, update the catch-all in `server.js`.

# Part XI
# Repository Structure

## 42 hydra-saml-auth

```
hydra-saml-auth/
|-- index.js                    # SAML auth, JWT, routes, WebSocket
|-- routes/
|   |-- containers.js           # Container lifecycle
|   |-- resource-requests.js    # Resource allocations
|   |-- webui-api.js            # OpenWebUI proxy
|   |-- n8n-api.js              # n8n account management
|   |-- servers-api.js          # Cluster status
|   |-- admin.js                # Admin panel
|-- services/
|   |-- db-init.js              # Database init
|   |-- resource-expiry.js      # Resource expiry checker
|   |-- security-monitor.js     # Process monitoring
|-- config/
|   |-- resources.js            # Presets and node config
|   |-- runtime.js              # Docker/K8s switcher
|-- k8s/
|   |-- base/                   # Namespace, RBAC, storage
|   |-- components/
|   |   |-- traefik/            # Reverse proxy
|   |   |-- hydra-auth/         # Auth service
|   |   |-- cs-lab/             # CS Lab website
|   |   |-- ollama/             # LLM inference
|   |   |-- openwebui/          # AI chat + middleman
|   |   |-- n8n/                # Workflows + user manager
|   |   |-- ray/                # Distributed computing
|   |   |-- hackathons/         # Hackathon app
|   |   |-- java-executor/      # Code execution
|   |   |-- git-learning/       # Git learning
|   |   |-- sshpiper/           # SSH proxy
|   |   |-- student-pods/       # Pod templates
|   |-- gpu/                    # GPU operator config
|-- ansible/
|   |-- inventory.yml           # Node definitions
|   |-- playbooks/              # Deployment scripts
|-- student-container/
|   |-- Dockerfile              # Student image
|   |-- supervisord.conf        # Process manager
|-- docs/                       # This document + sources
|-- docker-compose.yaml         # Legacy Docker deployment
```

# 43 Other Repositories

| Repo | Path | Description |
|---|---|---|
| NewPaltz-CS-Lab-Website | `~/NewPaltz-CS-Lab-Website/` | React + Express CS Lab homepage |
| Hackaton-Voting | `~/Hackaton-Voting/` | Vue.js hackathon app |

# Part XII
# Environment Configuration

## 44 Required Variables (hydra-saml-auth)

| Variable | Description |
|---|---|
| BASE_URL | https://hydra.newpaltz.edu |
| METADATA_URL | Azure AD federation metadata URL |
| SAML_SP_ENTITY_ID | SP Entity ID (must match Azure) |
| COOKIE_DOMAIN | .newpaltz.edu |
| PORT | Service port (default: 6969) |
| DB_PATH | SQLite path (/app/data/hydra.db) |
| JWT_TTL_SECONDS | Token lifetime (default: 86400) |

## 45 Ansible Inventory Variables

```
rke2_version: "v1.28.4+rke2r1"
cluster_domain: hydra.newpaltz.edu
nfs_server: "192.168.1.160"
nfs_path: "/srv/hydra-nfs"
```

# Appendices

## A Cleanup History (February 2026)

A comprehensive infrastructure cleanup was performed February 4–7, 2026:

| Node | Action | Reclaimed |
|---|---|---|
| Hydra | Docker system prune | 114.8 GB |
| Hydra | Remove stale files (`/opt/local-path-provisioner.bak`, temp files) | 20+ GB |
| Hydra | Truncate backup log | 389 MB |
| Chimera | Remove Docker Ollama duplicate + prune | 41.2 GB |
| Cerberus | Docker system prune | 51.3 GB |
| **Total** | | **~227 GB** |

Key cleanup actions:

- Migrated all services from Docker containers to K8s pods
- Archived `legacy/` directory to `legacy-archive` git branch
- Relocated middleman sources to `k8s/components/` directories
- Removed stale Apache configs, scripts, temp files across all nodes
- Cleaned orphaned Docker networks, volumes, and images
- Fixed Traefik stuck rolling update (added `strategy: Recreate`)
- Fixed Ray cluster (removed GPU request from head, deployed properly)
- Verified all middleman APIs operational
- Cloned hydra-saml-auth repo to all 3 nodes

## B Migration History

The infrastructure evolved through several phases:

1. **Bare metal** — Apache web server, manual user management
2. **Docker Compose** — Containerized services, Nginx reverse proxy
3. **K3s** — Initial Kubernetes, migrated from Docker Compose
4. **RKE2** — Current production cluster (January 2026), Traefik ingress

## C References

- RKE2 Documentation: https://docs.rke2.io/
- Traefik Documentation: https://doc.traefik.io/traefik/
- SAML 2.0 Spec: https://docs.oasis-open.org/security/saml/v2.0/
- Azure AD SAML: https://learn.microsoft.com/en-us/entra/identity/
- NVIDIA GPU Operator: https://docs.nvidia.com/datacenter/cloud-native/gpu-operator/
- OpenWebUI: https://docs.openwebui.com
- Ray: https://docs.ray.io/
- n8n: https://docs.n8n.io/