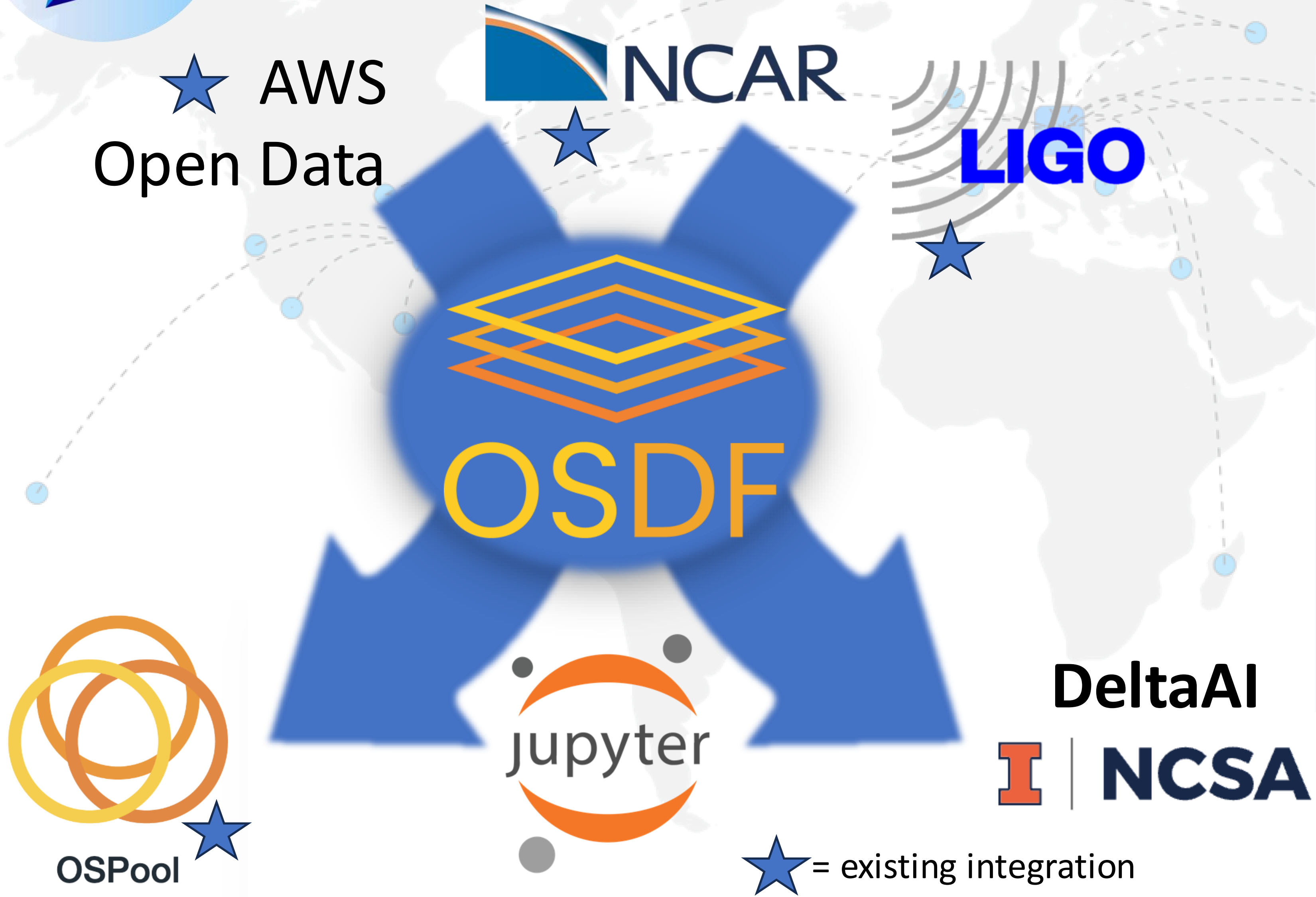
Pelican and the Open Science Data Federation

Introducing the OSDF

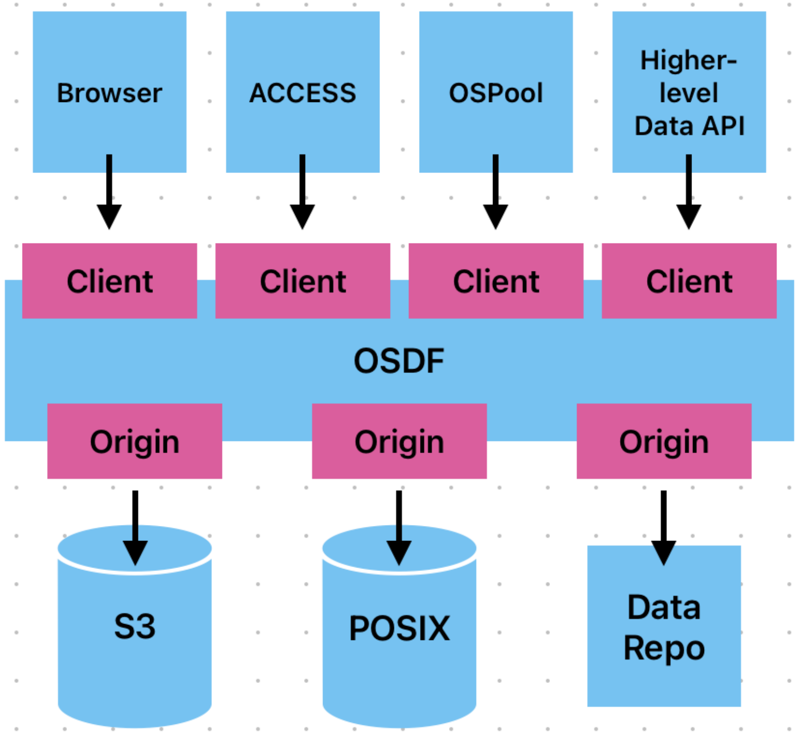
The OSDF is a federated platform for delivering datasets from repositories to compute in an effective, scalable manner.

OSDF Integrates Independent Repositories into a common fabric



- About a dozen repositories integrated already, more on the way.
- Working to grow:
  - clients,
  - integrated resources, and
  - environments.

OSDF Architecture - Vision



Long-term vision:
We want OSDF to be an “all-science” CDN.

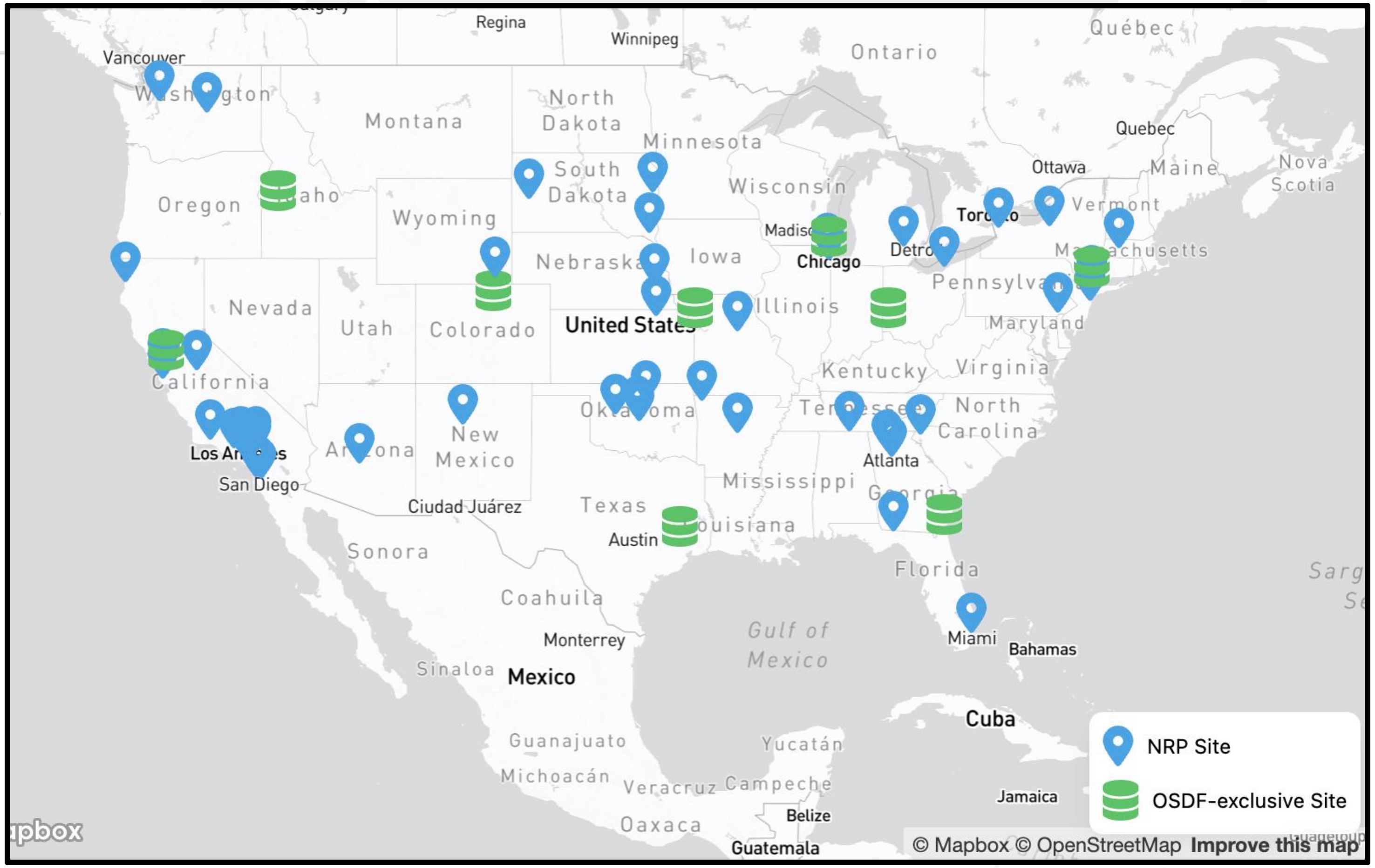
Requires:

- Connect many repositories to the distribution fabric.
- Provide clients that enable as many use cases.

And benefit from the network effects.

A bit on the cache layer…

- Anyone can run a cache!
- However, the OSDF centrally runs regional caches, mostly at network locations.
- Builds on top of a distributed Kubernetes cluster run by the National Research Platform (NRP).
  - Single, uniform interface to run services across the country.
- “Typical” cache hardware is ~100GbE / 20TB NVMe.



The OSDF: Connecting your repository

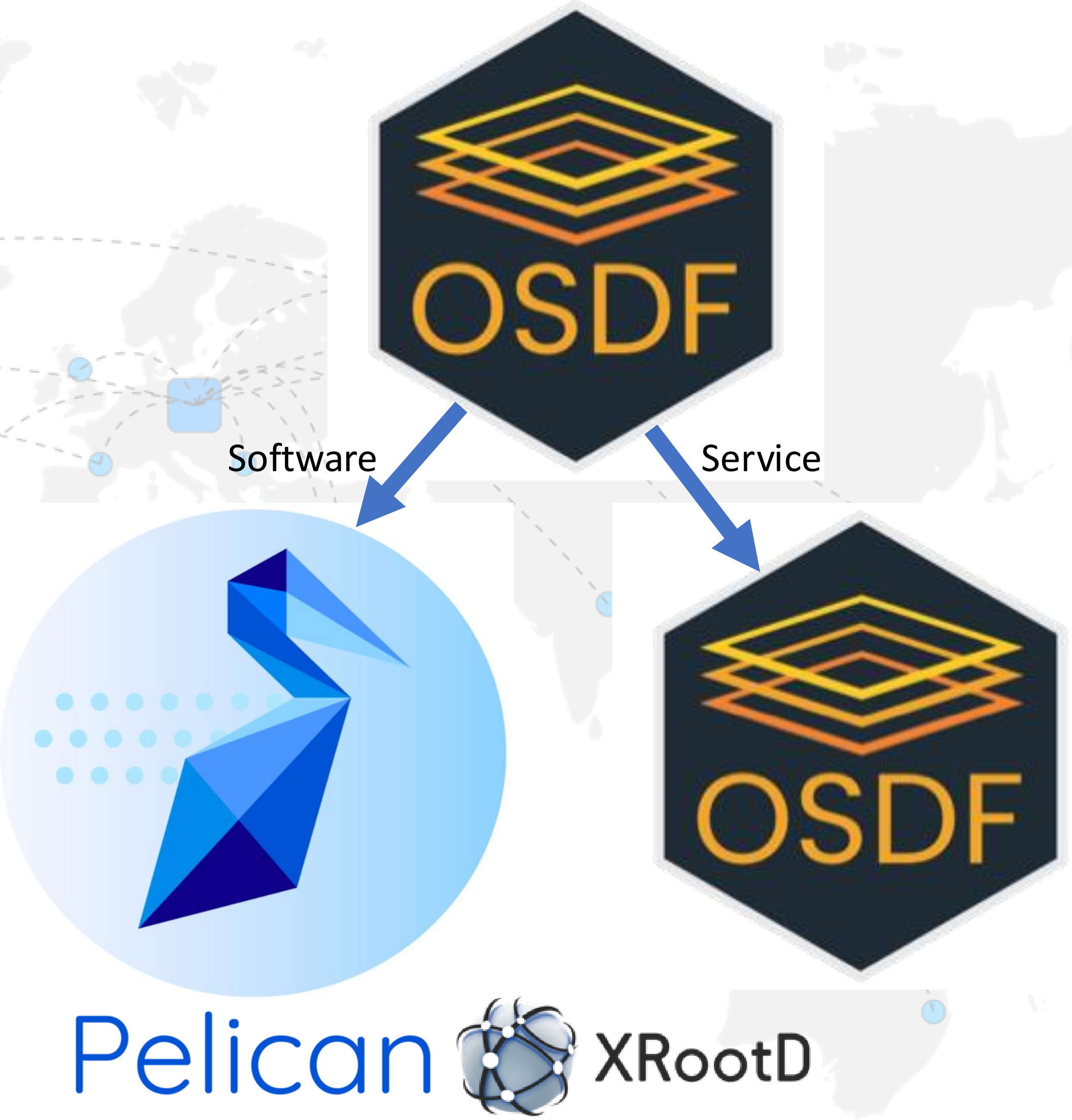
The OSDF provides an "adapter plug", connecting your science repository to the national and international cyberinfrastructure.

The OSDF is operated by PATh Using hardware from NRP And integrates a wide range of open science,

As part of the OSG Consortium's Fabric of Services

OSDF & Pelican

- You may have seen prior presentations about the OSDF – it (or predecessors) have existed for ~10 years.
- We split out the technology powering the OSDF and christened it the "**Pelican Platform**".
  - Same components as before, just integrated into a standalone platform.



The Pelican Project

The OSDF is operated by PATh using hardware from NRP and others.

Who develops the software?

The Pelican project (OAC-2331480) is a newly-funded, $7M/4-year project with the following goals:

1. Strengthen and Advance the OSDF.
2. Expand the types of computing where OSDF is impactful.
3. Expand the science user communities.
   - With a particular driver of the climate community.

OSDF by the numbers

Over the last 12 months, the OSDF transferred

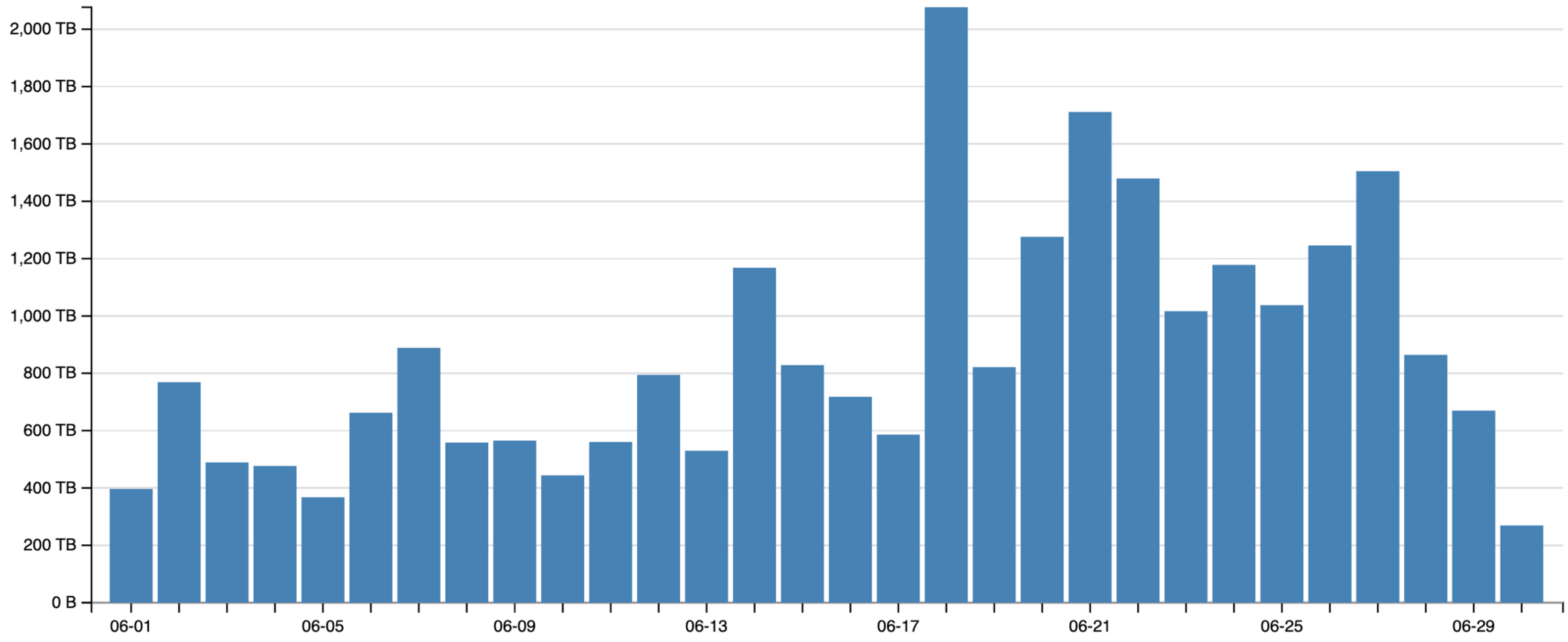
230PB & 125 req/s

Data used by

15 science collaborations &

~120 OSPool users

Example Daily Volume – June 2024



Note: individual experiments can still dominate a day’s activities.

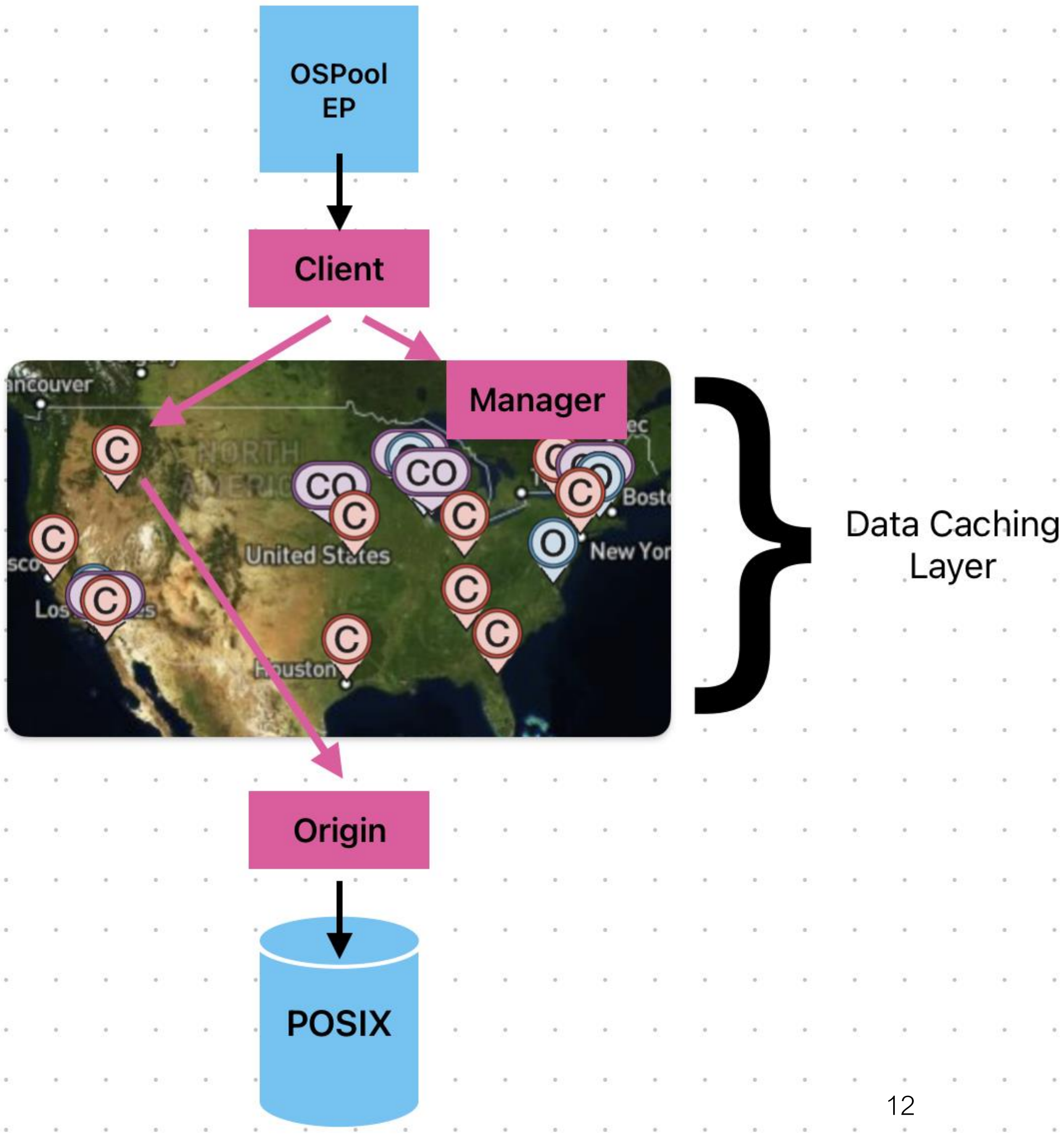
How does the OSDF work?

A brief tour through the Pelican architecture as implemented by the OSDF.

OSDF in Practice

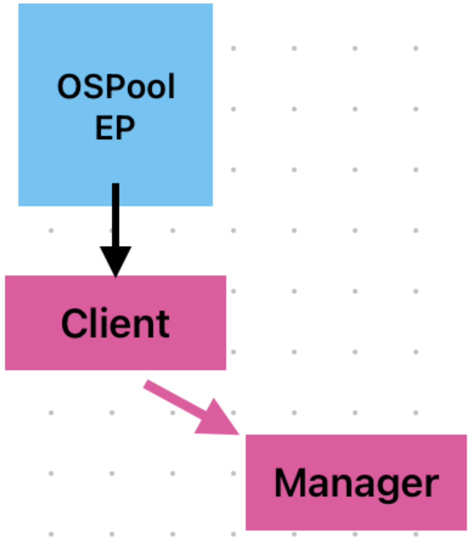
- Currently, the most common client for the OSDF is the OSPool.
- The OSPool is a distributed High Throughput Computing service, part of the OSG Consortium and run by PATh.
  - The OSPool is a distributed HTCondor pool, run across ~60 US sites, including **28 CC* awardees** (active + ‘alumni’).

Let’s run through a HTCondor Example



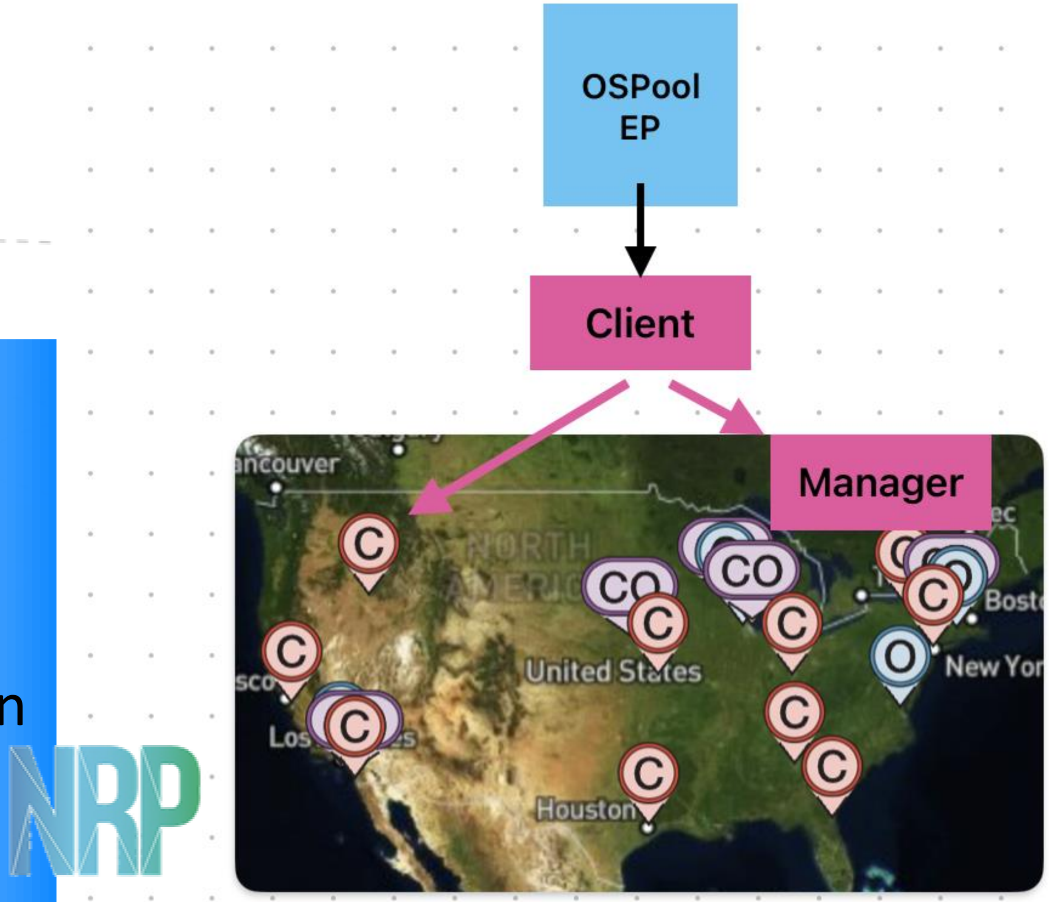
OSDF In Practice

- If HTCondor needs an object – say, a container – for a job, the first step is to start the OSDF client.
- The OSDF client contacts the **manager**, requesting to read the object.



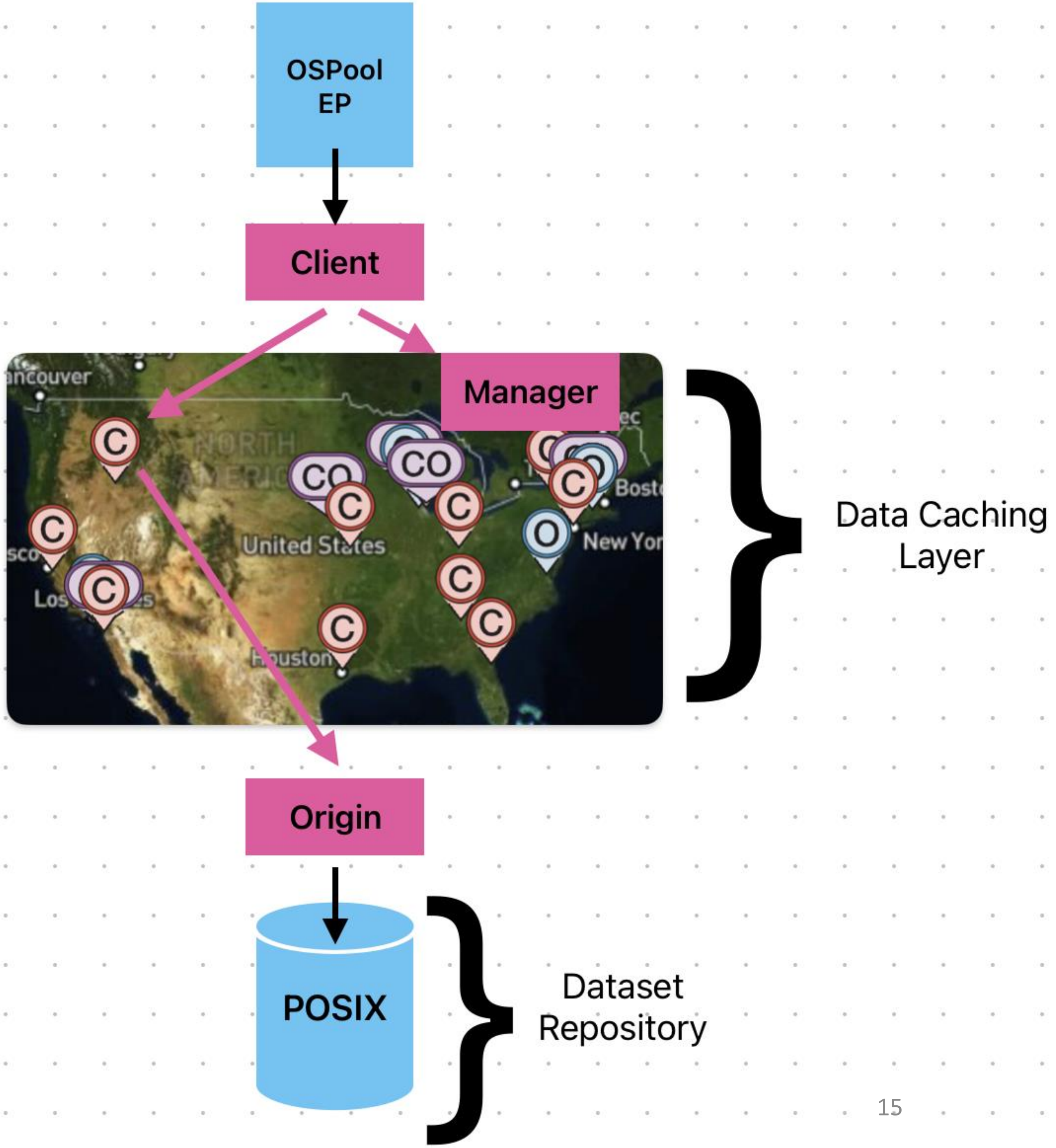
OSDF In Practice

- The manager determines a nearby **cache** to serve the object.
  - Every location in the lower 48 states is within 500 miles from an OSDF cache hosted by the NRP.
- If the object is in cache, it is served to the client immediately.
  - Otherwise…



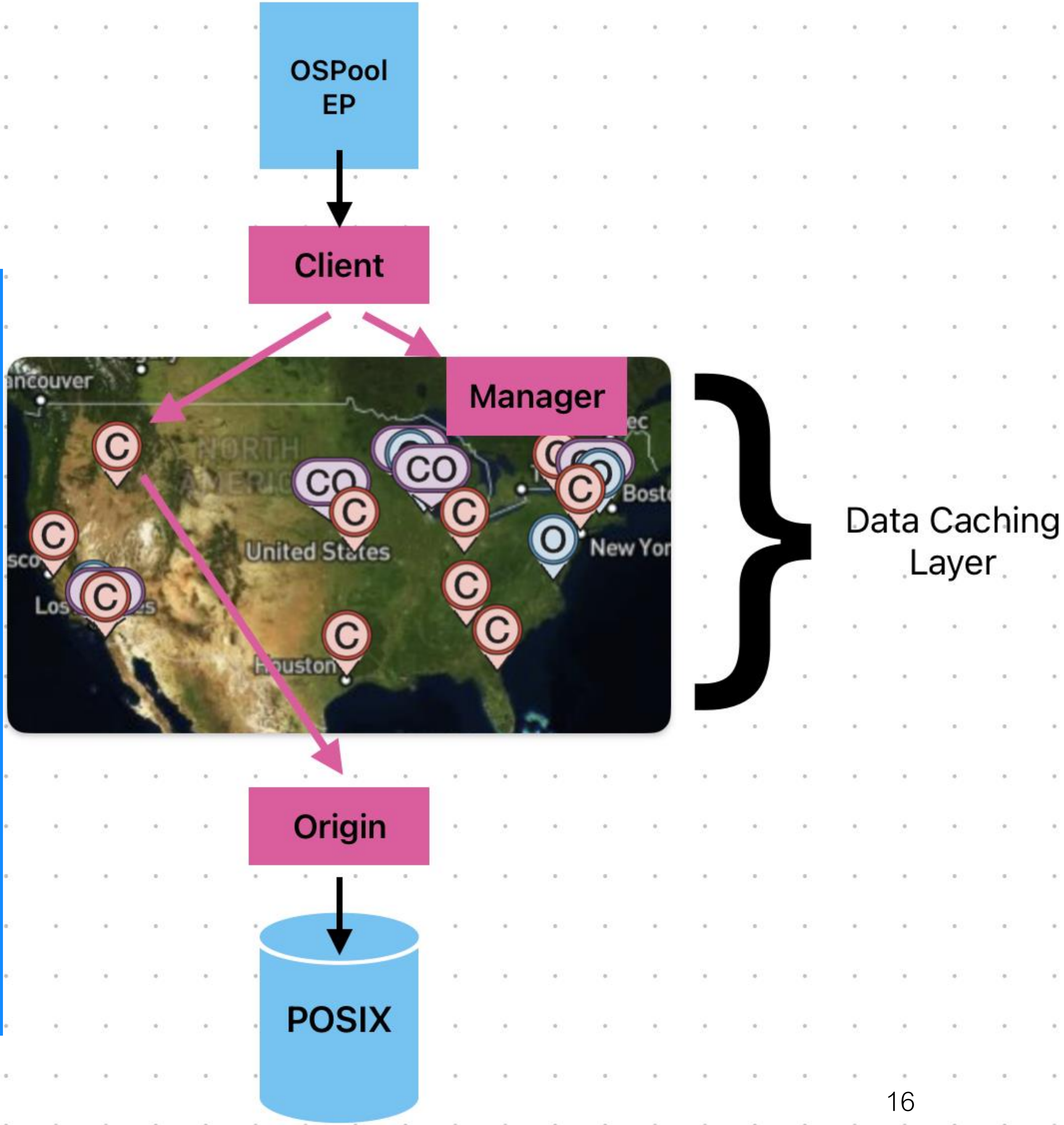
OSDF In Practice

- The cache contacts the origin hosting the object.
  - The object prefix is used as a routing key to determine the correct origin.
- The origin will read the object from the underlying object store.
  - Typically, a filesystem – but expanding to many dataset repository types!



Architecture: Recap

- An **origin service** integrates the object store into the OSDF in the same way a CE integrates a batch system into the OSPool. Interfaces to move data and map authorizations.
- The **cache service** stores and forwards objects, providing scalability to the data access.
- The **manager** selects a source/sink of an object for clients and maintains the namespace.

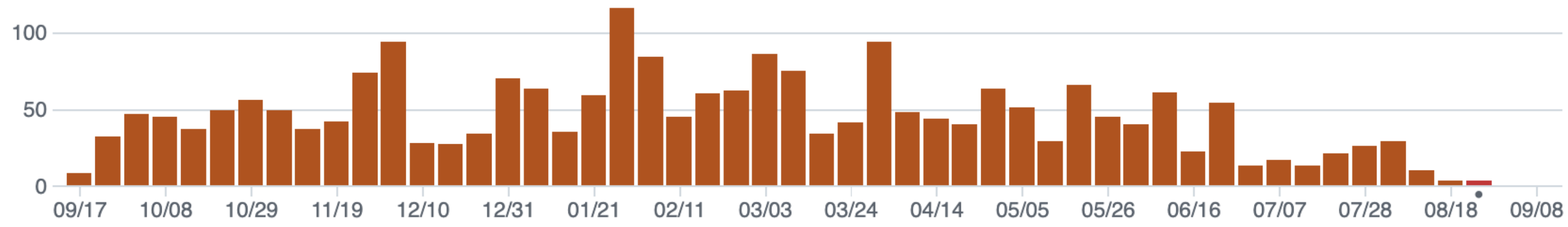


Zooming in –
Technical Components

Pelican Implementation

https://github.com/PelicanPlatform/pelican

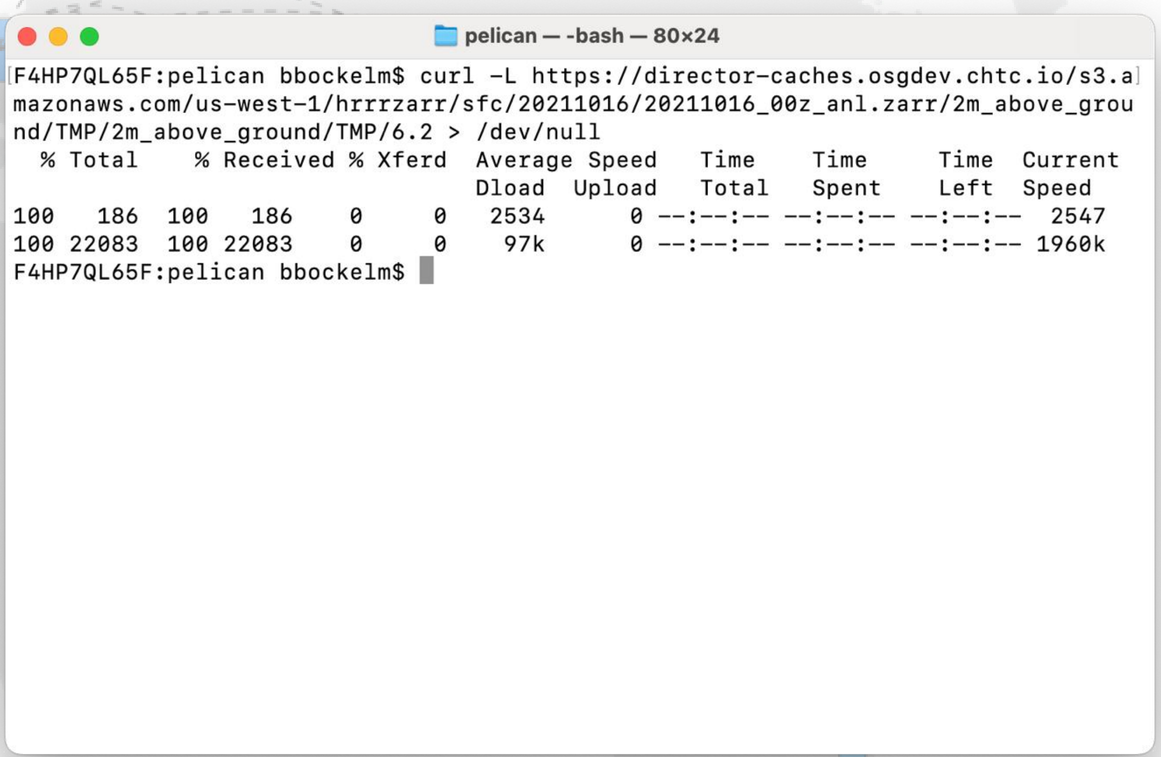
- The Pelican core is a standalone software project.
  - Golang for core; Next.js for web UI.
  - Shipped as a single statically-linked executable.
  - Fairly significant reasonable test suite (~50% code coverage).
- For origins/caches, forks & manages an XRootD process.
  - Dynamically generates XRootD configuration. One, YAML-based config file for admins to manage.
- All components have a web (management) interface.
- Distributed via RPM and containers. Majority use is containers.



Commit graph from the last 12 months

Pelican uses HTTP

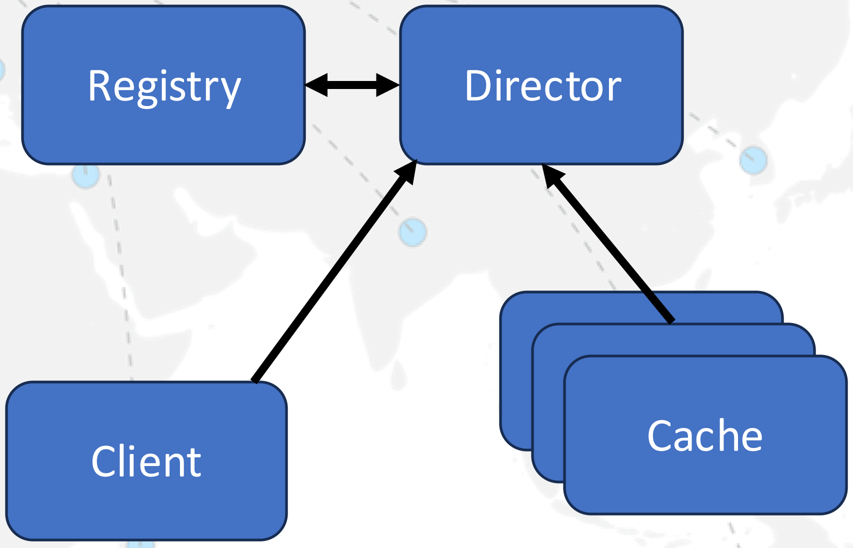
- Pelican uses HTTP to move bytes.
- We hew to using standard HTTP where possible. While we *prefer* you use the Pelican client, any HTTP client suffices.
    - Downloading an object? => GET
    - Uploading an object? => PUT
    - Want to know if the object exists? => HEAD



Pelican "Manager" Components

The central manager contains two components:

- The **Registry** maintains the authoritative list of known caches, origins, and namespaces.
  - Also associates each entity with a list of public keys.
  - Authorization is done by signing an appropriate token with the pubkey.
- The **Director** receives requests from clients / caches and selects an appropriate service.
  - All communication done over HTTP!



Example request from client to director

```
> GET /chtc/staging/bbockelm/testfile HTTP/2
> Host: osdf-director.osg-htc.org
> User-Agent: curl/8.4.0
> Accept: */*
```

Example director response

< HTTP/2 307
< content-type: text/html; charset=utf-8
< date: Mon, 08 Jul 2024 17:17:17 GMT
< link: <https://osdf-uw-cache.svc.osg-htc.org:8443/chtc/staging/bbockelm/testfile>; rel="duplicate"; pri=1; depth=3, <https://stash-cache.osg.chtc.io:8443/chtc/staging/bbockelm/testfile>; rel="duplicate"; pri=2; depth=3,...
< location: https://osdf-uw-cache.svc.osg-htc.org:8443/chtc/staging/bbockelm/testfile
< x-pelican-authorization: issuer=https://chtc.cs.wisc.edu
< x-pelican-namespace: namespace=/chtc, require-token=true, collections-url=https://origin-auth2000.chtc.wisc.edu:1095
< x-pelican-token-generation: issuer=https://chtc.cs.wisc.edu, max-scope-depth=3, strategy=OAuth2
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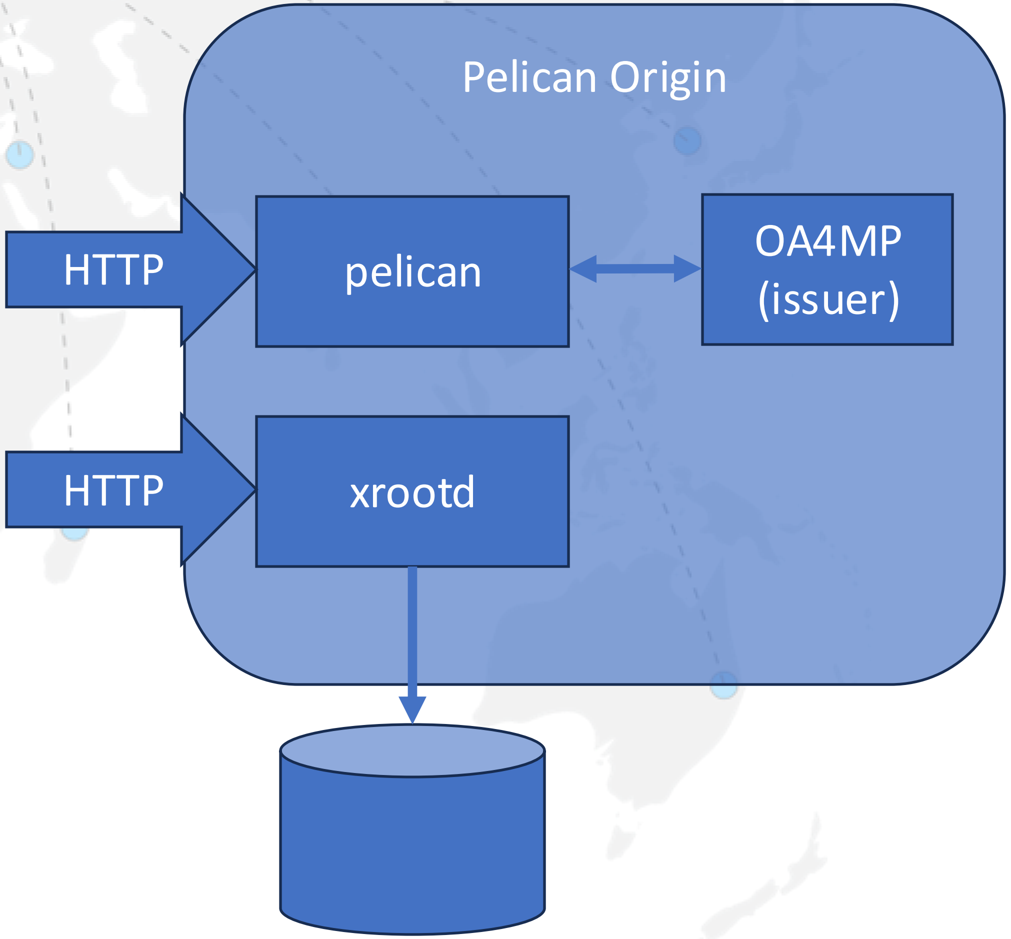
< content-length: 109

Director Response

- If you speak “plain HTTP”, you only understand the “blue” headers and will successfully access the data.
- If you are the “Pelican client”, you can interpret the “red” headers:
  - X-pelican-authorization: What token the client needs to successfully access the data.
  - X-pelican-namespace: What namespace the object is in. Informs client how to reuse the director response; no need to return to director for each object.
  - X-pelican-token-generation: If the client doesn’t have a usable token, how to receive one.
  - Link: An ordered list of potential endpoints (caches) that can serve the requests. Actually, a standard RFC header (RFC 6249).

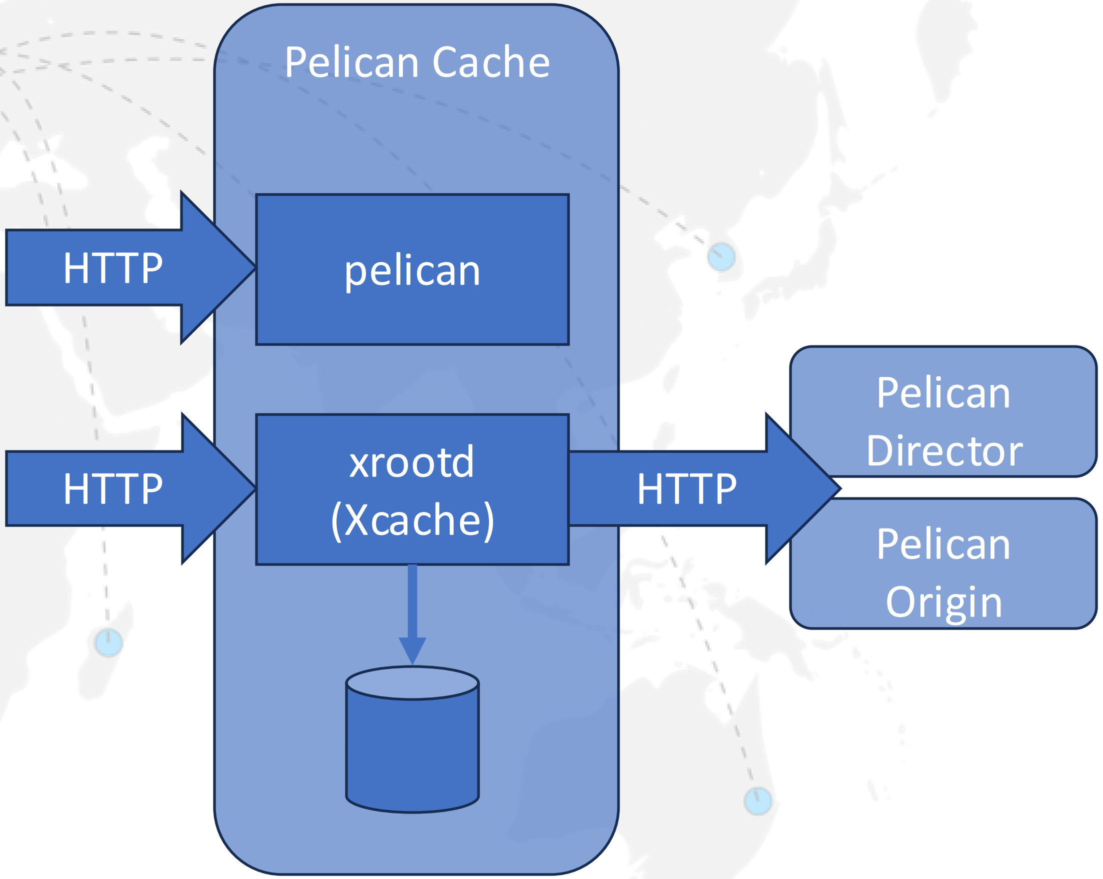
Pelican Origin

- Pelican daemon launches and manages the xrootd daemon.
  - However, HTTP data movement requests go straight to the xrootd process.
  - pelican's HTTP interface is used for monitoring, management, and token issuer.
- XRootD can be configured for a variety of backends.

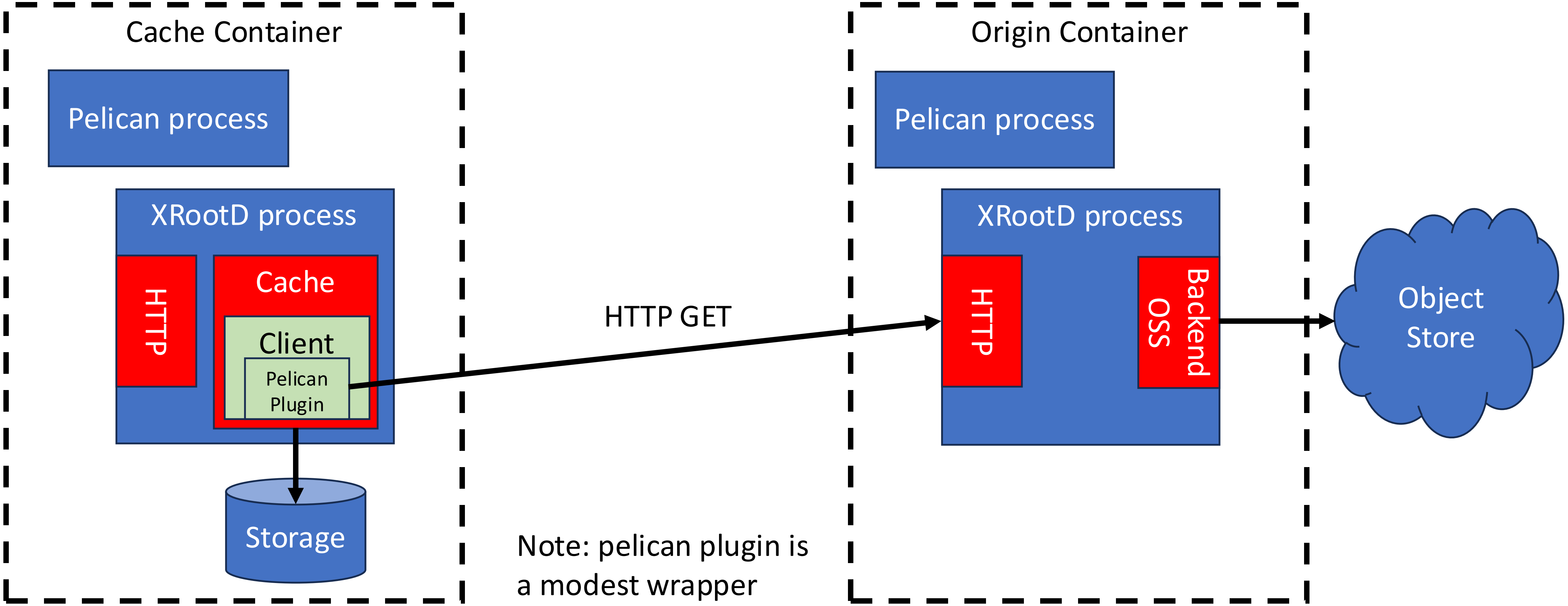


Pelican Cache

- Similar setup to the origin: two separate processes, two ports for HTTP.
  - Given the director and origin works exclusively over HTTP, the XCache must talk to them over HTTP as well.
  - How is this done? See next talk!



A slide for the XRootD people out there…



Note: pelican plugin is a modest wrapper around libcurl.

Client - CLI

- While curl *can* be used, we have quite a bit of specialized knowledge:
  - Immutable files means file download resumption is straightforward.
  - Parse the extra director headers to understand where backup caches are. Retry as necessary.
  - From the director headers, we know what tokens are required and how to generate them.
- The client can also do metadata operations ("stat", "list"), recursive upload/downloads of directories.
- The client also serves as a plugin to HTCondor, enabling HTCondor to do the data movement (instead of buried inside user scripts).
- The client is all in the same static binary as the server – the entire system is the one file.

Client - Python

- While we love CLIs, we want to tap into the Python community (which is more interactive/visualization focused).
- Accordingly, we started a FSSpec for Pelican.
  - Summer student was able to use the FSSpec to run PyTorch against the OSDF.
- Allows us to tap into more communities (particularly, a large contingent of climate science).

Client – CVMFS?

Replacing CVMFS_EXTERNAL_URL

- The Pelican director provides a list of caches, sorted by some criteria, for a given client.
  - Like a dynamic version of CVMFS_EXTERNAL_URL!
  - Based on RFC 6249 (Metalink headers), nothing Pelican-specific.
- OSG has long manually synchronized CVMFS_EXTERNAL_URL and the caches in the OSDF.
  - A bit maddening: always out-of-sync, hard to propagate changes, GeoIP-only.
- **Could we do an RFC 6249 configuration of an external URL?**
  - Cannot do this in-place due to interaction with GeoIP sorting.
  - Looks relatively straightforward!

CVMFS_EXTERNAL_METALINK!?!?

Complementing the Stratum-1

- Maintaining a full Stratum-1 is quite expensive.
  - All data must be replicated, at every Stratum-1, and performance needs to be high due to GC.
- Can we have a “stratum-1 light” based on a caching proxy?
  - As we have high hit rates, this mostly avoids direct connections to the repositories.
  - We could serve more repositories if we didn’t have to worry about providing space for a complete replicas.
- Pelican, based on XCache, assumes immutable objects.
  - This is not true for CVMFS: the root of the repo is changed for each update.
  - So, a “Stratum-1 light” may need to use the existing Stratum-1 network for the mutable pieces.

The OSDF: Connecting to your datasets

To acknowledge all of the partners working together...

OAC-2331480

Provides the software

OAC-2030508

Operates the OSDF services

OAC-2112167

Operates (most of) the OSDF hardware

The OSG Consortium is the "umbrella" we work within.

Questions?

This project is supported by the National Science Foundation under Cooperative Agreements OAC-2331480. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.