CSCS
Centro Svizzero di Calcolo Scientifico
Swiss National Supercomputing Centre

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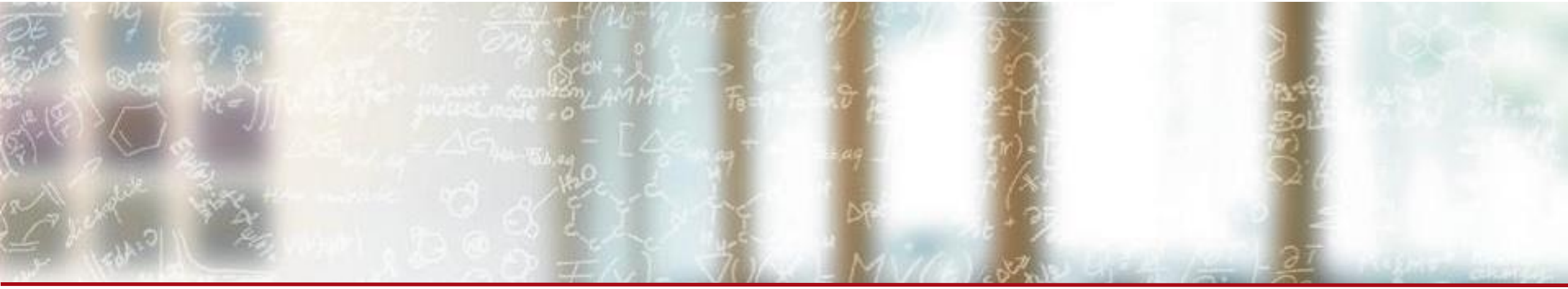

Service Management and the vCluster Technology

SOS27

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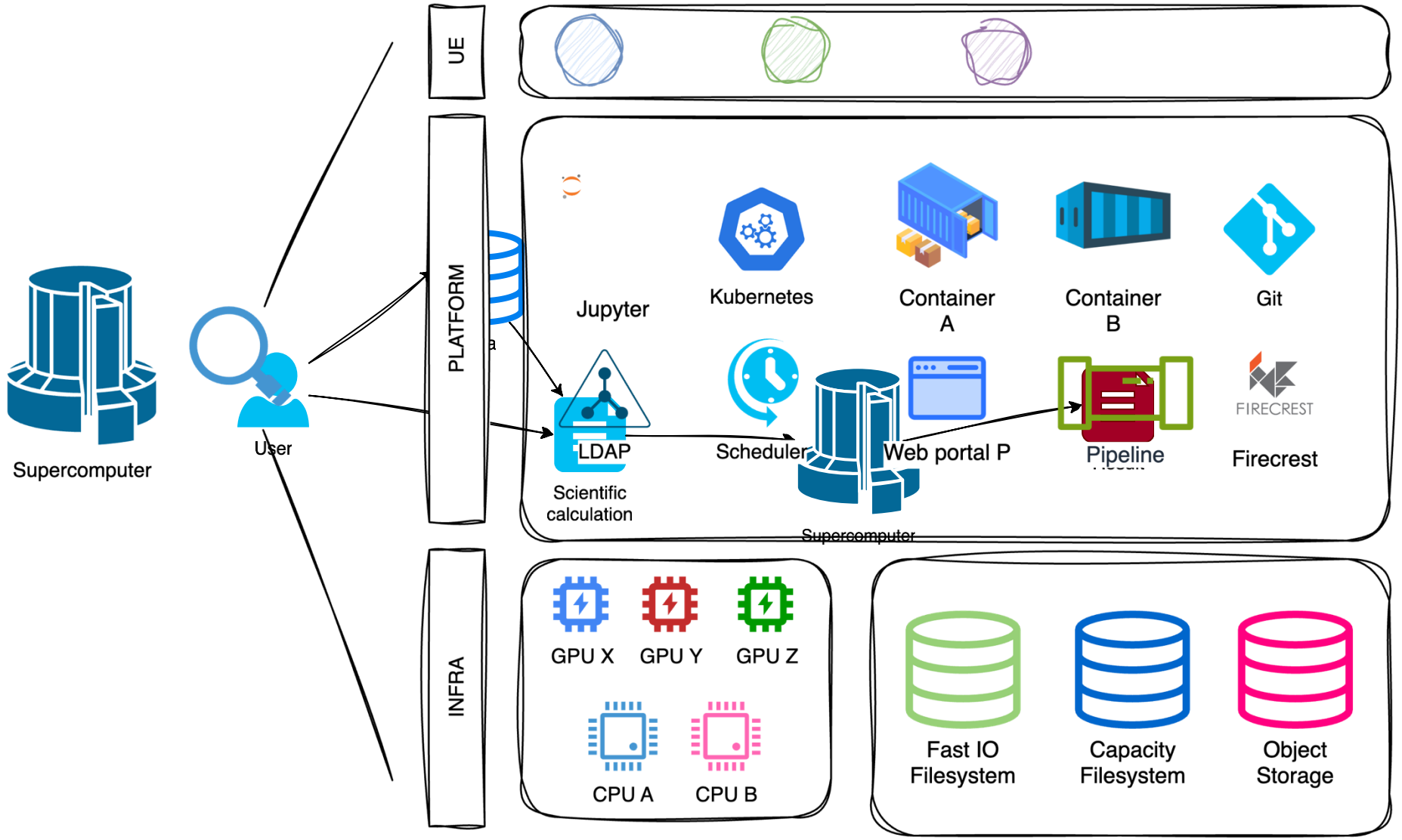
March 18, 2025

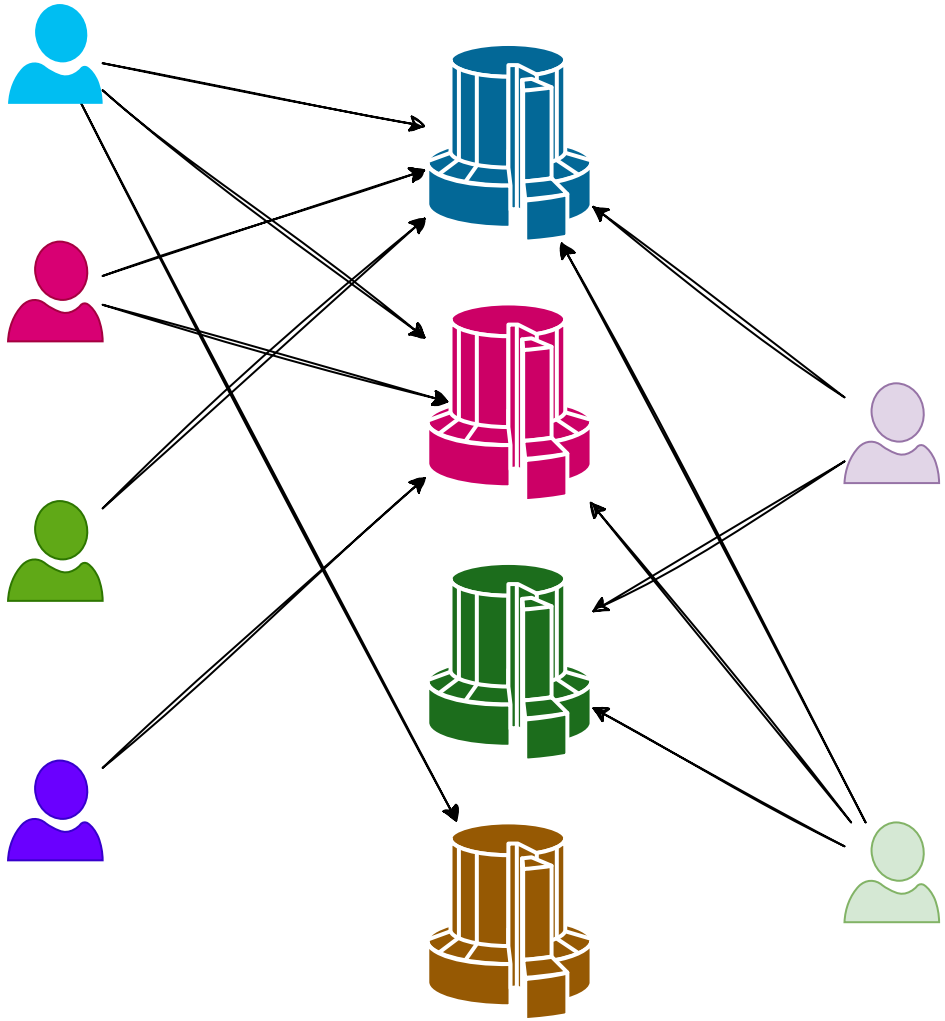
Running jobs, right?



Adding dimensions complicates things even more

- Multiple user **communities**
- **Different requirements** per community, and of course, even within a given community
- Multiple **sites**
- Potentially several infrastructure **vendors**
- Different **configurations** of hardware and software

- Data management
- Service management
- User management
- …



vCluster Technology

HPC and Cloud convergence

- Science and engineering requires more and more computer assisted experiments
  - Simulation of physical phenomena and behaviours
  - Digital Twins
  - Design engineering products
  - AI/ML solutions

- HPC offers high-performance compute and data access
  - Improves time to solution
  - Managed efficiently data to compute

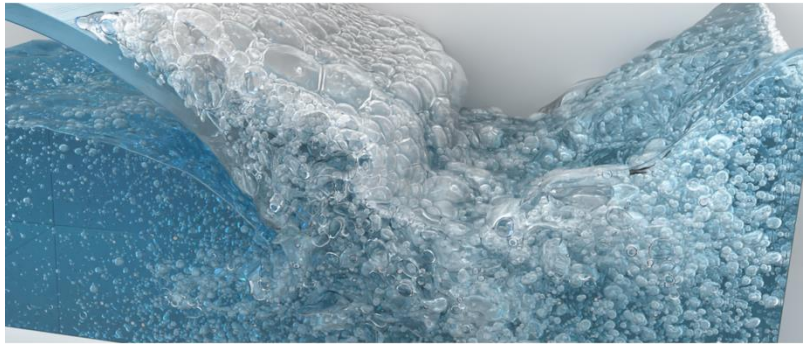
- Cloud offers high flexibility for business needs
  - XaaS – business logic as a service
  - Economy of scale – oversubscription of resources

How to combine the best of the two worlds?

HPC and Cloud convergence

- Cloud providers have invested heavily in abstractions from the hardware (IaC, APIs, virtualization, etc.)
- **Cloud** design principle – towards enterprise
- Economy of scale – oversubscription of resources

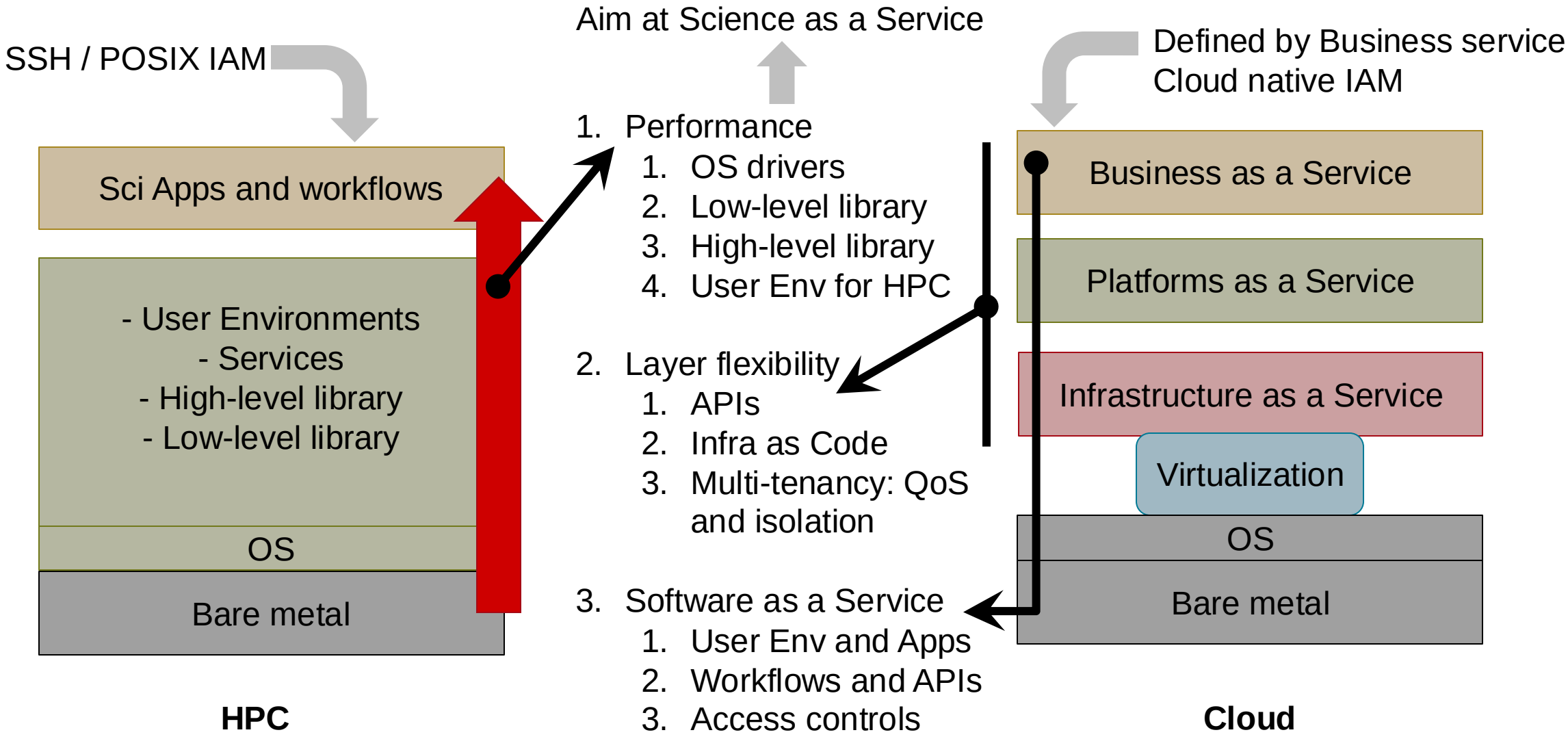
Virtualization at scale → High **flexibility** → Limited performance



- **HPC** design principle – towards science
- Traditionally, HPC has invested heavily in vertically integrated environments
- Improves Time to Solution

High performance → **Limited** set of services → Fully integrated stack

HPC and Cloud concepts to enable Science



How to achieve HPC and Cloud convergence?

- Performance and Flexibility
  - Use container as an abstraction layers with OCI hooks
    - Keep OS near bare metal – Accelerators and High-speed network drivers
    - Bring low-level libraries in the container with OCI Hooks
  - Bring your own UE technology
    - Decouple HPC programming environments from underlying layers
    - UE as an artifact mounted in the container
- Separation of concerns with layers
  - Platforms
    - Provisioning of services with orchestrators
    - Container as an abstraction layer for compute nodes
  - Infrastructure as code
    - APIs and configuration management
    - Multi-tenancy: exclusive compute, network and storage segregation
- HPC business logic
  - Web-facing API to access HPC resources (submit jobs, move data)
  - Web gateway

Versatile software-defined cluster

vCluster Technology

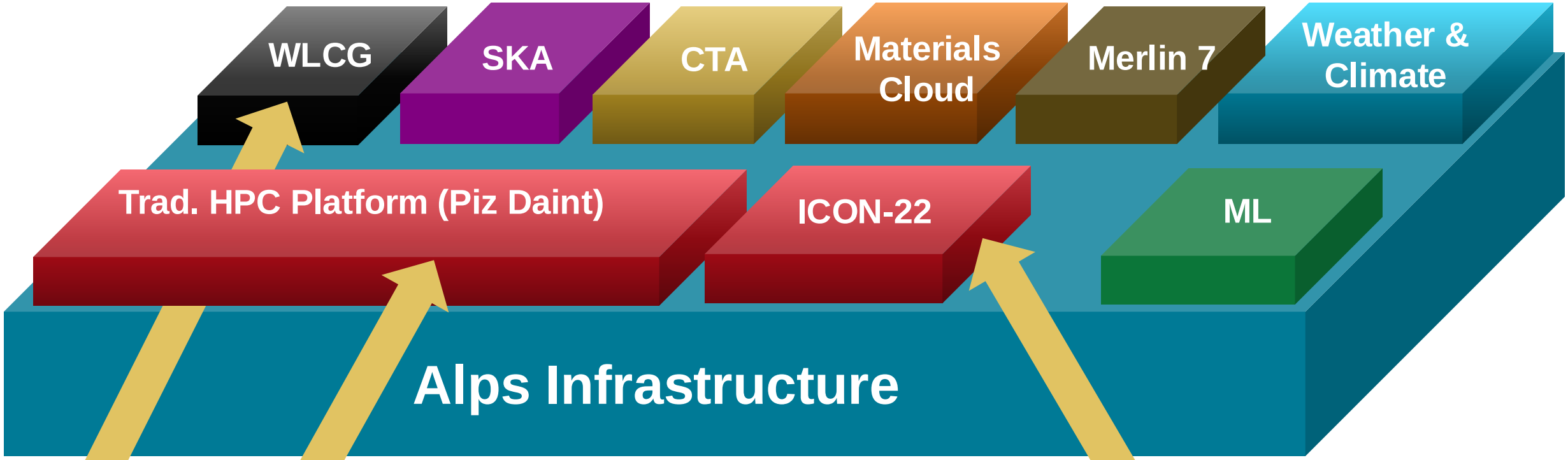
- The vCluster Technology is a set of components and practices that allows CSCS to “partition” one or more computing systems into logical units called Platforms and vClusters

- A Platform is a collection of 1 or more vClusters

- A vCluster is a collection of resources and services grouped for a common set of use-cases (e.g., ML community, HPC community, WLCG, etc.)

- Relies on DevOps concepts, mixing ideas from both the cloud world, and the traditional HPC environment

Consolidation of platforms

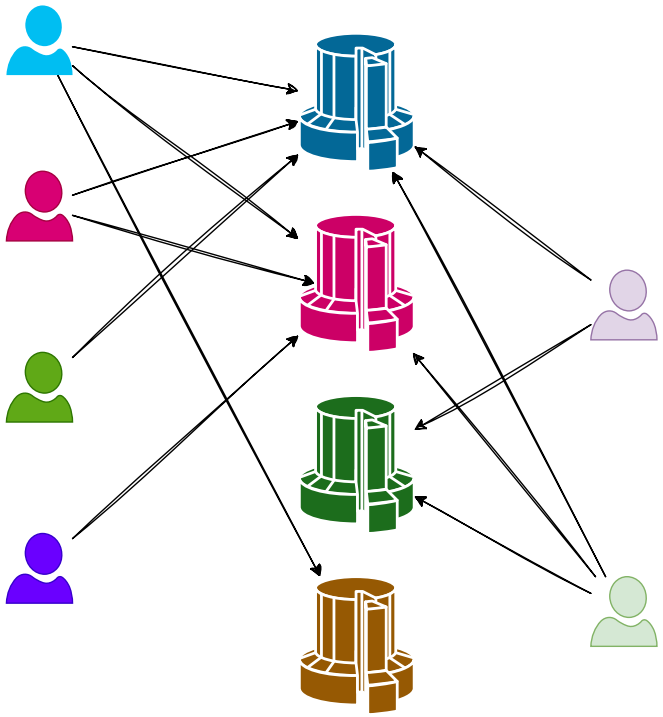


Piz Daint
User lab and WLCG

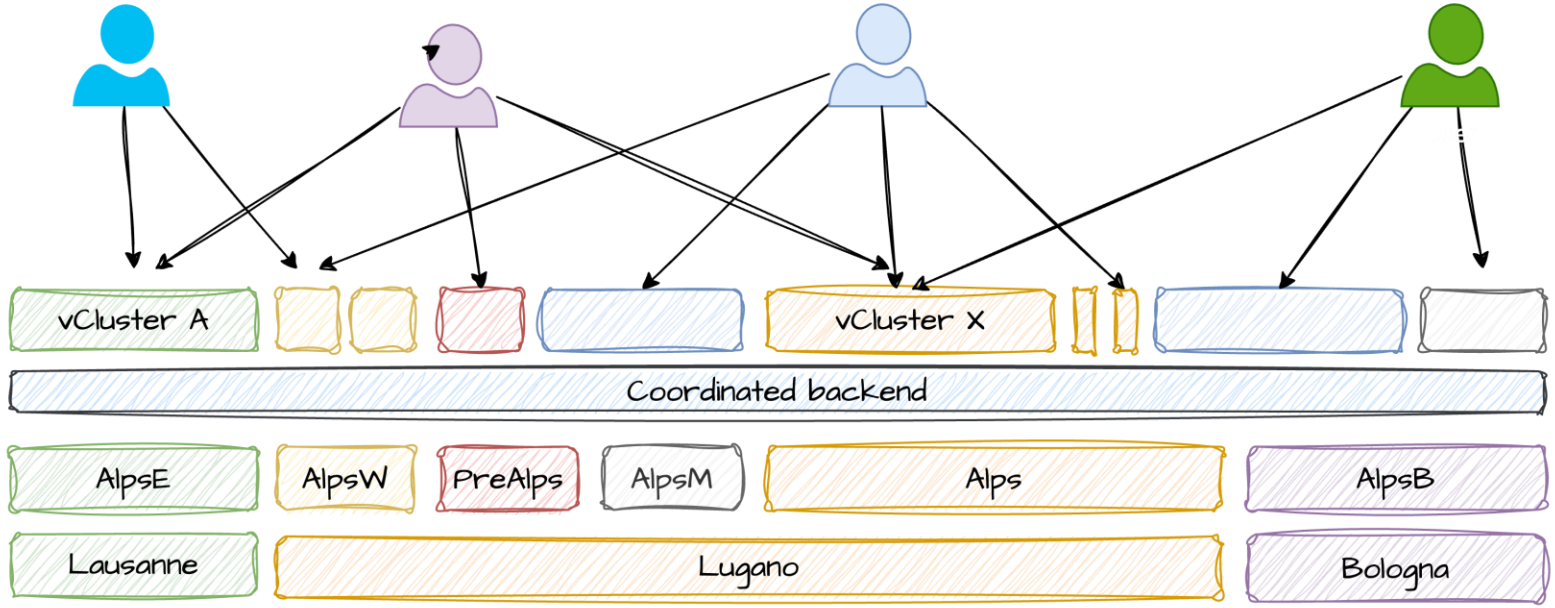
MeteoSwiss
Arolla/Tsa
COSMO/ModInterim

vClusters in context

- Instead of having discrete HPC systems, one per community group:

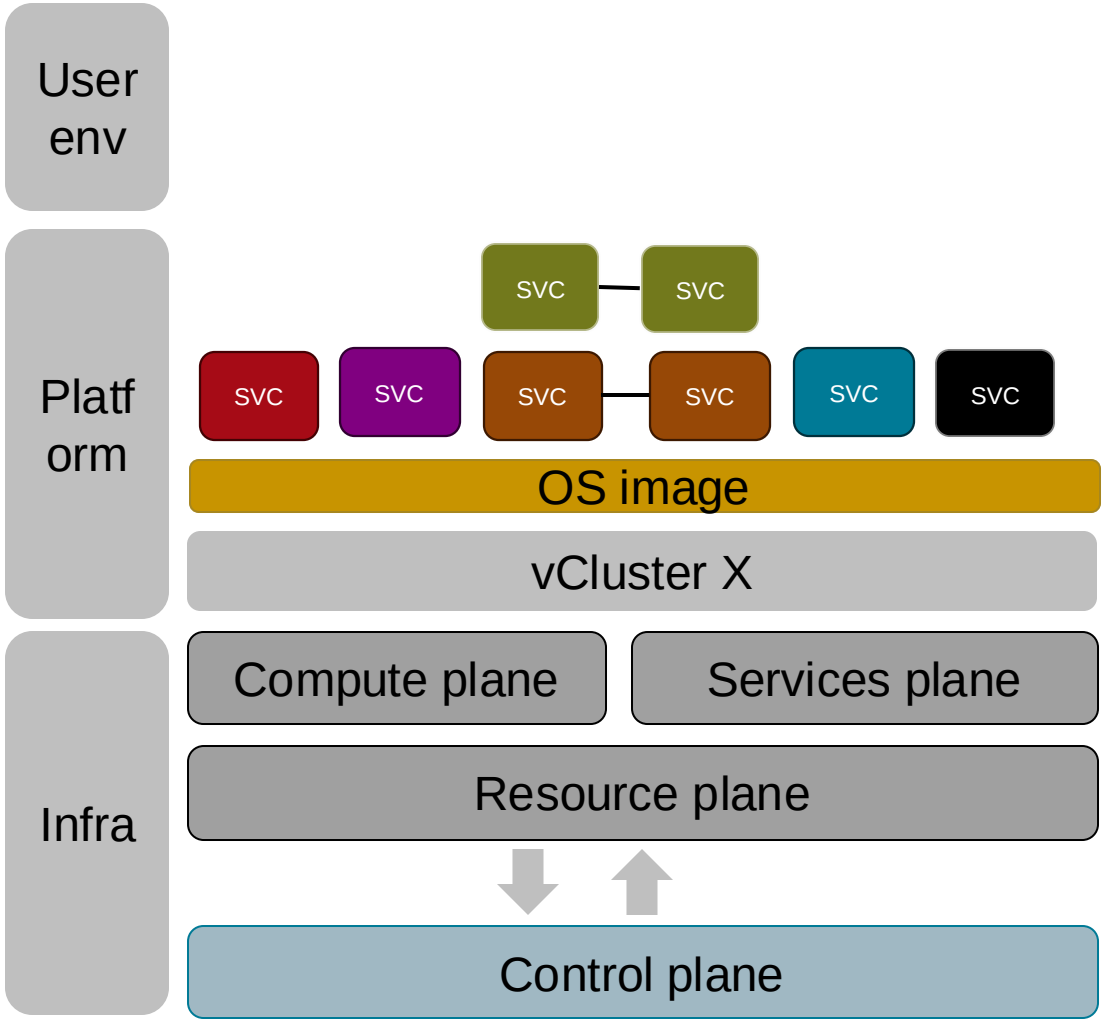


- To a distributed environment with multiple infrastructures acting as a coordinated backend to run multiple vClusters



Service management

Composability and modularity

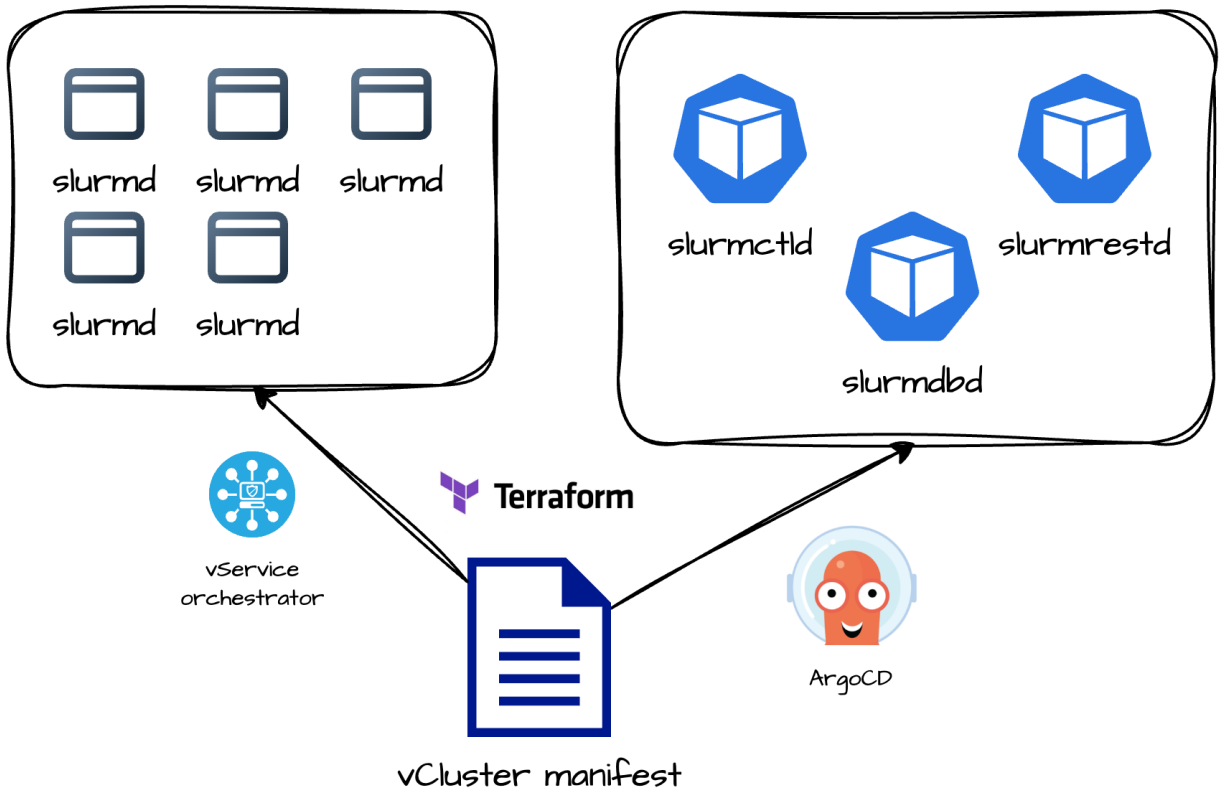


- A vCluster is a collection of resources on top of hardware
- On those resources, we run an OS image validated by infra team, and collection of services, named vServices
- Those vServices can span across multiple planes, e.g.,:
  - Compute plane
  - Services plane
- An example:
  - Slurmd runs on the compute plane
  - Slurmctld (+ SlurmDBD + SlumRESTd) run on the services plane

Example: Slurm vService

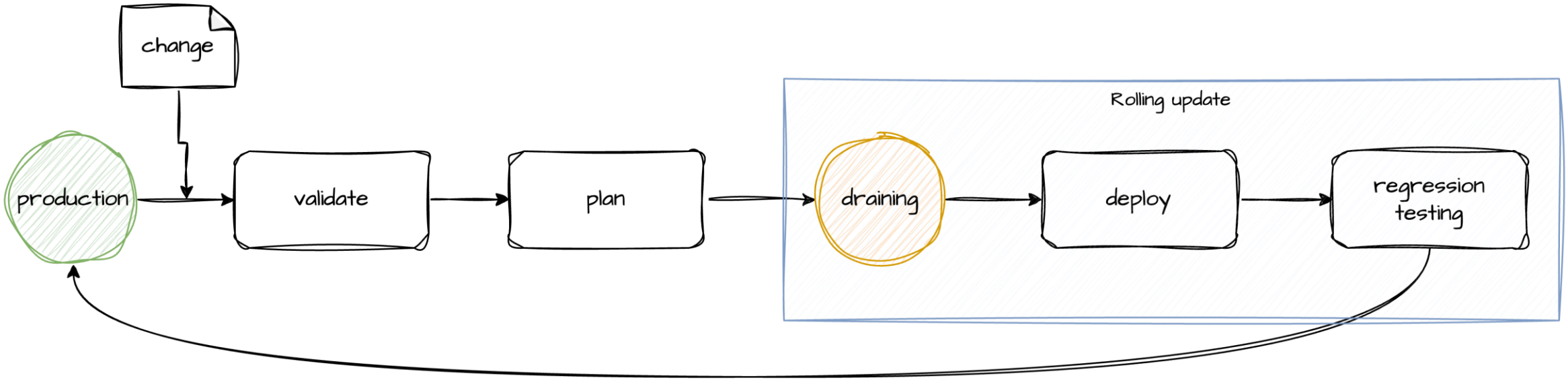
- Services on both planes are declared in a single manifest, and provisioned **as a single entity**:

- On the compute plane, our vService orchestrator ensures that the relevant Slurm artifacts for a given release (packages, config files, etc.) are deployed and running.
- On the services plane, ArgoCD deploys the necessary helm charts, pods (potentially even VMs), for the selected product release.



What makes this special?

- Simplified view of the configuration of a vCluster
- vServices and vClusters are products that follow common development, testing and validation processes
- This enables automated integration testing and rolling updates(*) with minimal human intervention



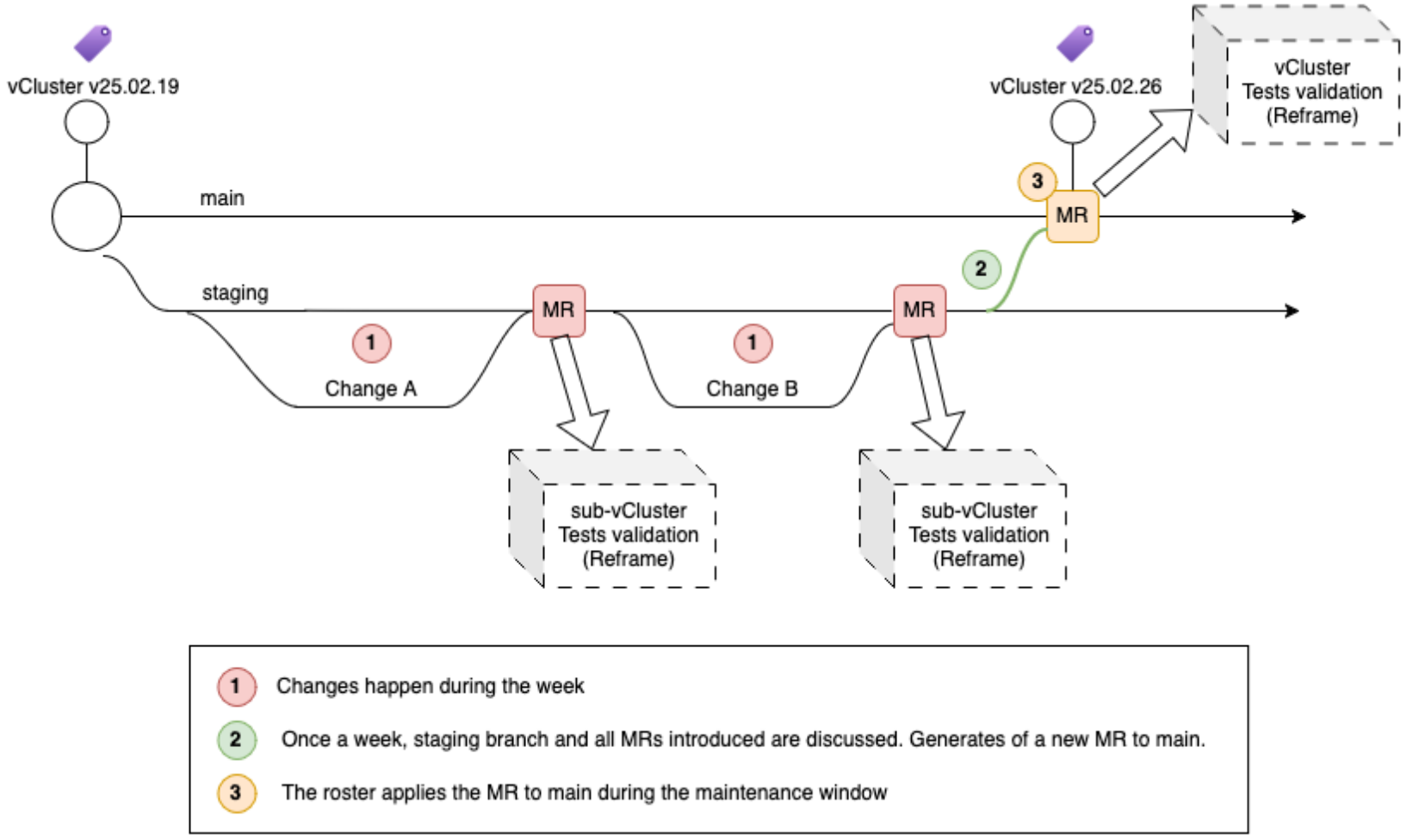
(*) work in progress

Simplified manifest

```
34  module "cscs-config" {
35    source       = "git@git.cscs.ch:alps-platforms/vservices/vs-cscs-config.gi?ref=v1.0.1"
36    deploy       = true
37    vcluster     = module.vcluster
38    hsm_groups   = "daint"
39    ansible_vars = file("platform/config/cscs-config/vars.yml")
40    ccm_version  = "cscs-24.8.0"
41    playbook     = "site.yml"
42  }
43
44  module "storage" {
45    source            = "git@git.cscs.ch:alps-platforms/vservices/vs-storage.git?ref=v1.0.6"
46    deploy            = true
47    vcluster          = module.vcluster
48    ansible_vars      = file("platform/config/storage/vars.yml")
49    node_dependencies = ["cscs-config"]
50
51    capstor_scratch_cscs_state  = "mounted"
52    capstor_store_cscs_state    = "mounted"
53    capstor_users_cscs_state    = "mounted"
54    iopsstor_scratch_cscs_state = "mounted"
55    iopsstor_store_cscs_state   = "mounted"
56    vast_users_cscs_state       = "mounted"
57  }
58
```

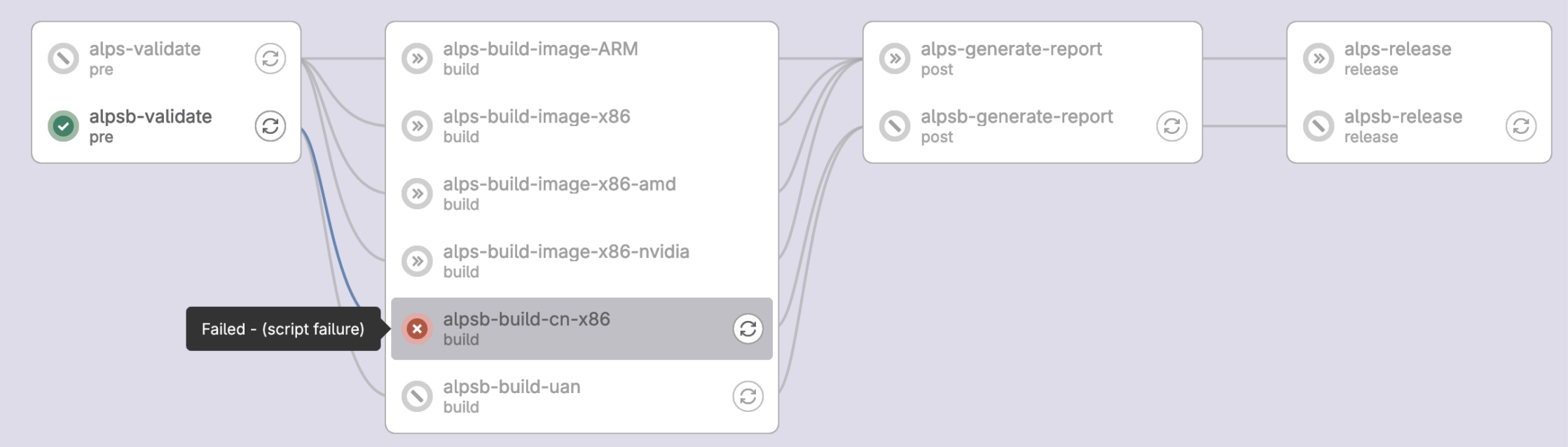
Introducing changes with full test coverage

- GitFlow
- Using and abusing Git and pipelines for **any** change
- Tests happen with each MR
- Service changes are orchestrated in a rolling fashion
- Minimal human intervention



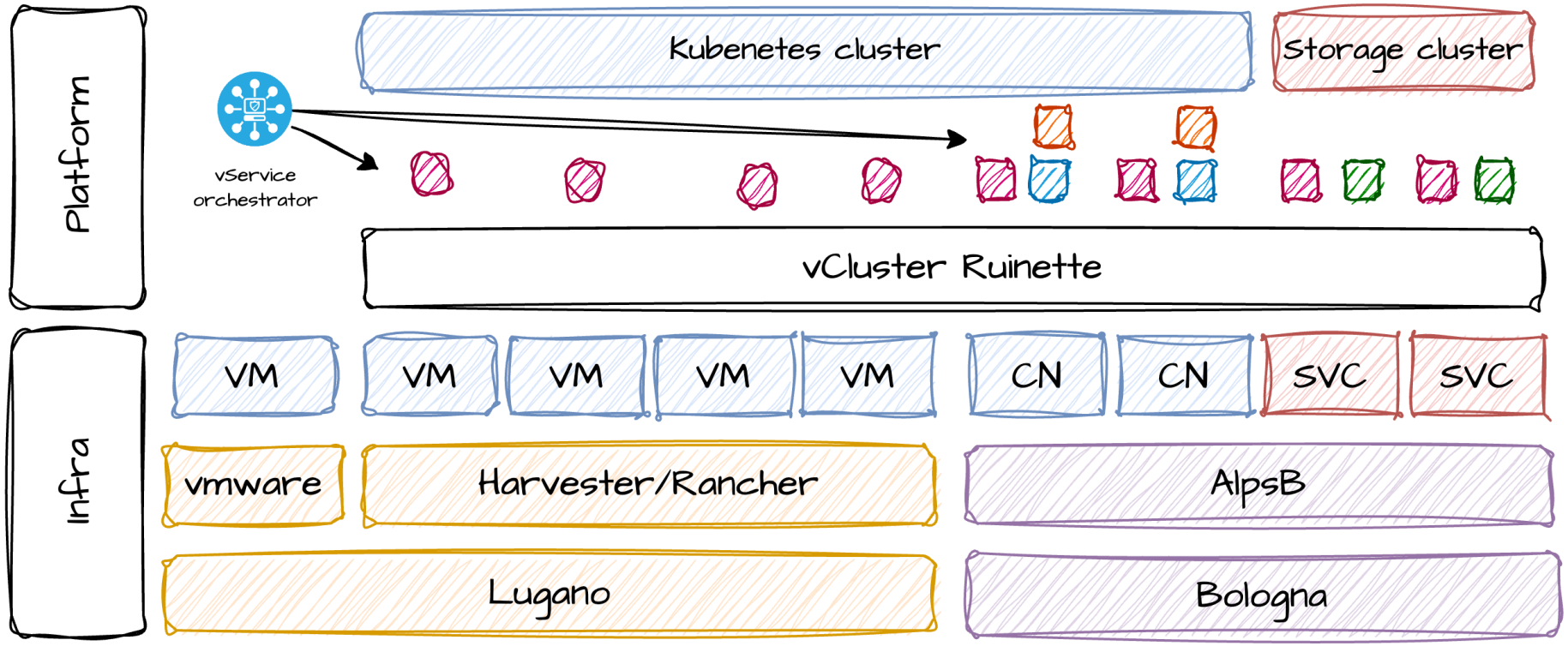
Example: building a vCluster image

- vCluster images are generic: one per infra and hardware type
- Built automatically by a pipeline using **manta**
- Ready for OpenCHAMI



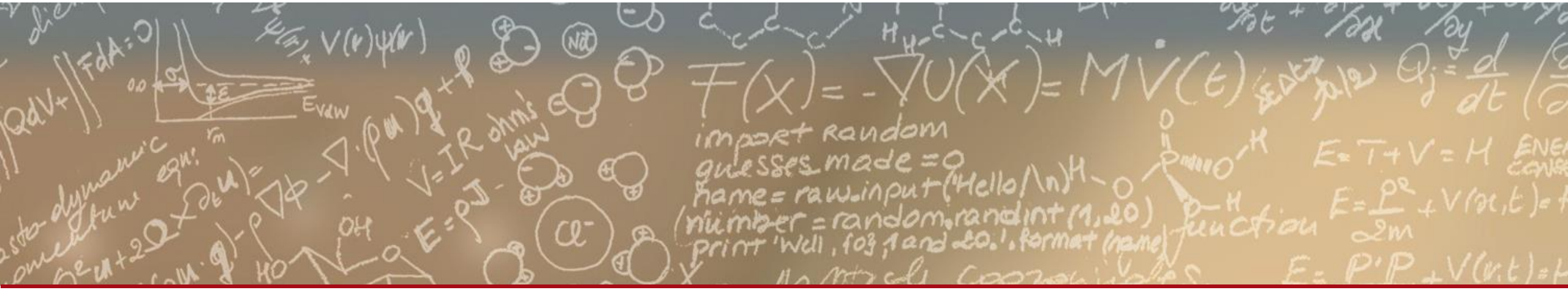
Example: vCluster Ruinette

- Best example of a vCluster: some components live in Lugano, others in Bologna, all are orchestrated with the vCluster technology



vClusters and vServices in numbers

- Currently have around 20 vServices in active development (and usage)
  - Core: IAM, Storage, Container Engine(s), **Network**, Slurm, **Security**
  - Uenv, Firecrest, Observability, Validation, Health Engine etc.
- ~900 MRs in the last two years
- A given vCluster operates with a manifest of about 100 lines of code
- 16 vClusters in operation with this model
- About 8 more that will transition to it in 2025 Q2
- After this, Alps alone will have about 50k vService instances running



Thank you for your attention.