Hydra Infrastructure
Complete Reference Manual

RKE2 Kubernetes Cluster
Student Container Platform
GPU Computing Infrastructure

SUNY New Paltz — Computer Science Department

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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

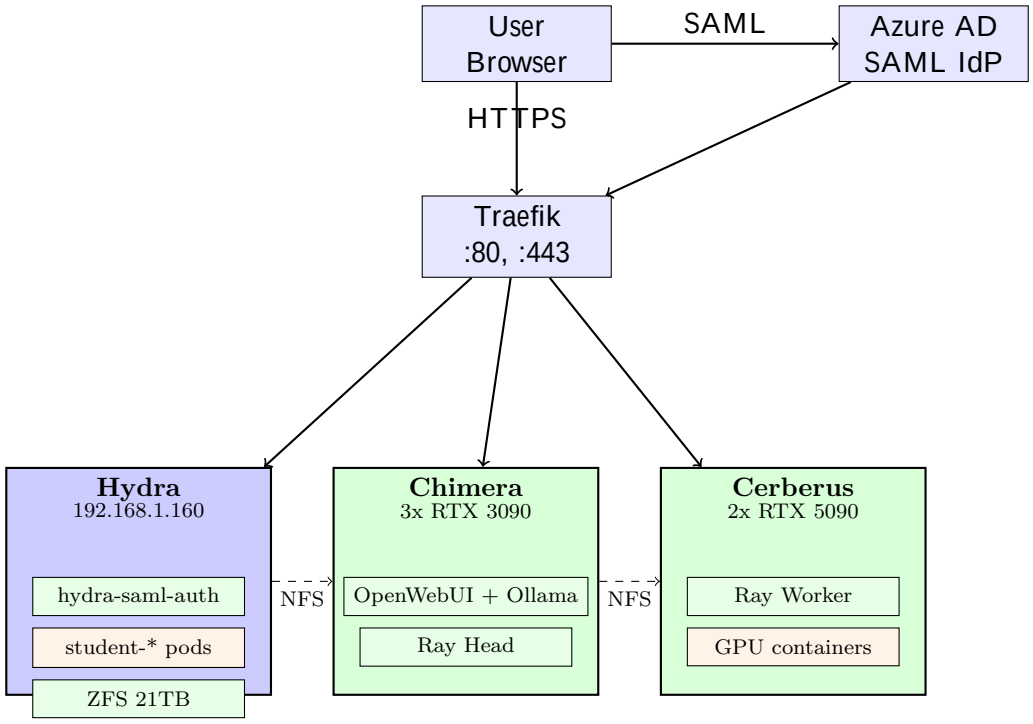
2 Cluster Architecture

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	192.168.1.242	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 + SQLite database (single pod). Serves the department homepage at `hydra.newpaltz.edu`. MariaDB was removed on Feb 9, 2026 — the codebase uses `better-sqlite3` exclusively.

Component	Port	Image
cs-lab	5001	newpaltz-cs-lab-website-backend:latest

Database: SQLite at `/app/server/data/cslab.db`. 15 tables including Admins, Events, Faculty, Courses, StudentHighlightBlog, TechBlog, etc. Persisted via PVC `cs-lab-data`.

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)

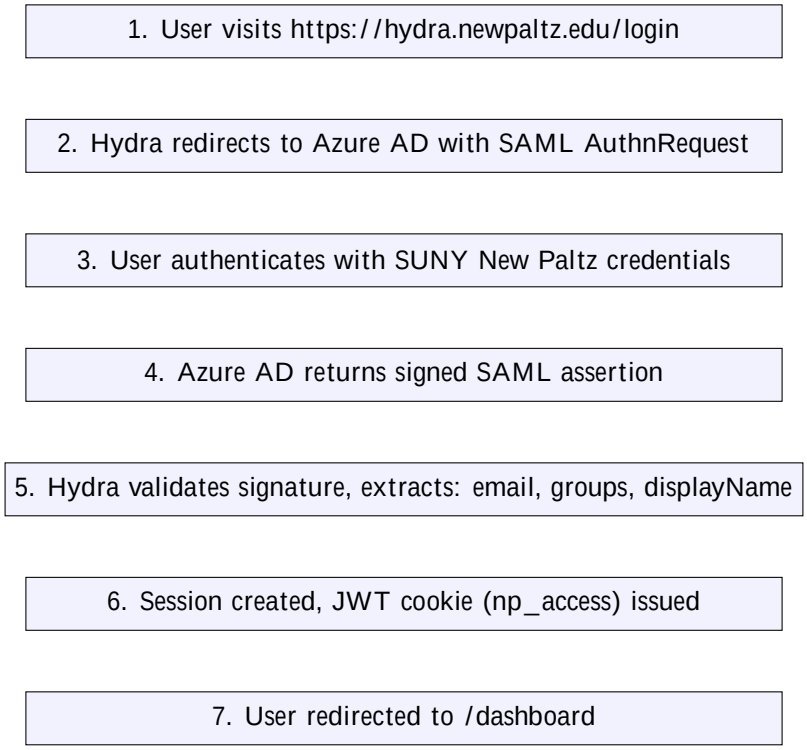
Hydra Exclusion: Hydra (control plane) has no GPUs. All `nvidia.com/gpu.deploy.*` labels are set to `false` on Hydra to prevent GPU operator pods from scheduling there.

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



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 CLI (Docker-in-Docker via rootless)
VS Code	code-server browser IDE (port 8443, always on)
Jupyter	JupyterLab (port 8888, approval required)
Jenkins	CI/CD server (port 8080, approval required)
SSH	Direct access via SSHPiper (port 2222)
Tools	Git, curl, wget, build-essential, gdb, cmake

11.1 Service Management

Each student container runs managed services via `supervisord`. Code-server and Jenkins are always available; Jupyter requires admin approval.

Service	Port	Path	Autostart	Approval
code-server	8443	`/students/{user}/vscode/`	On init	None required
Jenkins	8080	`/students/{user}/jenkins/`	On init	None required
Jupyter Lab	8888	`/students/{user}/jupyter/`	No	`jupyter_execution_approved`
SSH	22	via SSHPiper port 2222	Yes	None required

Jupyter approval flow:

1. Student clicks "Request Jupyter Access" on the dashboard
2. Request stored in `resource_requests` table (type: `jupyter_execution`)
3. Admin approves via admin panel, setting `jupyter_execution_approved` in `user_quotas`
4. On next container init, the `JUPYTER_APPROVED` env var is injected
5. `entrypoint.sh` creates `/var/run/jupyter-approved` marker
6. Supervisor starts Jupyter

CLI gating: Jupyter also has a CLI wrapper (`jupyter-gate.sh`) that blocks direct `jupyter` command usage. The real binary is at `/usr/local/bin/jupyter.real`. Students see an error directing them to request access via the dashboard.

Jenkins: Always available to all students. Start/Stop/Open buttons on the dashboard. Jenkins data persists at `~/.jenkins` in the student's PVC. See the dashboard FAQ for Jenkinsfile examples and test commands.

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 Pod Timing and Lifecycle

14.1 Duration Tiers

When requesting resources, students select a duration for how long their allocation lasts:

Duration	Label	Auto-Approve	Description
1 day	Default	Yes	Quick testing
3 days	Short	Yes	Short assignment
7 days	1 Week	Yes	Short projects
14 days	2 Weeks	Yes	Standard project
30 days	1 Month	Yes	Semester project
60 days	2 Months	No	Extended project
90 days	3 Months	No	Full semester

Config: `config/resources.js` lines 201–213. Default: 1 day. Maximum: 365 days (enforced at `routes/resource-requests.js:500`).

14.2 Resource Limits

Limit	Value
Max containers per user	1
Max storage per user	200 GB
Max memory per container	48 GB
Max CPUs per container	16
Max GPUs per container	2

Config: `config/resources.js` lines 227–234.

14.3 Auto-Approval Thresholds

Requests within these limits are automatically approved without admin intervention:

Resource	Auto-Approve Up To
Memory	4 GB
CPUs	2 cores
Storage	40 GB

Conservative presets on Hydra are always auto-approved. GPU requests always require admin approval. Pending requests expire after 7 days.

Config: `config/resources.js` lines 236–246.

14.4 K8s Resource Quotas per Preset

Each preset maps to specific Kubernetes requests/limits:

Preset	Request Mem	Limit Mem	Request CPU	Limit CPU
Minimal	512Mi	1Gi	250m	1
Conservative	768Mi	1536Mi	500m	1
Standard	1Gi	2Gi	500m	2
Enhanced	2Gi	4Gi	1	4
GPU Inference	16Gi	32Gi	4	8
GPU Training	32Gi	48Gi	8	16

Config: `config/resources.js` lines 256–282.

14.5 Max Concurrent Pods per Node

Node	Max Containers	Notes
Hydra	100	No GPU, control plane
Chimera	20	3 GPUs (1 reserved for OpenWebUI)
Cerberus	10	2 GPUs (training)

14.6 Pod Lifecycle Settings

Setting	Value
Restart policy	`Always`
Termination grace period	30 seconds
Resource requests	50% of limits
Image pull policy	`IfNotPresent`
Security context	`fsGroup: 1000`, `seccompProfile: RuntimeDefault`
Service account	`student-workload`
PVC mount	`/home/student` (persists across restarts)

14.7 JWT Session Duration

Setting	Value
Default JWT TTL	900 seconds (15 minutes)
Production JWT TTL	2,592,000 seconds (30 days)
Algorithm	RS256

Configured via `JWT_TTL_SECONDS` in `.env`. JWKS endpoint: `/.well-known/jwks.json`.

15 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`)

16 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

17 Firewall Configuration (UFW)

17.1 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
```

17.2 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
```

17.3 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
```

18 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)

19 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

20 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
```

20.1 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

20.2 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)

21 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`.

22 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

23 Backup System

23.1 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`

23.2 etcd Snapshots

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

23.3 Backup Exclusions

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

24 Automation and Scheduled Tasks

All recurring automation is documented here for operational reference.

24.1 System Cron Jobs

Schedule	Component	Script	Purpose
Daily 1:00 AM	Root crontab	`/usr/local/bin/backup-cluster.sh`	rsync backup of `/mnt/sdh4/backu`
Weekly Sat 2:45 AM	Root crontab	`certbot renew`	Let's Encrypt SSL newal
1st Sunday/month	`/etc/cron.d/zfsutils`	`/usr/lib/zfs-linux/trim`	ZFS TRIM
2nd Sunday/month	`/etc/cron.d/zfsutils`	`/usr/lib/zfs-linux/scrub`	ZFS scrub integrit
Every 12 hours	RKE2 built-in	etcd auto-snapshot	Stored `/var/lib/ranche`

24.2 Application Background Services

These services run inside the `hydra-auth` Node.js process (started in `index.js` lines 906–958):

Service	Interval	File	Purpose
Metrics collector	30 seconds	`services/metrics-collector.js`	Collects CPU/RAM/disk from all 3 nodes (Chimera/Cerberus via port 9100)
Security monitor	5 minutes	`services/security-monitor.js`	Mining detection (18 known miners), CPU/RAM threshold alerts
Resource expiry	1 hour	`services/resource-expiry.js`	Migrates expired GPU containers back to Hydra, resets to defaults
Container reminders	24 hours	`services/container-reminder.js`	Monthly email reminders to students about their containers

24.3 Security Monitor Thresholds

Metric	Warning	Critical
CPU usage	80%	95%
Memory usage	85%	95%
Mining detected	—	Auto-pause container

Mining enforcement is controlled by `MINING_ENFORCEMENT_ENABLED` in `.env` (default: `true`). Detects: xmrig, ethminer, cgminer, nicehash, etc. (18 process names).

Config: `SECURITY_STATS_INTERVAL` env var (default 300000ms = 5 min, set to 0 to disable).

24.4 Resource Expiry Behavior

When a student's GPU resource allocation expires:

1. Resource expiry checker detects `resources_expire_at` has passed (hourly check)
2. Container is migrated from GPU node (Chimera/Cerberus) back to Hydra
3. Resource config reset to defaults: 4 GB memory, 2 CPUs, 0 GPUs

4. Email notification sent to student
5. Database updated via `resetContainerConfigToDefaults()`

24.5 Dynamic Route Management

Traefik IngressRoutes and SSHPiper configs are managed dynamically:

Event	Action	Details
Pod init	Create routes	`k8sClient.createIngressRoute()` creates 3 routes (vscode, jupyter, jenkins) + ForwardAuth + StripPrefix middleware
Pod init	Update SSHPiper	Writes `sshpiper/config/{user}/sshpiper_upstream` with pod IP
Pod start	Update SSHPiper	Refreshes SSHPiper config with new pod IP
Pod destroy	Delete routes	`k8sClient.deleteIngressRoute()` and `deleteMiddleware()`
Pod destroy	Delete SSHPiper	Removes SSHPiper config directory for user

Key files:

- Route creation: `services/k8s-containers.js` lines 245–323 (`buildIngressRouteSpec`, `buildMiddlewareSpec`)
- SSHPiper update: `services/k8s-containers.js` lines 415–431 (`updateSshPiperConfig`)
- Route recovery on boot: `scripts/fix-k8s-routes.sh` (systemd one-shot service)

24.6 Environment Variables for Automation

Variable	Default	Purpose
`SECURITY_STATS_INTERVAL`	300000	Security check interval (ms), 0 to disable
`MINING_ENFORCEMENT_ENABLED`	true	Auto-pause containers running miners
`JWT_TTL_SECONDS`	900	JWT token lifetime (production: 2592000)
`MAIL_METHOD`	—	Email backend: `graph` or `smtp`
`MS_TENANT_ID`	—	Azure AD tenant for Graph email API
`MS_CLIENT_ID`	—	Azure AD client ID
`MS_CLIENT_SECRET`	—	Azure AD client secret

25 Common Operations

25.1 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
```

25.2 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
Web Services and Route Map

This section documents every web-facing service, its URL, source code location, and how to update it.

26 Complete Site Inventory

Service	URL	Port	Source Code
Hydra Auth (Dashboard)	/dashboard, /login, /auth, /servers	6969	~/hydra-saml-auth/
CS Lab Website	/ (catch-all), /courses, /events, /faculty	5001	~/NewPaltz-CS-Lab-Website/
Hackathons	/hackathons	45821	~/Hackaton-Voting/
Git Learning	/git	38765	~/GG-git-learning/
FLAPJS	/jflap	8080	~/FLAPJS-WebApp/
Java Executor	/java	3000	~/java-executor/
OpenWebUI	gpt.hydra.newpaltz.edu	3000	Pre-built image (ghcr.io)
n8n	n8n.hydra.newpaltz.edu	5678	Pre-built image (docker.n8n.io)
Student VS Code	/students/{user}/vscode/	8443	In student container
Student Jupyter	/students/{user}/jupyter/	8888	In student container
Student Jenkins	/students/{user}/jenkins/	8080	In student container

27 Traefik Route Priority Table

Higher priority number wins when multiple routes match. This table shows how Traefik resolves conflicting paths:

Priority	Path / Host	Service	IngressRoute
100	/hackathons	hackathons:45821	hackathons
25	/api/events	hydra-auth:6969	hydra-main
20	/api/courses, /api/faculty, etc.	cs-lab-backend:5001	cs-lab-website
15	/api/servers, /api/webui	hydra-auth:6969	hydra-main
15	/java	java-executor:3000	java-executor
15	/jflap	flapjs:8080	flapjs
15	/git	git-learning:38765	git-learning
15	n8n.hydra.newpaltz.edu	n8n:5678	n8n
15	gpt.hydra.newpaltz.edu	open-webui:3000	openwebui
10	/dashboard, /login, /auth, etc.	hydra-auth:6969	hydra-main
10	/courses, /events, /admin, etc.	cs-lab-backend:5001	cs-lab-website
5	/css, /js, /static, /SUNYCAT	hydra-auth:6969	hydra-main
1	/ (catch-all, no path)	cs-lab-backend:5001	hydra-default

Route conflicts: If a new API path overlaps with an existing route (e.g., both hydra-auth and cs-lab use `/api/events`), the higher-priority route wins. Always check existing routes before adding new ones: `kubectl get ingressroute -A -o wide`.

28 How to Update Each Service

28.1 Hydra Auth (Dashboard)

Stack: React SPA built with webpack, served by Nginx. Uses `sub_filter` to inject `<base href="/jflap/">` for subpath routing.

28.5 Git Learning

```
cd ~/GG-git-learning
sudo buildah bud -t gg-git-learning-app:latest .
kubectl -n hydra-infra rollout restart deploy/git-learning
```

Stack: Node.js with PM2 runtime.

28.6 Java Executor

```
cd ~/java-executor
sudo buildah bud -t docker-java-executor-java-executor:latest .
kubectl -n hydra-infra rollout restart deploy/java-executor
```

Note: Mounts host Docker socket for container-based Java compilation.

28.7 Student Container Image

```
cd ~/hydra-saml-auth
./scripts/build-deploy.sh student

# This builds the student-container image and notes that
# existing student pods need restart to use the new image.
# Update STUDENT_IMAGE in .env if using a versioned tag.
```

28.8 OpenWebUI and n8n

These use upstream pre-built images. To update:

```
# OpenWebUI: Update image tag in deployment spec
kubectl -n hydra-infra set image deploy/open-webui \
  open-webui=ghcr.io/open-webui/open-webui:vNEW

# n8n: Update image tag in deployment spec
kubectl -n hydra-infra set image deploy/n8n \
  n8n=docker.n8n.io/n8nio/n8n:NEW_VERSION
```

29 K8s Manifests Location

All K8s deployment manifests live in `~/hydra-saml-auth/k8s/`:

Service	Manifest Path
Namespaces, RBAC, storage	`k8s/base/`
Hydra Auth	`k8s/components/hydra-auth/`
CS Lab	`k8s/components/cs-lab/`
Traefik	`k8s/components/traefik/`
Hackathons	`k8s/components/hackathons/`
Git Learning	`k8s/components/git-learning/`
FLAPJS	`k8s/components/flapjs/`
Java Executor	`k8s/components/java-executor/`
n8n	`k8s/components/n8n/`
OpenWebUI	`k8s/components/openwebui/`
Ollama	`k8s/components/ollama/`
Student Pods	`k8s/components/student-pods/`
SSHPiper	`k8s/components/sshpiper/`

30 Namespace Layout

Namespace	Contents
`hydra-system`	Core services: traefik, hydra-auth, cs-lab
`hydra-infra`	Infrastructure: n8n, openwebui, ollama, ray, git-learning, hackathons, flapjs, java-executor, sshpiper
`hydra-students`	Student containers (dynamically created per-user)
`gpu-operator`	NVIDIA GPU Operator, device plugin, DCGM exporter
`kube-system`	K8s system components (etcd, coredns, canal, metrics-server)

Part VIII
OpenWebUI API Integration

31 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

32 API Configuration

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

33 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!"}]
  }'
```

34 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)
```

35 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 IX
Security

36 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

37 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.

38 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 X
RDMA and GPUDirect

39 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

40 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.

41 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
```

42 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 XI
Troubleshooting

43 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

44 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

45 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

46 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

47 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
```

48 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 XII
Repository Structure

49 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
```

50 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 XIII
Environment Configuration

51 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)

52 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
5. **Infrastructure Overhaul** — February 9, 2026 (see below)

C February 9, 2026 — Infrastructure Overhaul

Following a 5-hour OOM death spiral that made the server unresponsive, the following changes were applied:

1. **Phase 1: Docker cleanup** — Pruned 11.86 GB orphaned Docker volumes, stopped and disabled Docker daemon on all nodes. Build tool changed to `buildah` (daemonless).
2. **Phase 2: Networking** — Removed nginx (conflicted with Traefik on port 80), fixed SUNYCAT.png route, fixed OpenWebUI cross-namespace reference, corrected OpenWebUI API fallback URL.
3. **Phase 3: CS Lab consolidation** — Removed MariaDB pod (app uses SQLite). Went from 2 pods (backend + MariaDB) to 1 pod (cs-lab). Removed `mariadb` npm dependency.
4. **Phase 4: RKE2 data migration** — Moved `/var/lib/rancher/rke2` (40 GB) to RAID at `/data/rke2`. Symlinked old path for backward compatibility. Config updated: `data-dir: /data/rke2`.

5. **Phase 5: OOM prevention** — Added 32 GB swap on RAID (`vm.swappiness=10`), kubelet eviction thresholds (`memory.available<2Gi` hard, `4Gi` soft), `system-reserved=4Gi`, `kube-reserved=2Gi`. Applied `ResourceQuota` and `LimitRange` to `hydra-students` namespace (default 2Gi/1CPU per container, max 48Gi/16CPU). Enabled auto-reboot after kernel updates at 04:00.

Build tools after overhaul:

- `buildah` — Daemonless OCI image builder (primary)
- `nerdctl` — Docker-compatible CLI for containerd (`/usr/local/bin/nerdctl`)
- Docker daemon is **disabled** (`systemctl disable docker`)

D February 9, 2026 — Jenkins Service + Jupyter Gating + Repo Cleanup

1. **Jupyter execution gating** — Supervisor `autostart=false`, CLI gate wrapper (`jupyter-gate.sh`), API approval endpoints, `JUPYTER_APPROVED` env var marker. Students cannot run Jupyter until admin approves.
2. **Jenkins CI/CD service** — Added as 3rd managed service inside student containers. Supervisor config (port 8080, `autostart=false`), K8s pod/service/IngressRoute/strip-prefix routing, DB schema (`jenkins_execution_approved`), admin approval flow, dashboard UI card with Start/Stop/Open buttons.
3. **Repo cleanup** — Removed 12 dead Docker-era files (deploy scripts, old Python metrics agent, Apache config, SSHPiper Docker Compose, student-mvp, Ray reference compose files). Scrubbed plaintext secret files from git history. Added `.example` templates for K8s secrets.
4. **K8s template updates** — Added Jenkins port 8080 to pod template, Jenkins route/middleware/service port to IngressRoute template, flapjs deployment.
5. **Security** — Removed `cs-lab/secret.yaml` and `n8n/secret.yaml` from git tracking (contained plaintext credentials). Added to `.gitignore`. Credentials should be rotated.

E February 9, 2026 — Route Fixes + Pod Restart + Documentation

1. **FLAPJS fix** — Dockerfile wasn't copying `index.html` from project root (webpack outputs it outside `dist/`). Fixed Dockerfile + added nginx `sub_filter` for `<base href="/jflap/">` injection.
2. **Hydra-auth deployment** — Containerd ':latest' tag was resolving to stale Docker Hub image. Switched to unique versioned tags (`v20260209-HHMMSS`) with `imagePullPolicy: Never`. Created `scripts/build-deploy.sh` for reliable single-path builds.
3. **Jenkins ungated** — Removed approval requirement for Jenkins. All students can now Start/Stop Jenkins from dashboard without admin approval.
4. **Traefik route conflict** — `/api/events` was being intercepted by cs-lab-website (priority 20) instead of hydra-auth (priority 15). Bumped hydra-auth's route to priority 25.
5. **Pod batch restart** — All 26 student pods restarted from Completed state. PVC data preserved. Code-server started on all pods via supervisorctl batch command.
6. **Temp cleanup** — Freed 2.6 GB on Hydra (`/tmp` build artifacts), cleaned audit exports on Chimera and Cerberus.
7. **Documentation** — Added Pod Timing & Lifecycle section, Automation & Scheduled Tasks section, Web Services & Route Map with rebuild instructions for all services.

F 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/