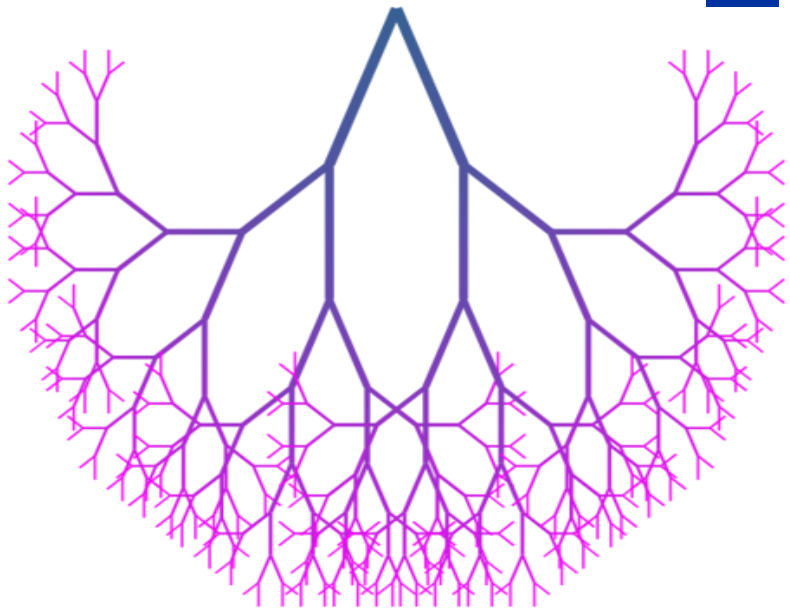


Flux, a next-generation resource management framework

April, 2026

Tom Scogland, Flux Lead

With work from the whole flux team

Prepared by LLNL under Contract DE-AC52-07NA27344.

What is Flux Framework About?

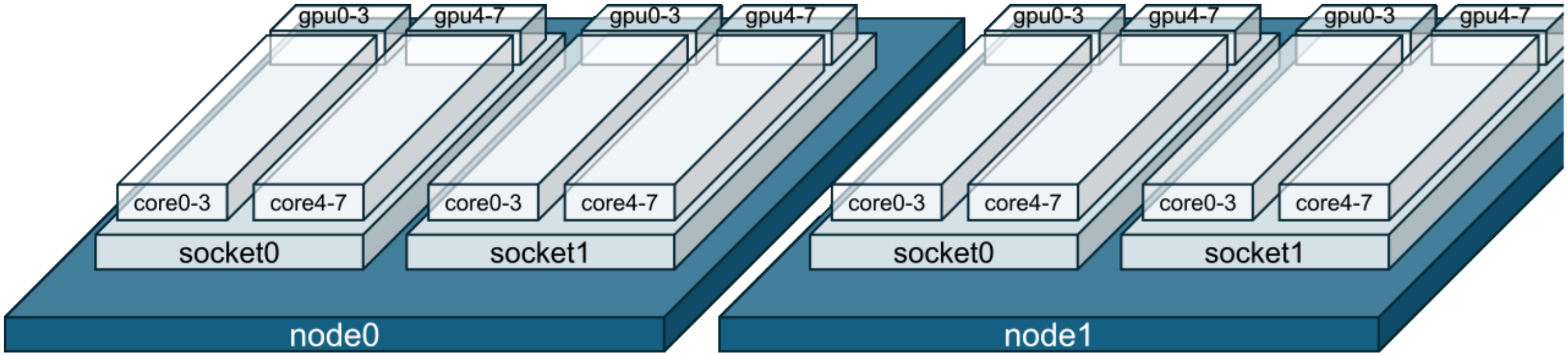
Flux Framework is the next-generation workload manager and resource orchestration suite designed for modern, complex, and heterogeneous high-performance computing (HPC) environments.

Backed by expertise

Flux has 25+ contributors, including principal engineers behind Slurm, and developers with expertise in container technologies, scheduling, workflows, and cloud computing.

What is Flux Framework About?

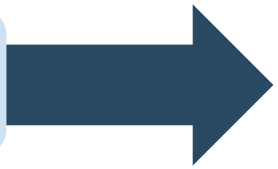
- Hierarchical scheduling breaks the traditional monolithic scheduler bottleneck by distributing scheduling decisions and managing resources at multiple levels.



What is Flux Framework About?

- Graph-based resource model to natively expresses and control complex hardware topologies and devices (like GPUs).

```
flux run -N 6  -n 216 ./app
```



```
version: 1
resources:
  - type: cluster
    count: 1
    with:
      - type: rack
        count: 2
        with:
          - type: slot
            label: myslot
            count: 3
            with:
              - type: node
                count: 1
                with:
                  - type: socket
                    count: 2
                    with:
                      - type: core
                        count: 18

# a comment
attributes:
  system:
    duration: 3600
tasks:
  - command: app
    slot: myslot
    count:
      per_slot: 1
```

How is Flux Framework Used?

Flux is built to solve the resource management challenges of the post-Exascale era, bridging the gap between traditional batch processing and modern, dynamic workflows.

- **Exascale & Top 500**: NNSA exascale system El Capitan and other Top 500 supercomputers.
- **Converged Computing (HPC + Kubernetes)**: fully functional batch schedulers inside Kubernetes pods, bypassing etcd bottlenecks (Flux Operator).
- **Complex, heterogeneous workflows**: oriented for workflows where simulation and AI/ML components must coexist and share resources efficiently.
- **Graph-based modeling**: handles complex hardware topologies, ensuring the right job gets the right hardware (e.g., GPUs, interconnects) for existing and future hardware.
- **Systems research and innovation**: prototype novel scheduling algorithms.

How did Flux come to be?

2012 — Project Established
Initial project funding proposal and staffing

2013 — Design
Preliminary design review

2014 — Instance Launch
Prototype Flux instance that could be launched by Slurm/mpiexec

2016 — Flux Core 0.1.0
First public release of Flux Core

2018 — Science
Flux used by Pilot2 cancer moonshot ensemble

2019 — Best Paper
Flux used by MuMMI, SC19 Best Paper Award winner

2020 — System Instances
Release of Flux Core with system instance support

2021 — MuMMI Workflow
Flux+MuMMI Integration used for RAS-RAF membrane dynamics ensemble

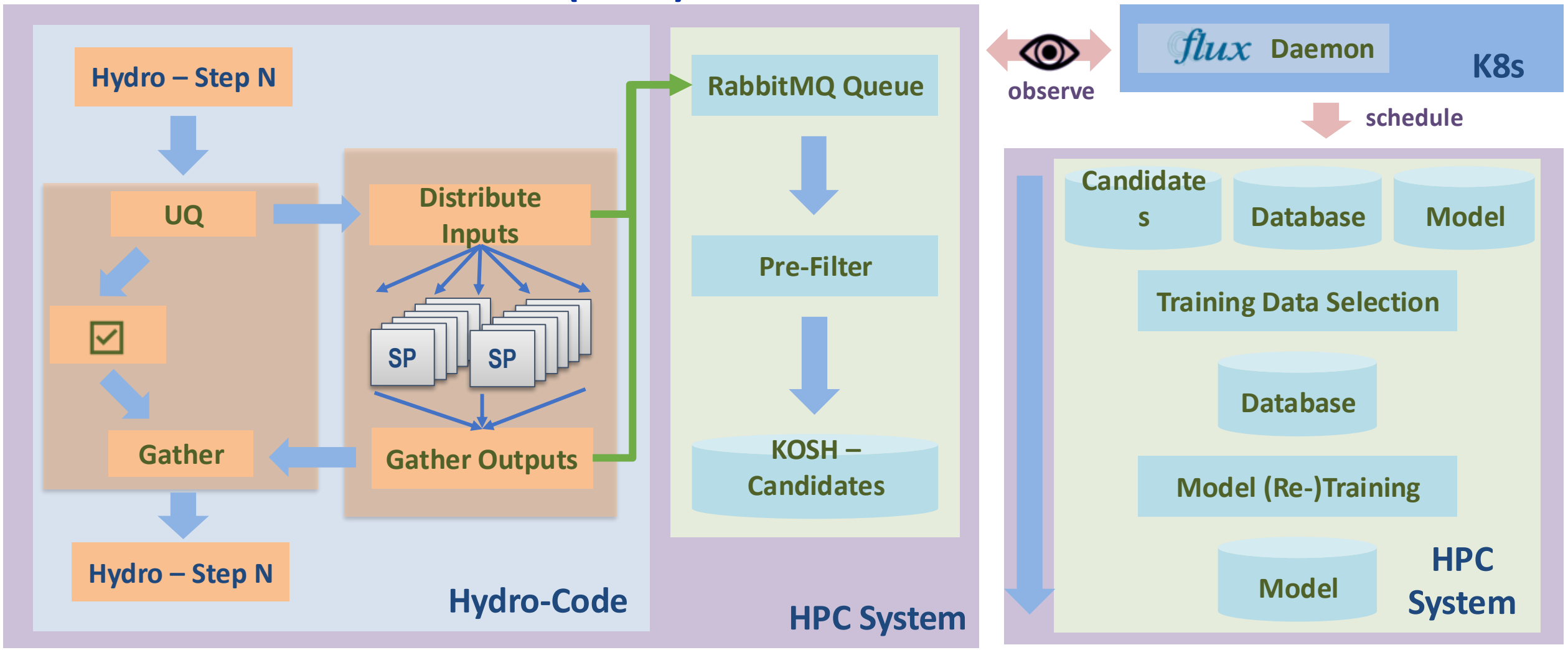
2024-2026 — El Capitan
Flux system instance deployed on El Capitan, #1 on Top500 (-2026)

...

Why build another one?

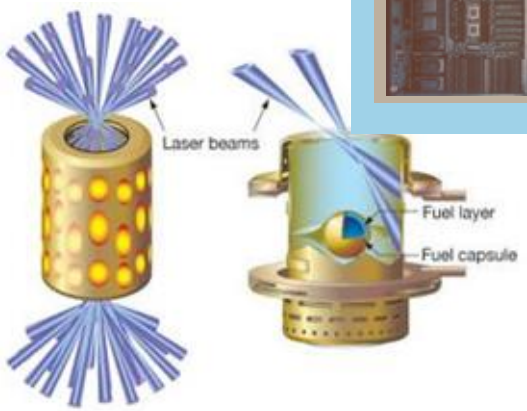
Or: Why not just use {slurm,PBS,LSF}?

Autonomous Multiscale (AMS) Workflow



https://github.com/LLNL/AMS

https://www.osti.gov/servlets/purl/1630805



flux

redis
Merlin
RabbitMQ

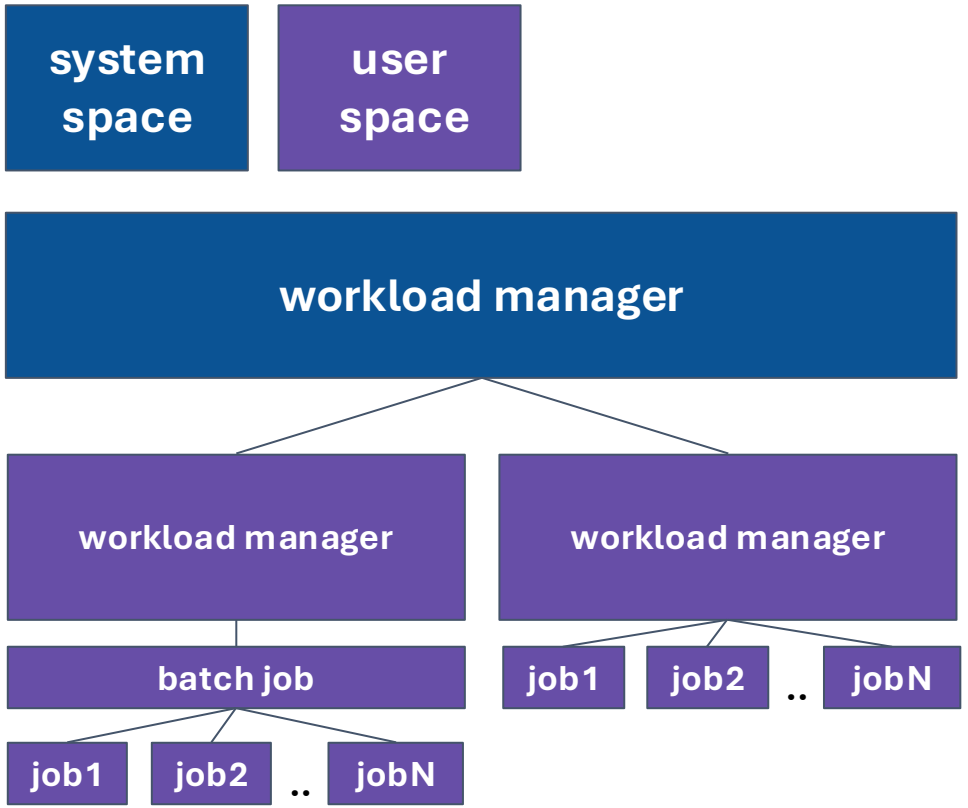
Combination of 1024- and 512-node jobs (blue subsquare is 32 nodes), 61,440 concurrent workers

1. Emerging workflows and systems need a flexible resource model

- Resources like network, power, storage, and **<insert future resource>** are not easily integrated into existing schedulers.
- A *flexible resource model* can express arbitrary resources, including those that don't exist yet.

2. The hierarchical design facilitates portability

- A resource manager can be instantiated *as a job* under another resource manager
- The resource manager itself can be a portability layer.



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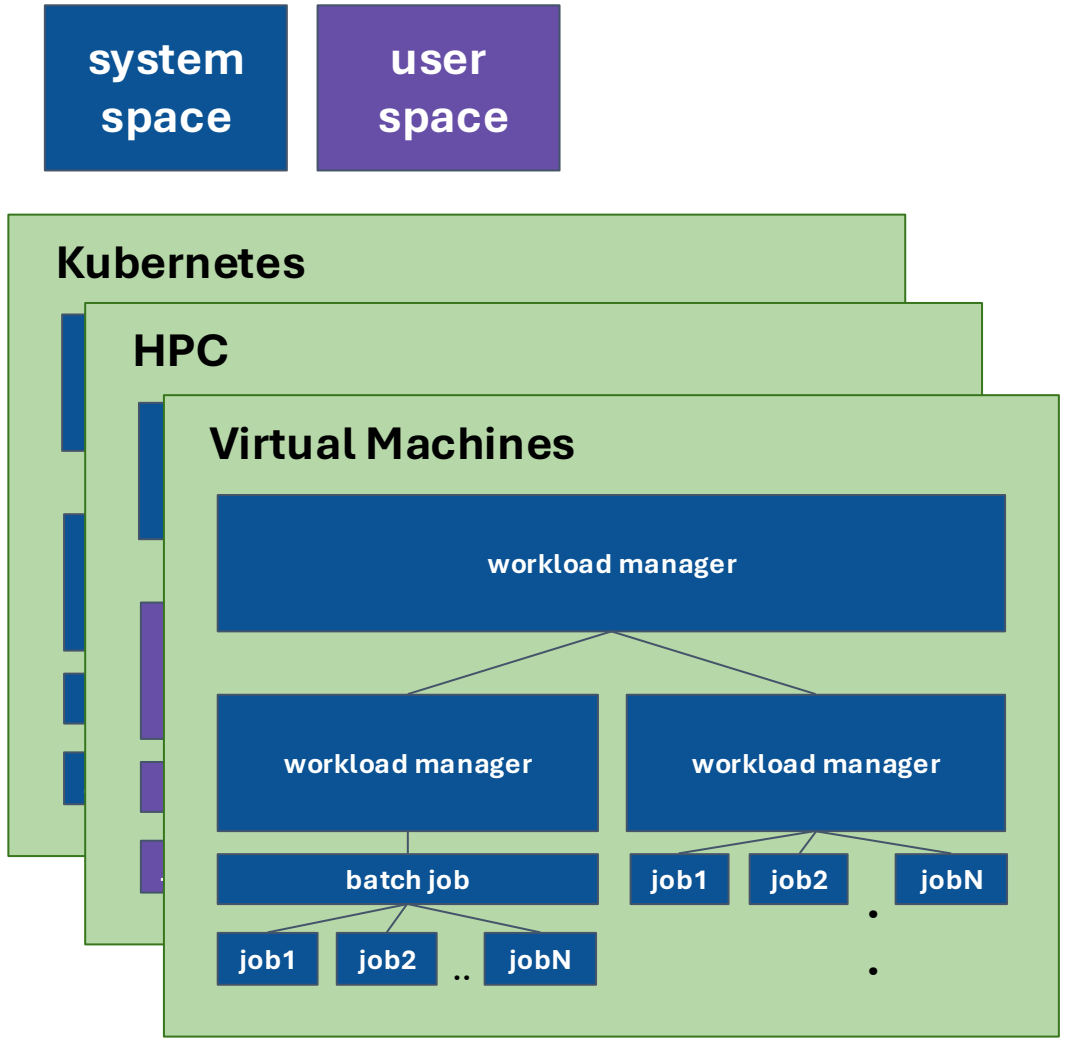
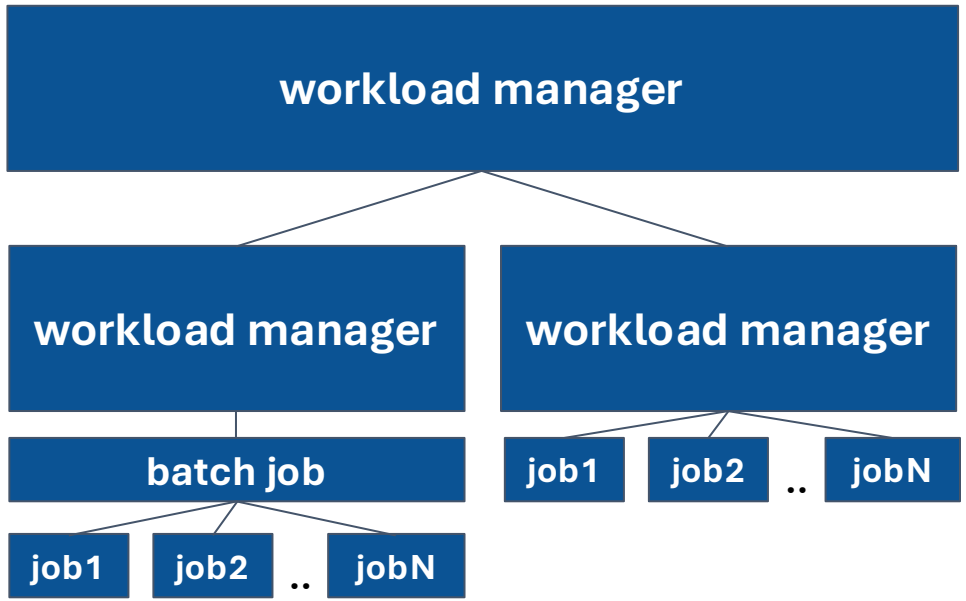


3. The hierarchical, modular design enables scheduler configurability

One scheduling algorithm to rule them all (what about queue)?



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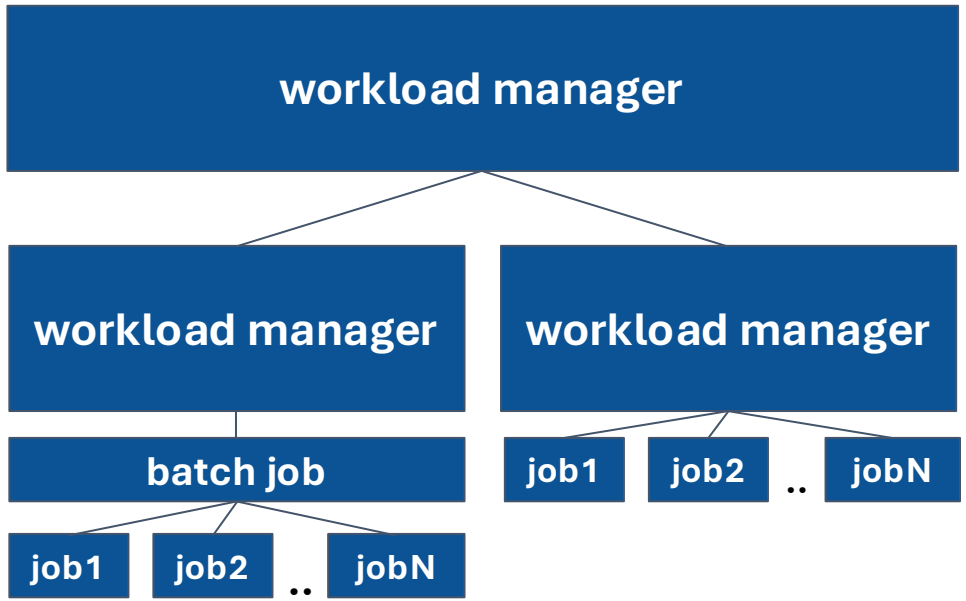
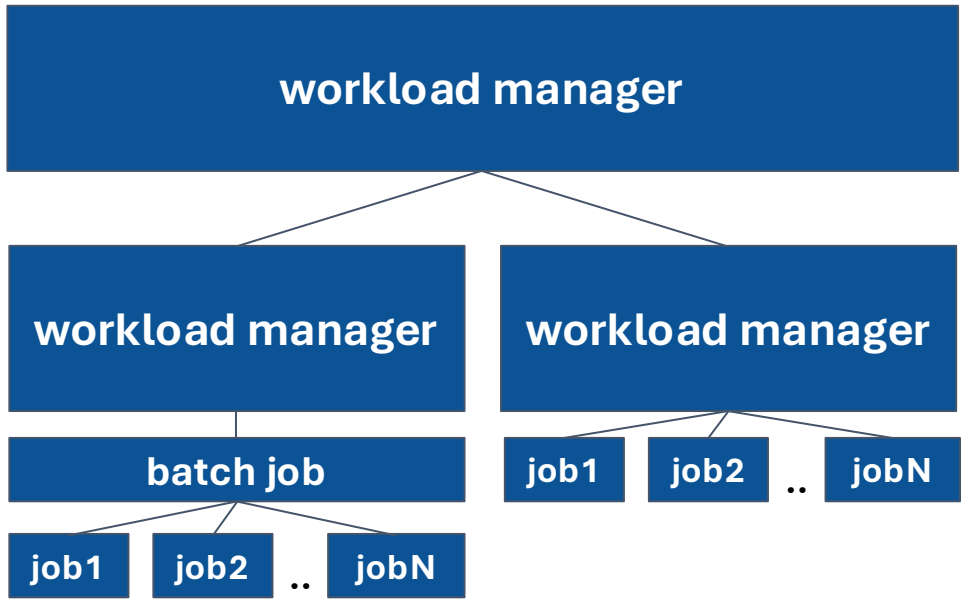


Did you know!

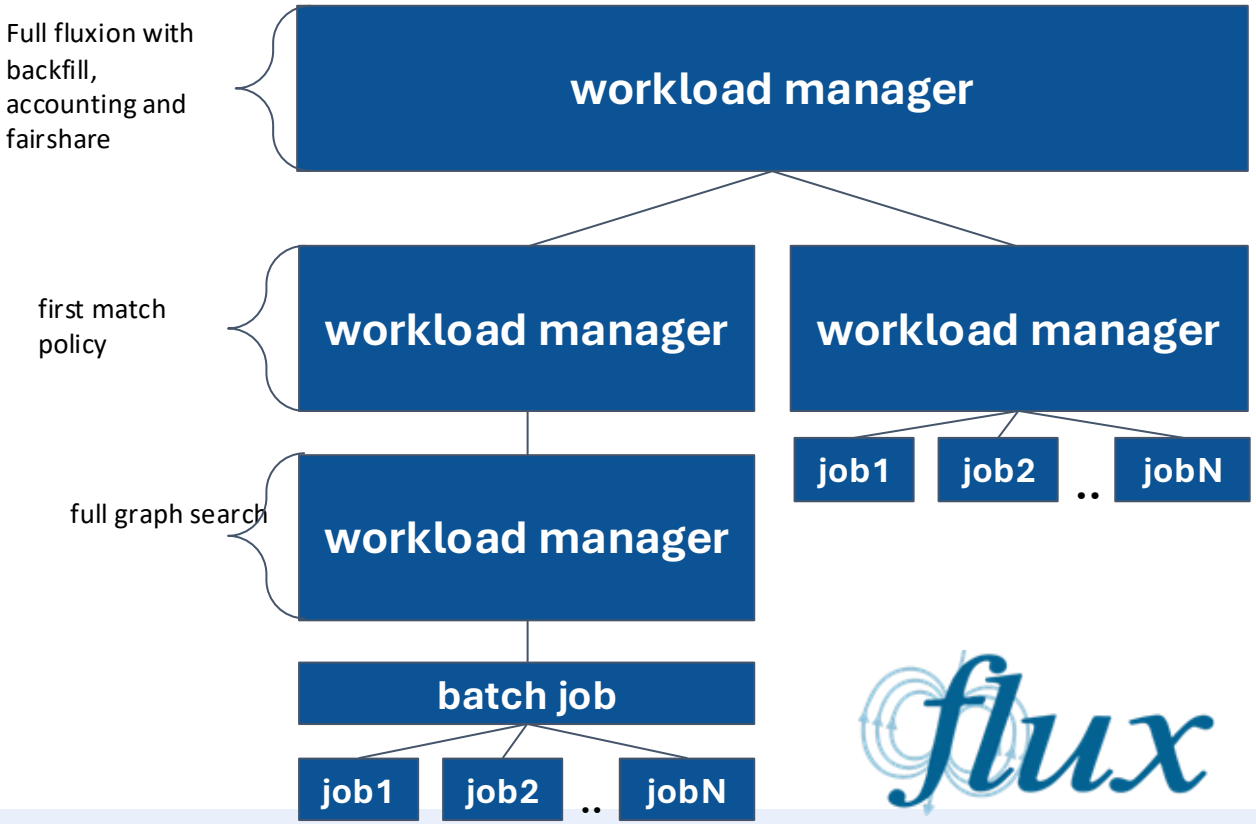
A **policy** can dictate how to schedule. Should we stop at the first match? Continue until we find all matches? Use a different algorithm?

3. The hierarchical, modular design enables scheduler configurability

One scheduling algorithm to rule them all (what about queue)?

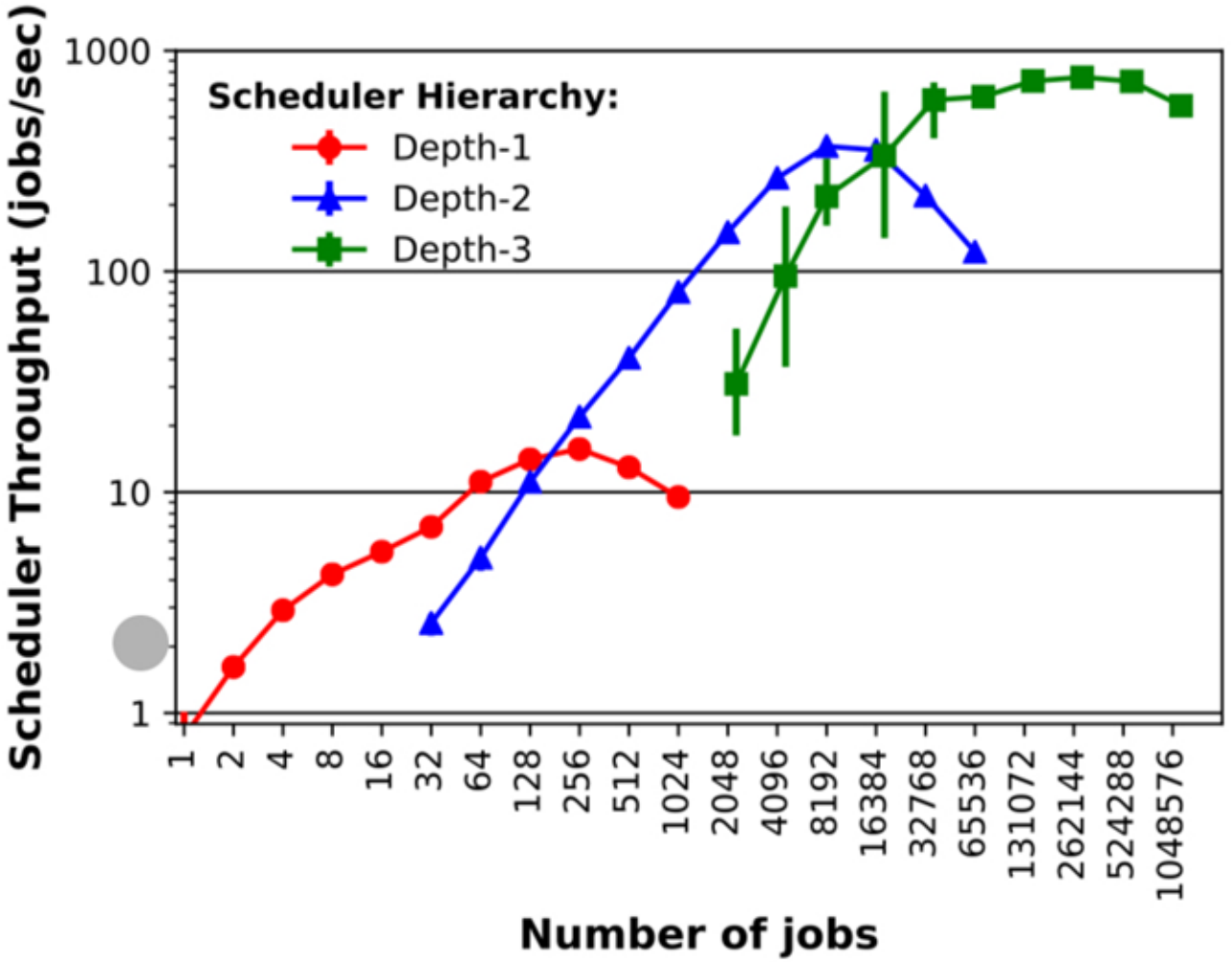


Choose an algorithm for each level (instance, or sub-graph) in the hierarchy.



4. The design enables increased scalability and throughput

Fractal scheduling enables high throughput



- Flux addresses demand for high throughput
- A hierarchy of Flux instances managing jobs increases throughput.
- We don't face the bottleneck of one, central scheduler

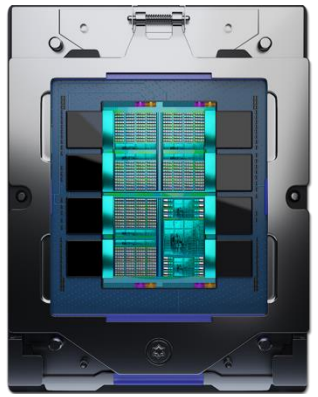
Ok, but how can we extend it?

Flux's interfaces are designed to be extensible

- Most of flux itself, and all of the framework projects, are extensions!
- From the bottom up:
  - Broker modules: Things like the fluxion scheduler and accounting module
  - Jobtap plugins: Direct feedback and control *in the job management loop*
  - Validator and Frobnicator plugins: Check or modify incoming jobs
  - Extending the Flux command line
  - The usual (prolog and epilog scripts)
  - User APIs

So, how do I customize it?

- ”I need to support a specific type of hardware”
- “I need to track a specific type of user’s job”
- “I want to add shortcuts for commonly-used submission combinations”



AMD MI300A can be split into multiple CPU/GPU configurations

```
(s=1153,d=0)  tuolumne2152 ~ $ flux alloc -N 4 --setattr=gpumode=TPX -o mpibind=on --env=MPIBIN
D_TOPOFILE=/tmp/hwloc.xml script.sh
```

“This is too much typing! Help!”

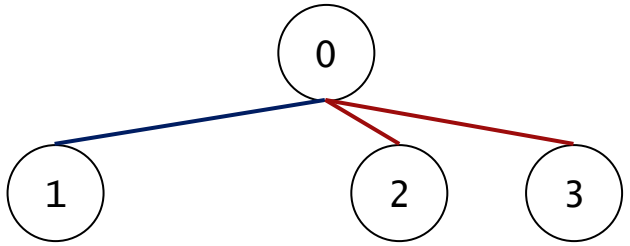
All of these customization interfaces can (with varying difficulty) be written in Python.

Why would I want a broker module?

- Modules are the core of flux, and can do nearly anything
- Things built as modules:
  - Both flux schedulers, sched-simple and fluxion
  - flux-accounting
  - The central key-value-store
  - The job-manager
- They are dynamic libraries or python files with full access to flux's messaging system

Modules are driven by messages (and callbacks)

job ingest module on login node



User on a login node sends a message

- *"Hey! I want to run a job!"*

Module on node picks up message, routes it appropriately

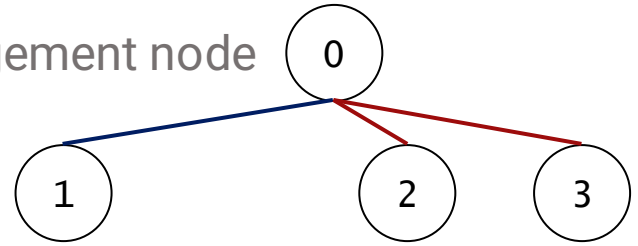
- *"This user wants to run a job! The job-manager should know!"*

The job-manager fulfills the appropriate callback for the specific message

- *"This user from node 1 wants to run a job on node 3, but I'm node 0. Phone my friends!"*

Modules are driven by messages (and callbacks)

job manager module on management node



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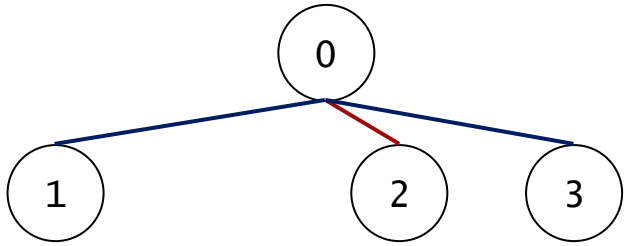

dispatches the work to compute nodes

User on a login node sends a message

- *"Hey! I want to run a job!"*

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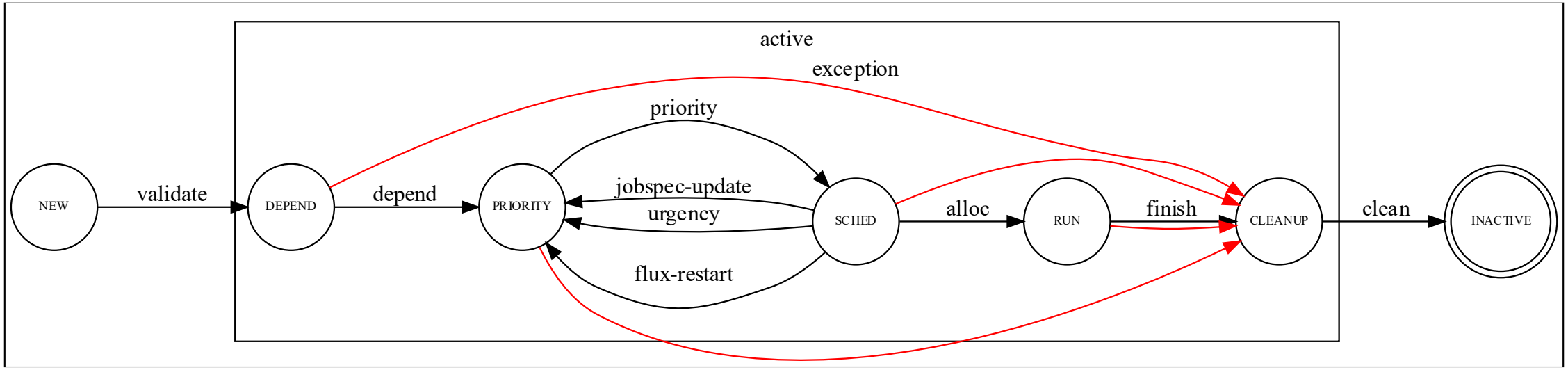
Why would I want a jobtap plugin?

- Jobtap plugins run *inside* the job manager, and can change its behavior
- Things you can build with this
  - A plugin to dispatch work to be serviced by another instance of flux
  - A new type of dependency between jobs
  - Anything that needs to make decisions on job-state changes that block the job manager waiting on their decision
- Jobtap plugins are libraries with a C ABI, should be quick to respond, but are *very powerful*

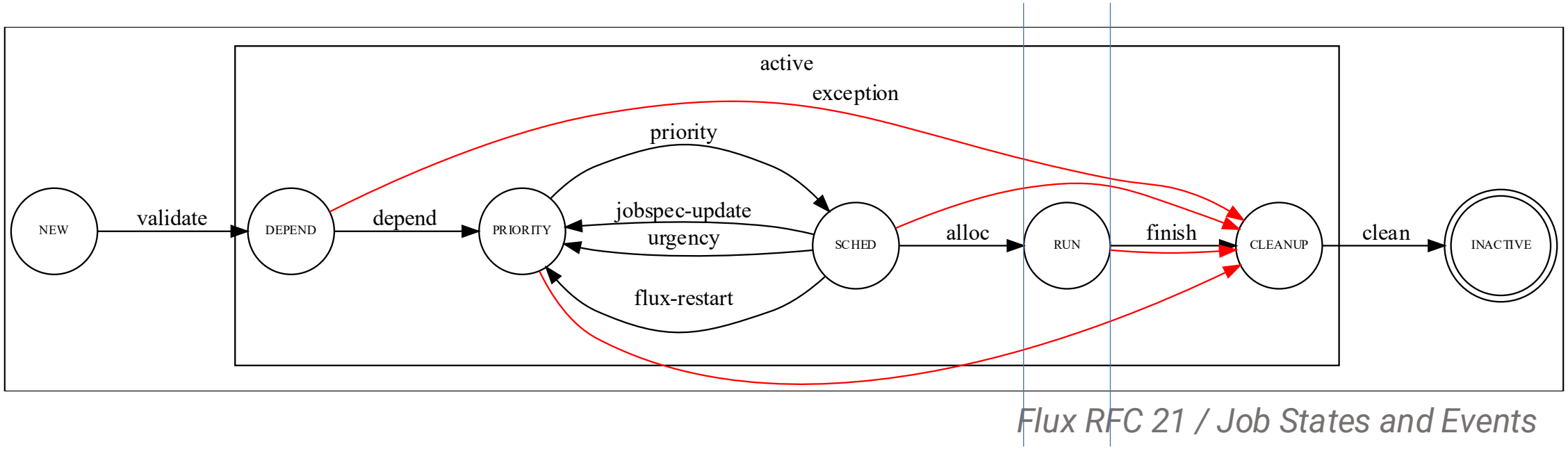
Jobtap Plugins: “tapping in” to job state



Flux RFC 21 / Job States and Events

- One module, the job manager, is involved in each *state transition* in a Flux job.
- The job manager allows callbacks to be invoked on each transition.

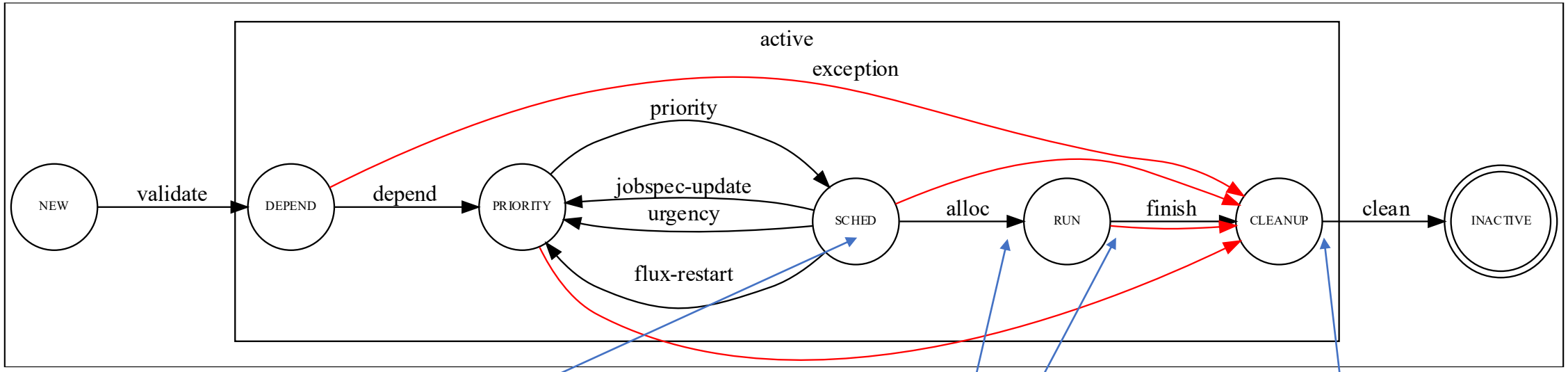
`sudo` actions happen before/after the RUN state



Flux RFC 21 / Job States and Events

- In addition to callbacks, before and after a job RUNs, an elevated privilege “prolog” and “epilog” runs on each node in the allocation for system services

Example use for plugins: Cray VNI support



Flux RFC 21 / Job States and Events

VNI ”tag” issued (round robin 64k integer) through a “jobtap plugin” (event callback)

VNI ”tag” released back into Flux-managed pool of tags

CXI service started via prolog / shut down via epilog

Why would I want a validator or frobnicator plugin? (and what on earth is a *frobnicator?*)

- Validator plugins… *validate*
  - Use them to take in jobspec (the complete description of a job request) and accept or reject it
  - Good for site-specific rules with complex logic
  - Example: Reject jobs *below* a certain size
- Frobnicator plugins take jobspec and *modify it* before it's signed
  - Good for adding requirements or modifying limits on all jobs submitted
  - Example: Add **requires: !hosts:donotuse[1:5]** to all incoming jobs

Prolog, epilog and housekeeping

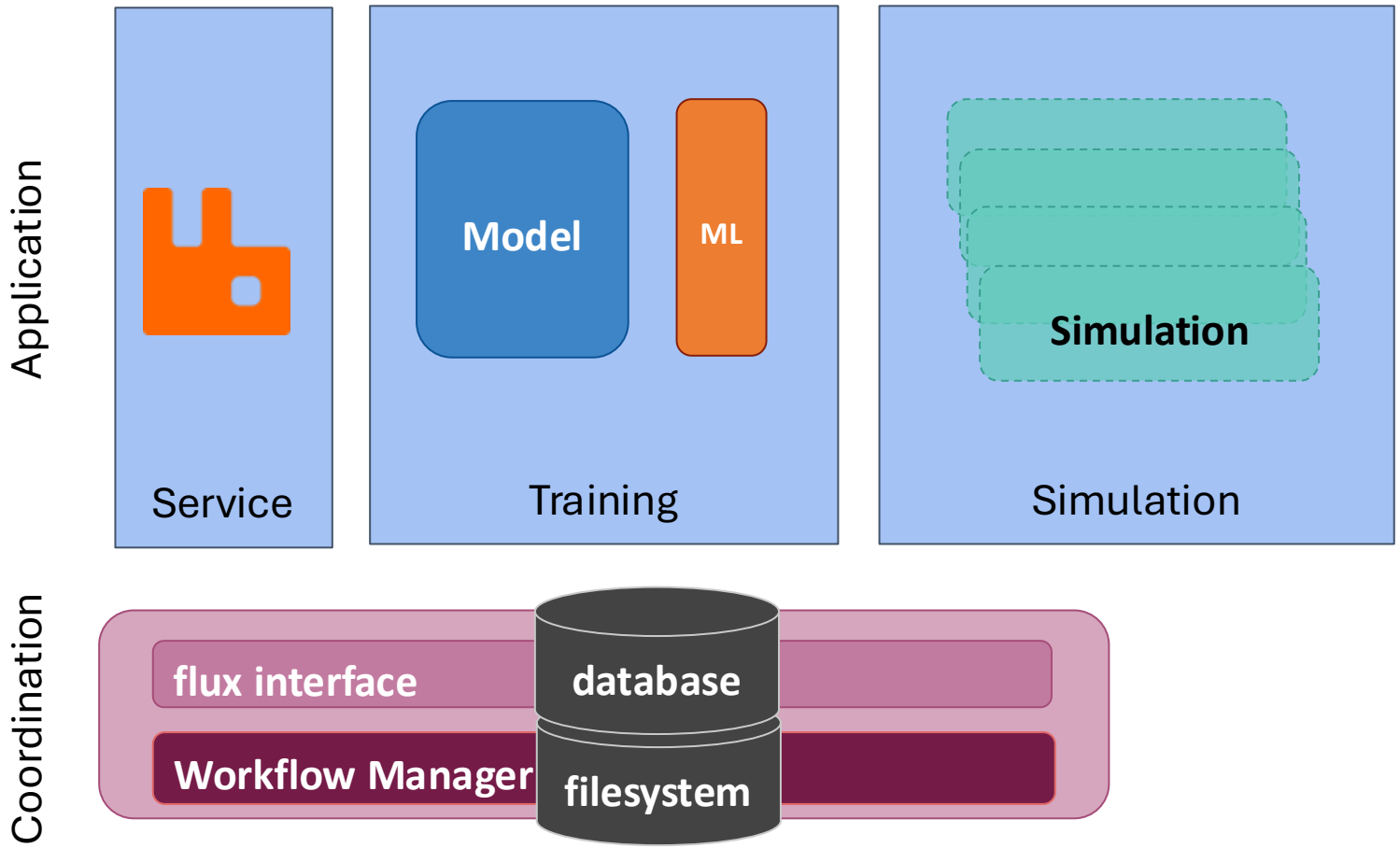
- In a system instance
  - Business as usual, runs as a privileged user:
    - Prolog: Before the job
    - Epilog: After the job *before the finish event*
    - Housekeeping: After the finish event, before releasing to the scheduler
- In a user instance
  - All the same still exist, but run as the user owning the instance
  - Sub-instances do not run the prologs/epilogs of the system instance by default

User APIs

- Not strictly “extensions”
- Users can interface with flux internal interfaces through:
  - Python
  - Lua
  - C
- Asynchronously submit jobs without needing **fork**
- Get callbacks on job state transitions
- Main use: Stop writing schedulers for workflow managers!

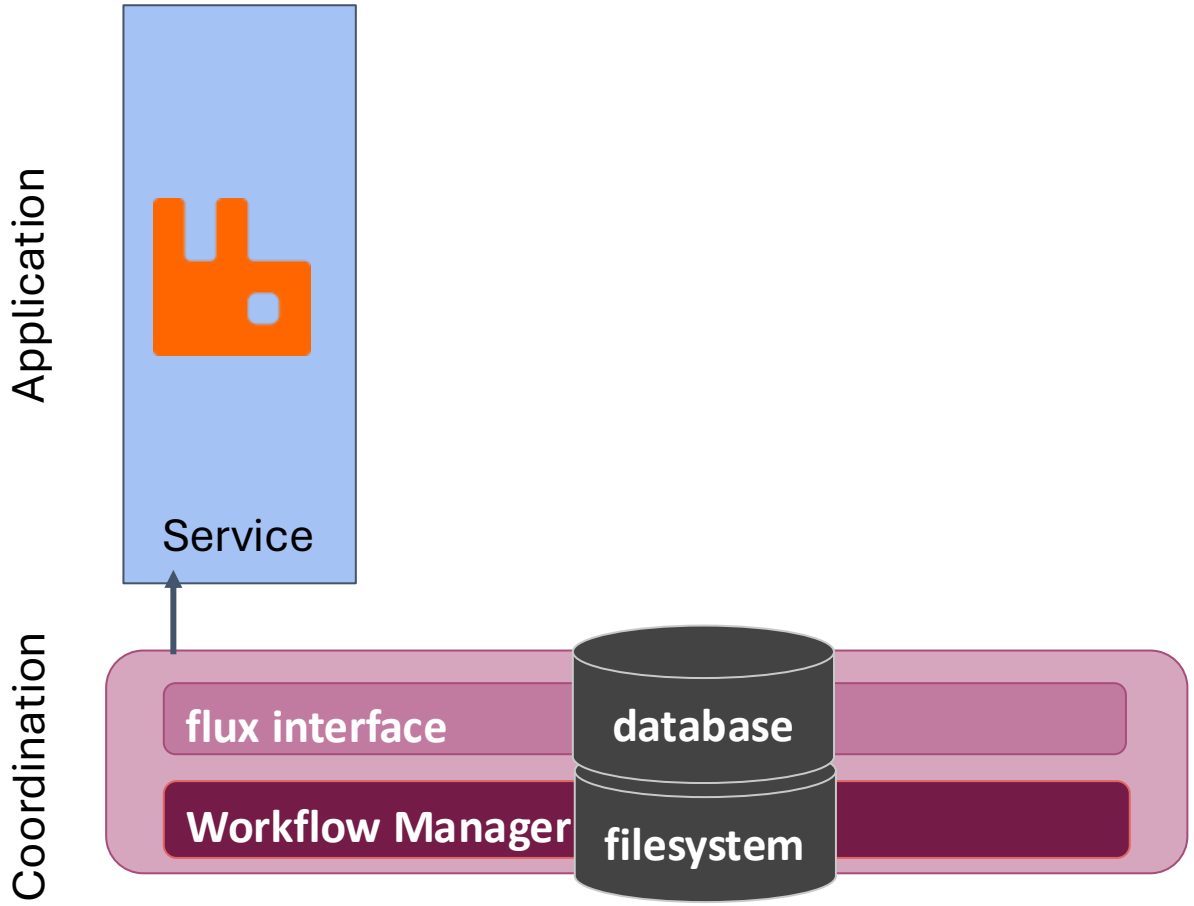
Flux APIs integrate with workflow managers

How might a workflow manager run this?



Flux APIs integrate with workflow managers

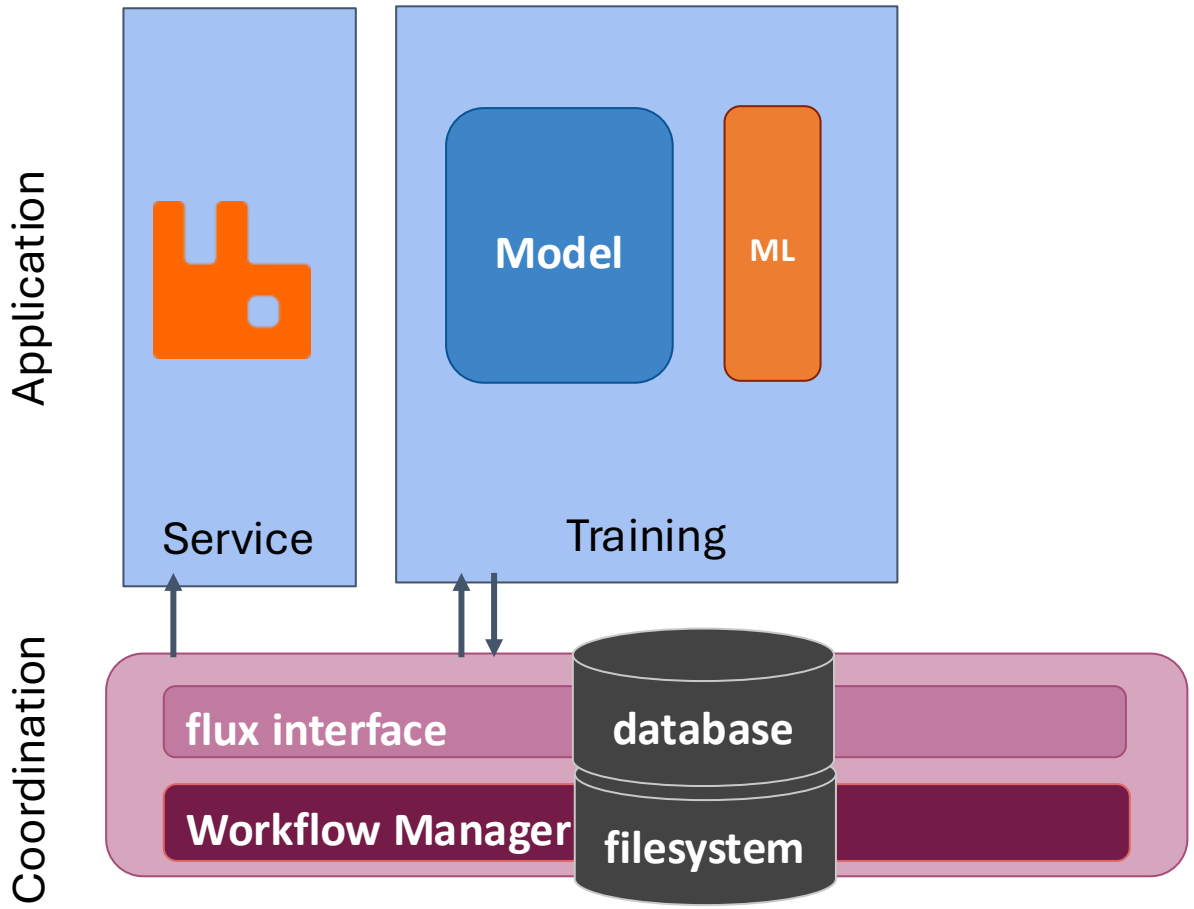
First submit a job for the service (not blocking)



flux submit sh service.sh
flux run -N4 -g1 python train.py
flux submit –wait -N4 python simulation.py

3. Flux APIs integrate with workflow managers

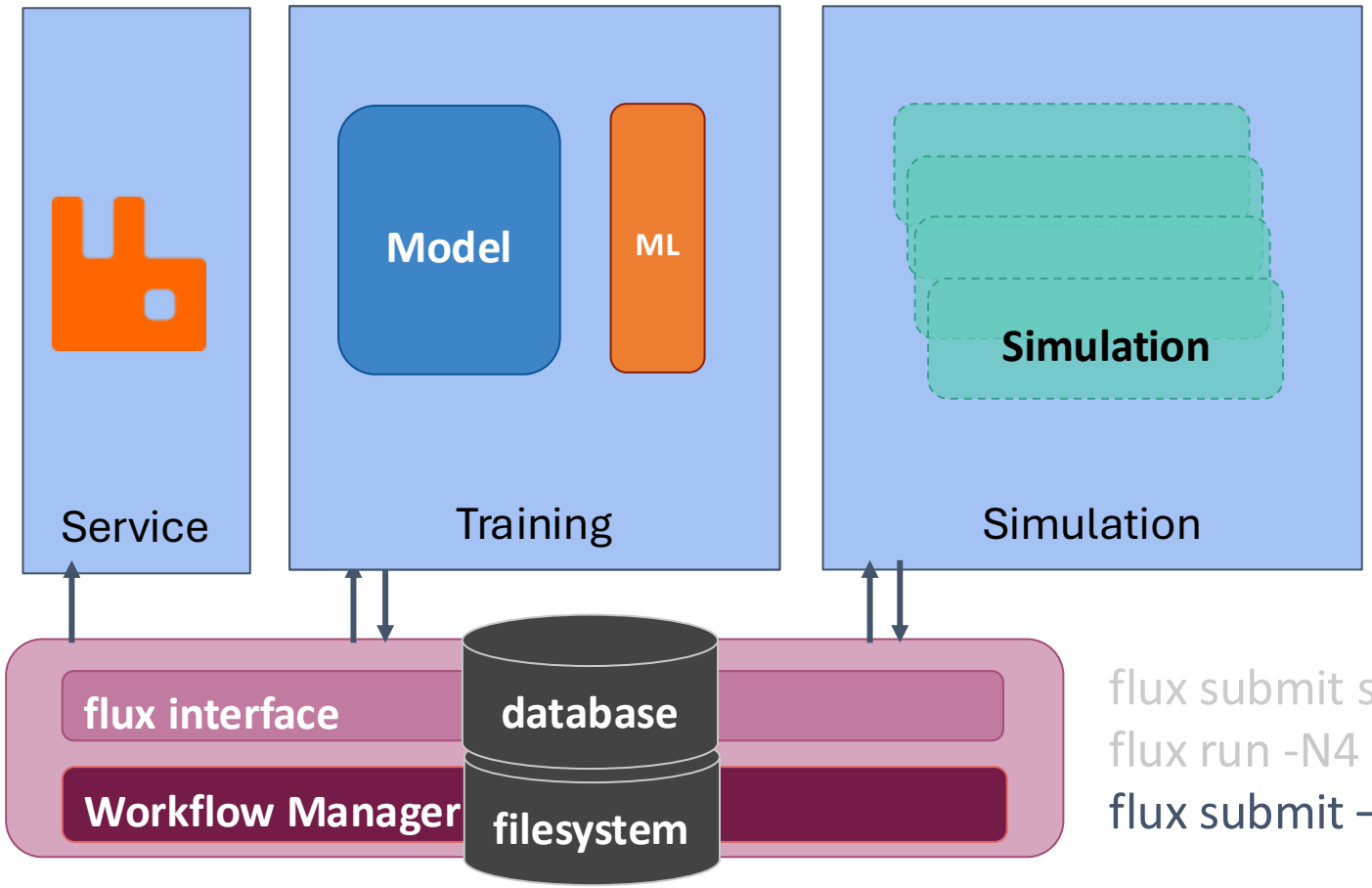
Next run training - we need to train *before* we run simulations, so block



flux submit sh service.sh
flux run -N4 -g1 python train.py
flux submit –wait -N4 python simulation.py

3. Flux APIs integrate with workflow managers

Finally, finish with simulations. Add "wait" so we wait until they finish!



flux submit sh service.sh
flux run -N4 -g1 python train.py
flux submit –wait -N4 python simulation.py

Which workflow and orchestration tools support Flux?

Streamflow

What have we been working on?

- **Support for grow/shrink of jobs (flux-sched):** Allows the underlying resource pool and active jobs to dynamically adjust their resource allocations mid-run.
- **Custom Resource Module Policies (flux-sched):** Provides flexibility for users or administrators to define their own resource management logic.
- **More Options for Generating Taskmaps:** Allows for fine-tuned control over process placement and task distribution on heterogeneous hardware.
- **Resource/Job Events Journal Consumer Interfaces (Python API):** programmatic access via Python to stream and consume real-time job and resource events. Includes utility for users to post events.
- **Interfaces for Watching and Querying Jobs and Queues:** Standardized methods for tracking job status and queue state, and queue metadata (e.g., runtime statistics).
- **Command flux update to change job duration after submit:** Allows users to modify job wall-time limits post-submission.
- **Optimizations:** ongoing to maintain performance on exascale-class machines.
- **Relaxation of scheduling constraints from data dependencies:** exposes further opportunity to optimize scheduling with data dependencies across/within jobs while allowing to leverage local storage

What's next?

El Capitan has helped us prov that a system-level Flux at the ~13,000 node scale is both possible and stable, but we're always working to improve things:

- **Rolling software upgrades:** Current upgrades to the Flux system instance require downtime and a full restart of the instance, losing running jobs.
- **Restart with running jobs:** restarting any Flux instance currently kills running jobs.
- **Reservation support:** support for deferring a job/reservation start time into the future, which is currently supported with admin intervention, scripting and queues.
- **Package availability:** Source RPMs are published with each tagged release, although `dnf install flux-core` is not currently available. Collaboration is underway with Fedora/Red Hat for inclusion in their Extensions Repository.

Thanks to everyone on the Flux team over the years!