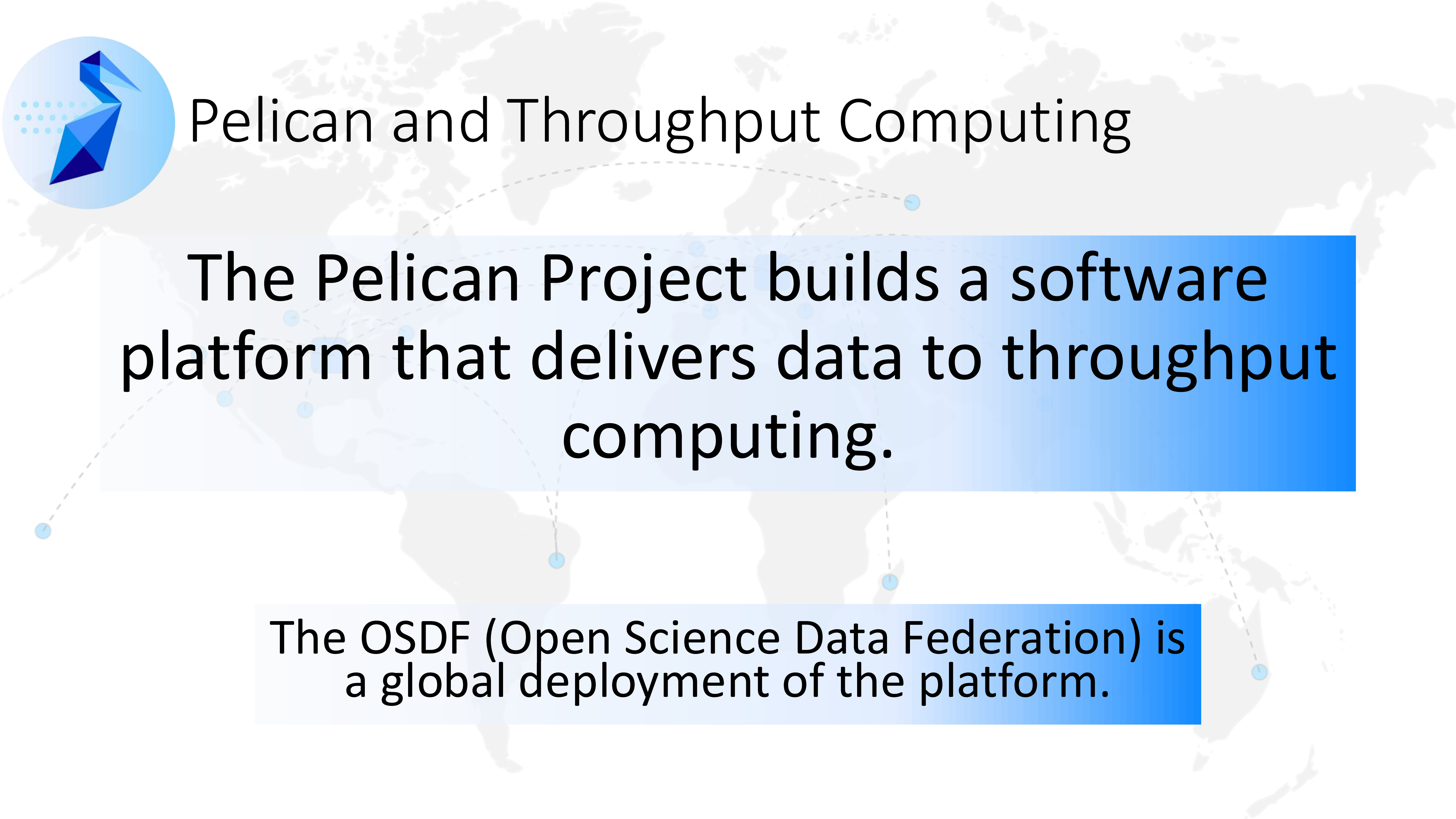
# The Pelican in Flight: Delivering Throughput Data

# Pelican and Throughput Computing



The Pelican Project builds a software platform that delivers data to throughput computing.

The OSDF (Open Science Data Federation) is a global deployment of the platform.

# What is the OSDF ?

… By Analogy…

+

“Netflix for Science”

Allowing computational workloads to stream data

# What is the OSDF ?

… By Analogy…

CLOUDFLARE +

“Cloudflare for Science”

Infrastructure for scaling access to your storage

# OSDF enabling science

- The LIGO collaboration stores their interferometer data at Caltech.
  - Scientists around the world want to access and use it from the computing *they* have access to.
  - LIGO wants to enable science beyond the (finite) compute capacity at Caltech.
- LIGO has connected their proprietary and public data to the OSDF.
  - Any browser, python notebook, or compute cluster access LIGO data via the OSDF.

LIGO
LIGO Scientific Collaboration
~ 1200 members ~ 100 institutions, 18 countries
LSC
Caltech
American University
Andrews University
Washington State University
California State University Fullerton
UTRGV
Southern University
University of Mississippi
The University of Sheffield
University of Maryland
indigo
PennState
Tsinghua University
University of Minnesota
Montclair State University
Monash University
Australian National University
Max Planck Institute for Gravitational Physics Albert Einstein Institute
International Institute of Physics
Bellevue College
UIB Universitat de les Illes Balears
University of Cambridge
Université de Montréal
Polytechnique Montréal
Lomonosov Moscow State University
The University of Western Australia
NCSA
University of Southampton
The University of Chicago
Texas Tech University
Sonoma State University
University of the West of Scotland UWS
University of Glasgow
Columbia University in the City of New York
CITA ICAT
The University of Adelaide Australia
LSU Louisiana State University
OzGrav
NASA
Bothell
RIT
University of Washington
University of Wisconsin Milwaukee
Marshall Space Flight Center
University of Strathclyde
Michigan
Whitman College
University of Birmingham
Università degli Studi del Sannio
University of Zurich
Cardiff University Prifysgol Caerdydd
King's College London
Hillsdale College
Colorado State University
東京大学 The University of Tokyo
Montana State University
Georgia Institute of Technology
Korean Gravitational Wave Group
The University of Melbourne
Northwestern
UF University of Florida
ACIGA
Universität Hamburg
Charles Sturt University
Leibniz Universität Hannover
Swinburne University of Technology
Trinity University
Goddard Space Flight Center
Embry-Riddle Aeronautical University
GEO 600

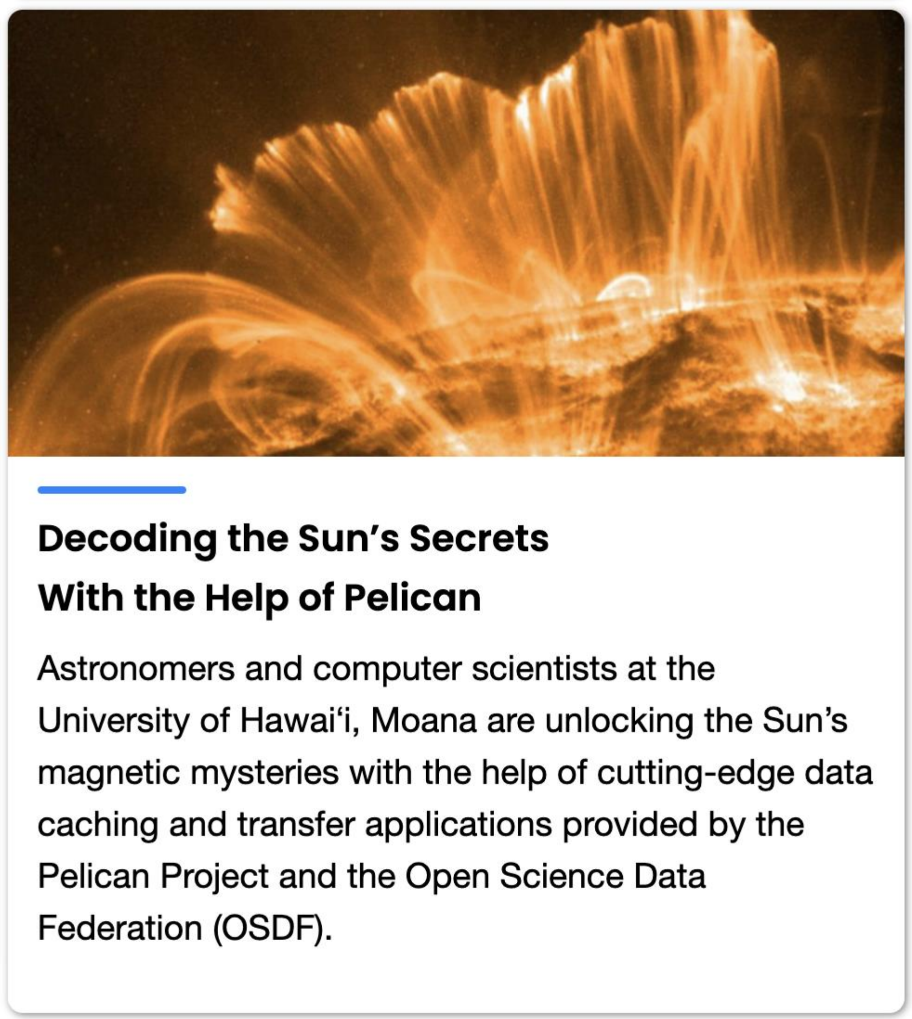
In 2024, LIGO moved 27PB of objects; 200TB of unique data.

# Not just "the big guys"

- At U. Hawaii, an individual PI - Curt Dodds – uses their CC*-funded storage to share data from the SPIN4D project
  - doi:10.5281/zenodo.13879854
- If you use the SPIN4D notebook to explore their dataset, you use the OSDF!
  - [https://github.com/ifauh/spin4d-data/blob/v0.5/spin4d-data-exploration.ipynb](https://github.com/ifauh/spin4d-data/blob/v0.5/spin4d-data-exploration.ipynb)

Check out [Curt Dodd's talk on Friday](#).

Research Highlight – U. Hawaii



**Decoding the Sun's Secrets With the Help of Pelican**

Astronomers and computer scientists at the University of Hawai'i, Moana are unlocking the Sun's magnetic mysteries with the help of cutting-edge data caching and transfer applications provided by the Pelican Project and the Open Science Data Federation (OSDF).

https://pelicanplatform.org/news/2024/12/20/sun-secrets

# OSDF - A national object delivery service

Operated by PATh
(NSF #2030508)

OSDF is powered by the
Pelican software
(NSF #2331480).

## Value Proposition

- **Shares** your data (Objects) with authorized consumers.
- **Manages** the load of Object reuse on your Object Store.
- **Fuses** Objects from diverse Object Stores through a common namespace and API.
- **Stages** Objects in network-embedded storage.

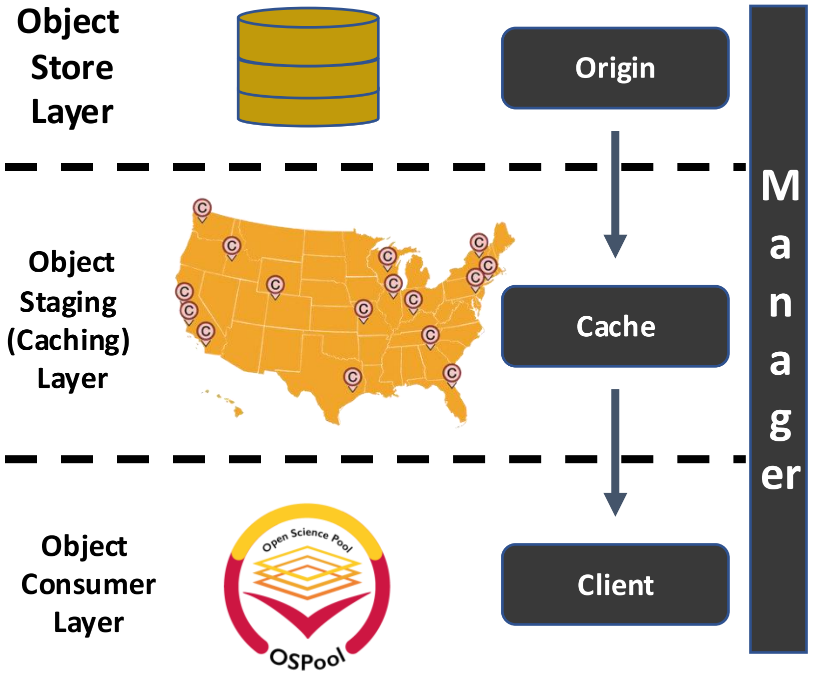
## Who can benefit?

- **Open** to any US researcher, data (object) provider, or computing facility.

**>140**
**PB moved**

**>3.5B**
**Objects delivered**

In the last 12 months.



**34 caches** throughout the world, at points of presence within major compute centers and the global R&E networks (ESNet, Internet2).

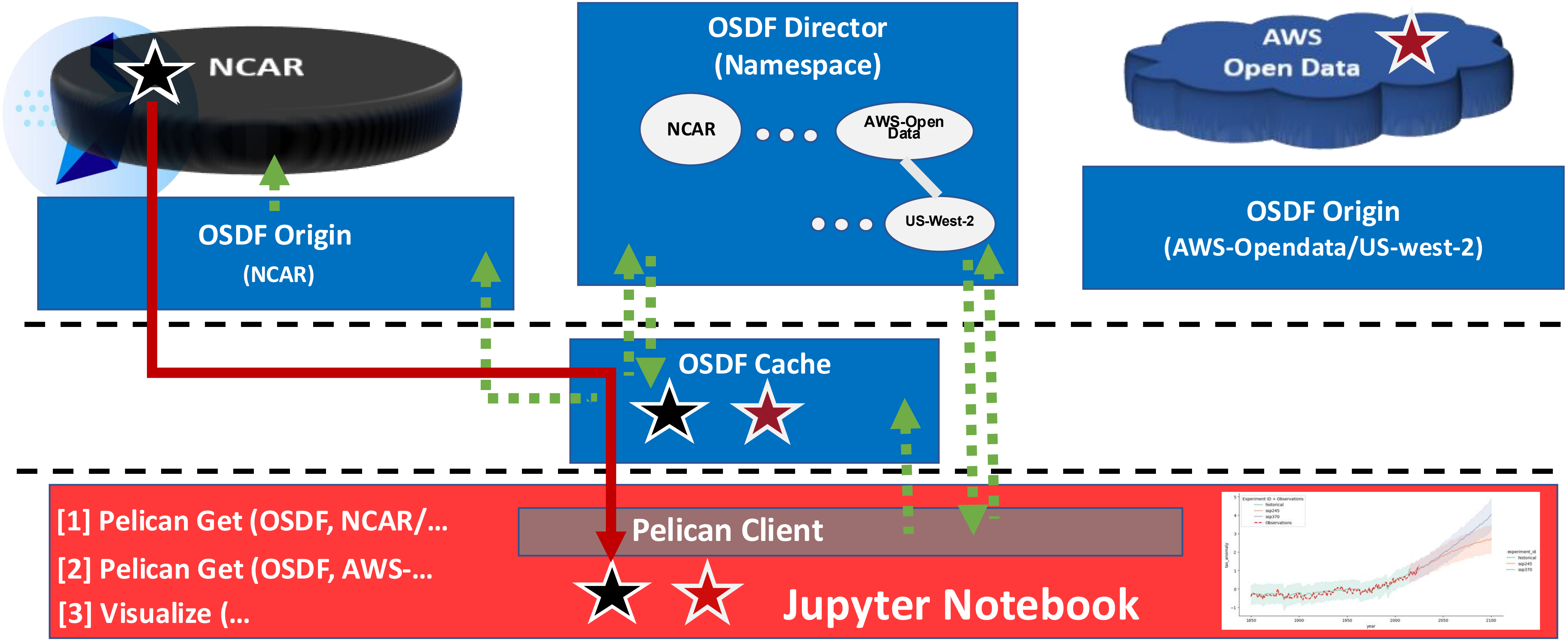
## Who is using the OSDF?

- Workloads that have significant **reuse and redelivery** of objects at remote autonomous Object Stores.
- Object Stores with limited capacity or egress costs.
- **NOAA**: Via AWS OpenData
- **NSF**: NCAR, NRAO, LIGO, EHT
- **DOE**: FNAL (LHC, DUNE), JLab, Fusion

## Key concepts

- **Object:** both data & non-data objects (containers, models, libraries).
- **Object Store**: a S3-compatible endpoint, filesystem, or HTTP webserver.
- **Origin:** connects an Object Store with national infrastructure. Objects are moved from (GET) and to (PUT) the store through Origin.

# OSDF – Core Concepts



NCAR

OSDF Origin
(NCAR)

OSDF Director
(Namespace)

NCAR

AWS-Open Data

US-West-2

AWS
Open Data

OSDF Origin
(AWS-Opendata/US-west-2)

OSDF Cache

Pelican Client

[1] Pelican Get (OSDF, NCAR/…
[2] Pelican Get (OSDF, AWS-…
[3] Visualize (…

Jupyter Notebook

Researcher uses a Jupyter Notebook to create a visualization that requires two objects:

★ NCAR/ rda/harshah/osdf_data/HadCRUT.5.0.2.0.analysis.summary_series.global.monthly.zarr

★ C AWS-OpenData/US-West-2/cmip6-pds/CMIP6/CFMIP/NCAR/CESM2/aqua-4xCO2/r1i1p1f1/Amon/co2mass/gn/v20190816

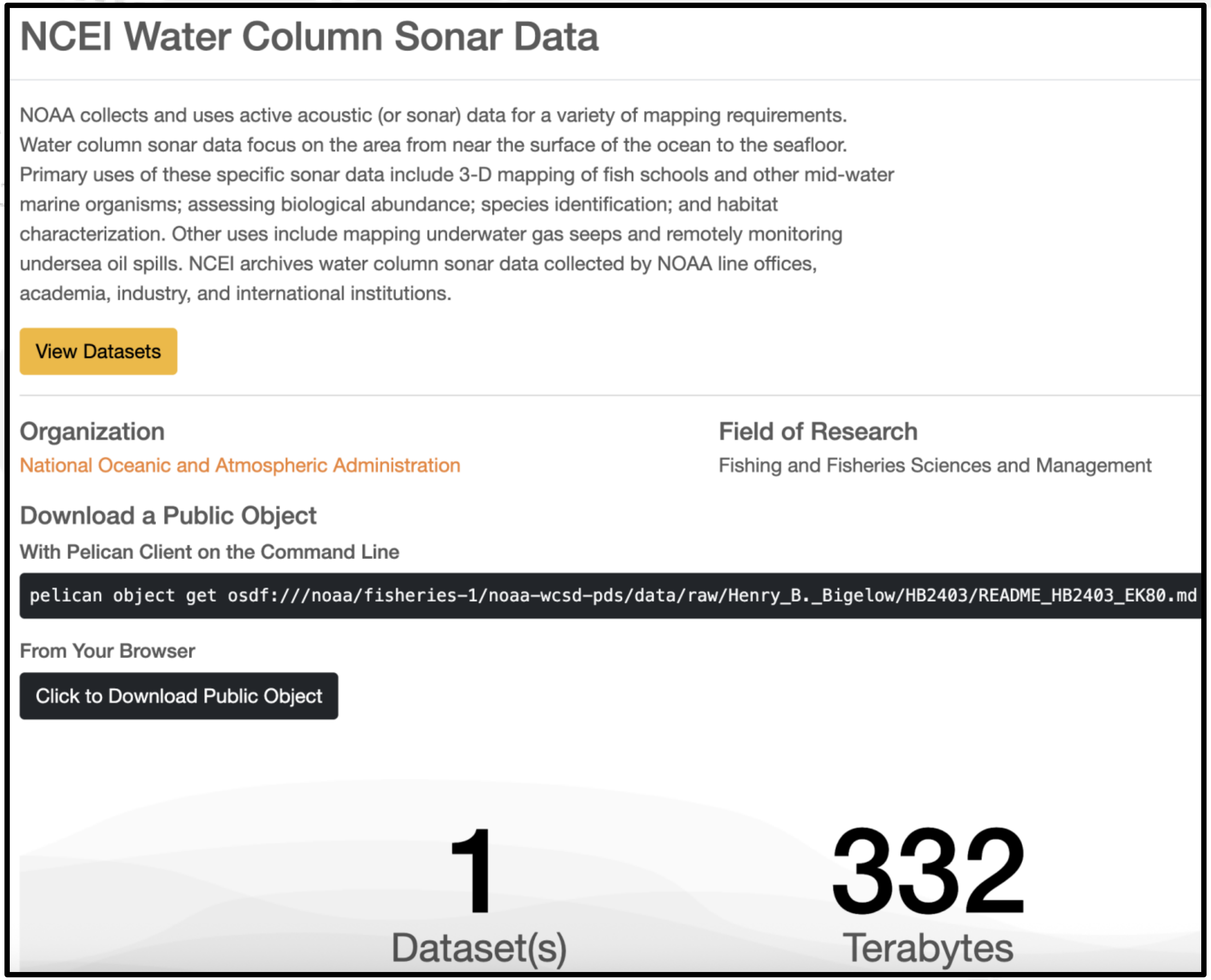
# What happened in the last year?

# Clients

- **Command line**: End-to-end checksumming, token auto-discovery.
- **HTCondor Plugin**: Extensive monitoring reporting, end-to-end checksums.
- **Python library / FSSpec**: First official release! Integrates with the “data science” ecosystem.
- **Web Browser**: Simple object download. Browser-based OAuth2 support in-progress.

## Explore the OSDF

at https://osg-htc.org/services/osdf/data



### NCEI Water Column Sonar Data

NOAA collects and uses active acoustic (or sonar) data for a variety of mapping requirements. Water column sonar data focus on the area from near the surface of the ocean to the seafloor. Primary uses of these specific sonar data include 3-D mapping of fish schools and other mid-water marine organisms; assessing biological abundance; species identification; and habitat characterization. Other uses include mapping underwater gas seeps and remotely monitoring undersea oil spills. NCEI archives water column sonar data collected by NOAA line offices, academia, industry, and international institutions.

**Organization**

National Oceanic and Atmospheric Administration

**Field of Research**

Fishing and Fisheries Sciences and Management

**Download a Public Object**

With Pelican Client on the Command Line

```
pelican object get osdf:///noaa/fisheries-1/noaa-wcsd-pds/data/raw/Henry_B._Bigelow/HB2403/README_HB2403_EK80.md
```

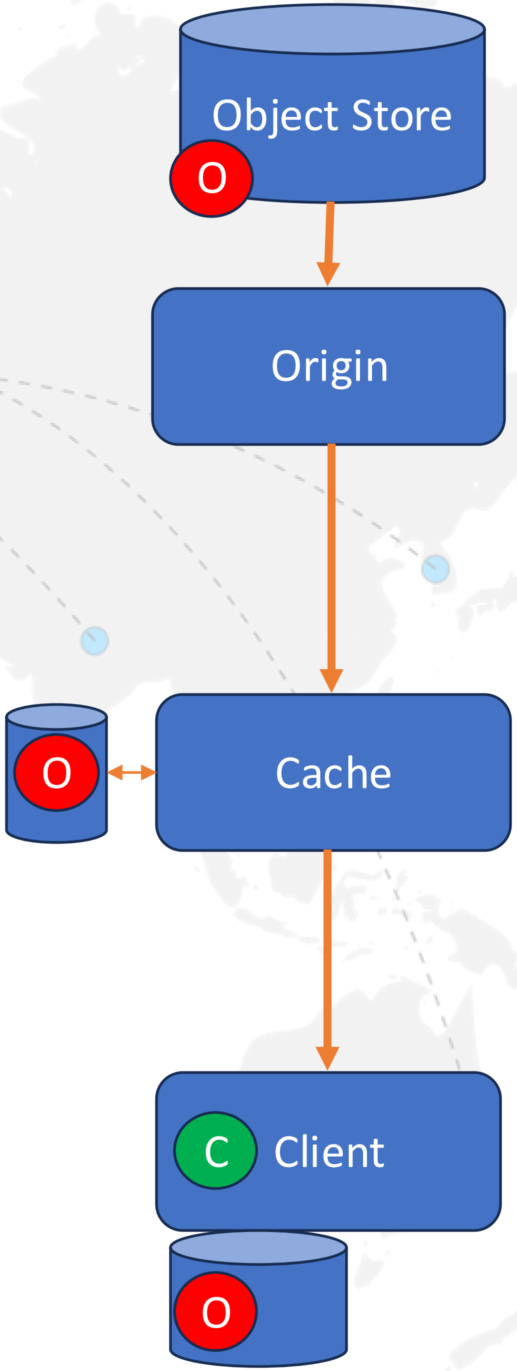
From Your Browser

1 Dataset(s)

332 Terabytes

# End-to-end checksumming

- Objects **(O)** travel from the object store through the data federation and to the client.
  - A copy may be made at the cache for repeated access.
- Ultimately, a copy of the object is made on disk by the client
- **New (v7.16)**: the client will also calculate the object's checksum **(C)** as it is downloaded.



# End-to-end checksumming

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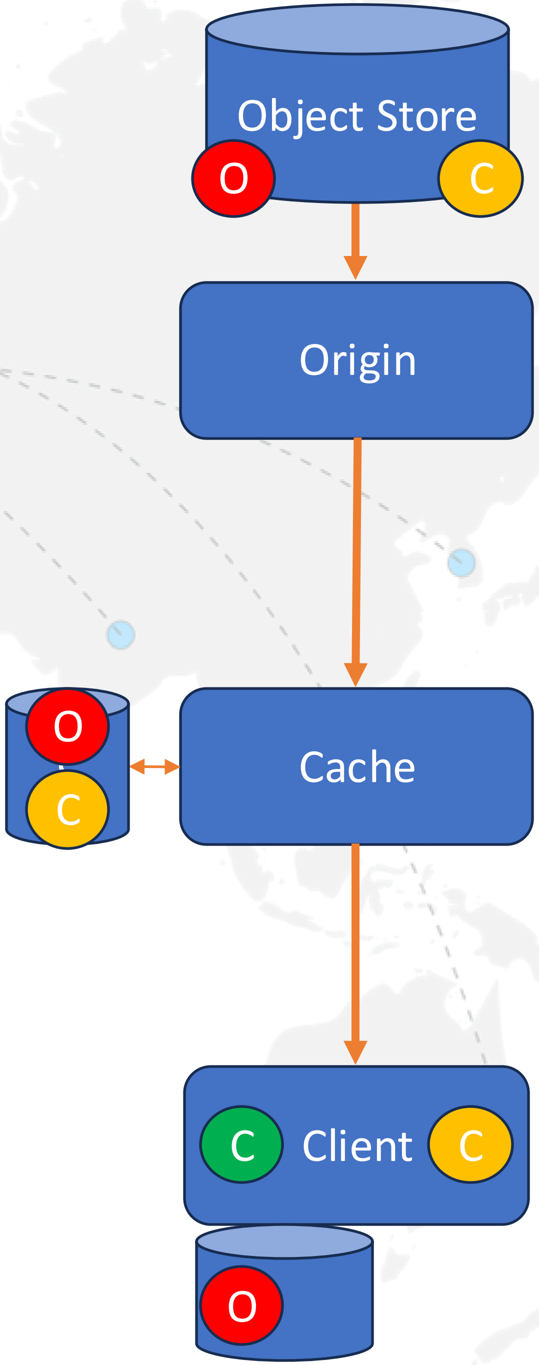
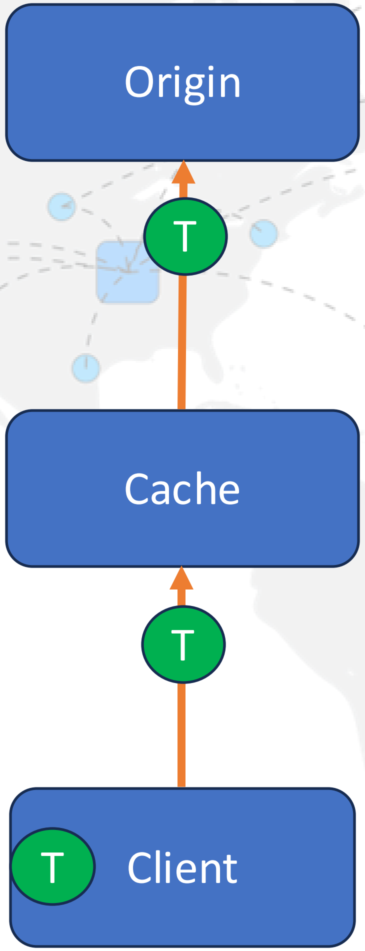
- **New (v7.16)**: the client will also calculate the object's checksum (C) as it is downloaded.
- **New (v7.16)**: the client will request a copy of the server-side checksum (C) in the object store and compare the two, failing the transfer on mismatch.



# Innovating in Authorization

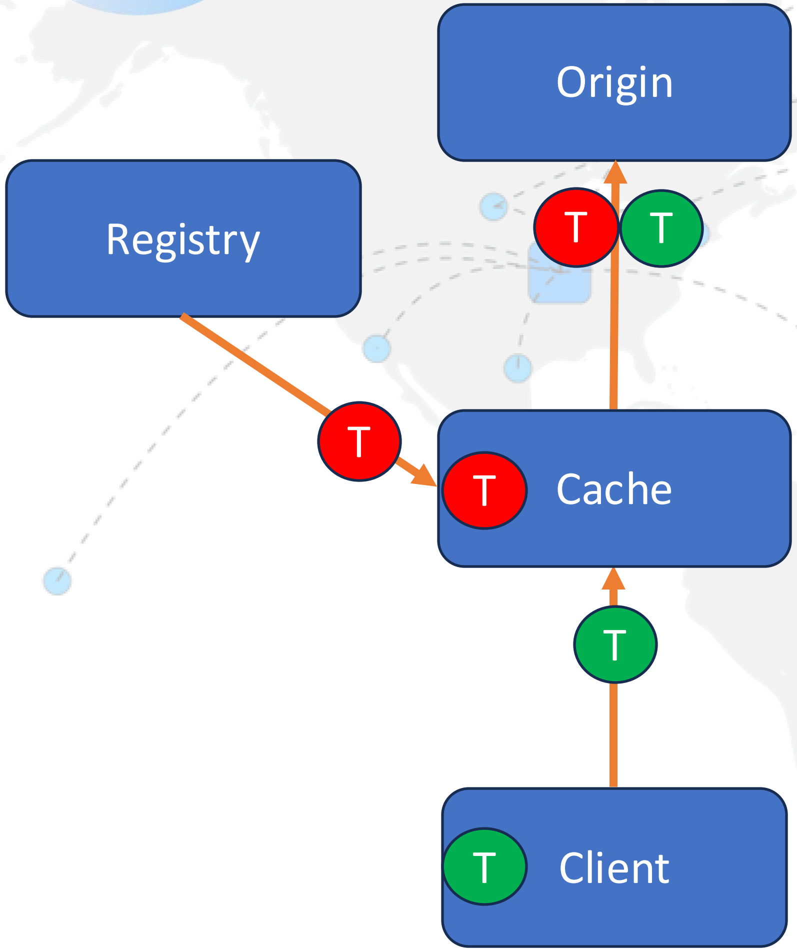


Who is the origin talking to?

- Originally, the client acquired a token (T) which was used to authorize the request to the cache.
- If the cache does not have the object, it will forward the request to the origin.
- Conveniently, the same token can also be forwarded to the origin to authorize the cache's request.
- **Problem**: How does the origin distinguish a cache from a "badly behaved client"?
  - Cannot prevent cache bypass!

# Innovating in Authorization

For more information about authorization, see Justin's talk later today!



New!

- Caches receive a token **(T)** from the registry service.
  - The token identifies the bearer as a service part of the federation.
- Origins can require:
  - A request be performed by a known service **(T)**,
  - On behalf of an authorized client **(T)**.
- Clients can no longer talk directly to origins, pretending to be a cache!

# 💪Powering Storage Backends

For more about our summer plans for the Globus backend, see the presentation today by our summer fellow, William.

Each origin is configured with a plugin based on the object store type:

- **S3**: Allows integration with AWS and compatible services. Support for write, object listings, and an overhaul of error handling in the last year.
- **HTTP**: Connects generic web servers to the data federation. Read-only.
- **Globus**: Connects a Globus collection to the federation. Read-only.
- **xroot**: Full-featured! The “native language” of the XRootD server.
- **POSIX**: Still the most popular!

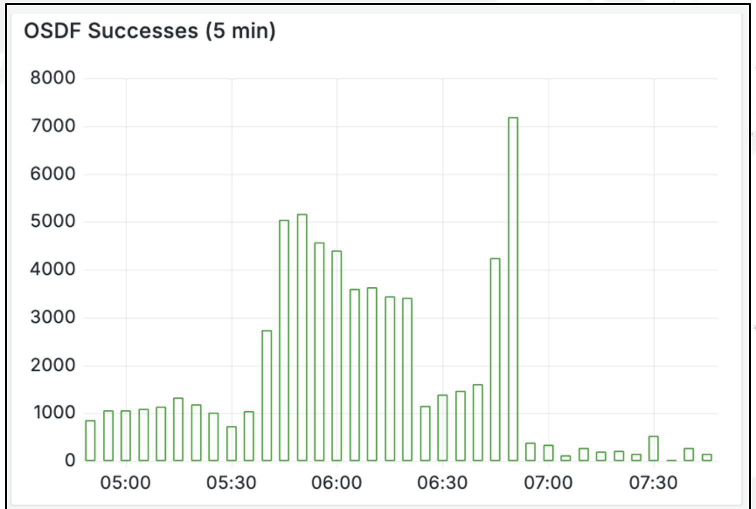
What happens when an “overly enthusiastic user” launches **a large workload with little reuse?**

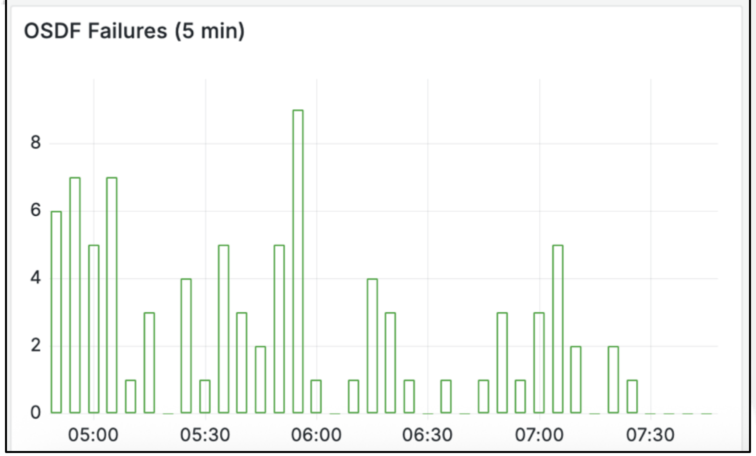
- The “throttling” component purposely slows the user requests to protect the object store.
- **Object store protection** is a core value proposition provided by the OSDF, *even without reuse*.
- New: The throttle is now multi-user aware. Only the “overly enthusiastic user” is slowed, not every user.

**Much to do**: When HTCSS manages the workload, there’s plenty of opportunities for the AP to be aware

# Keeping a Close Eye on You

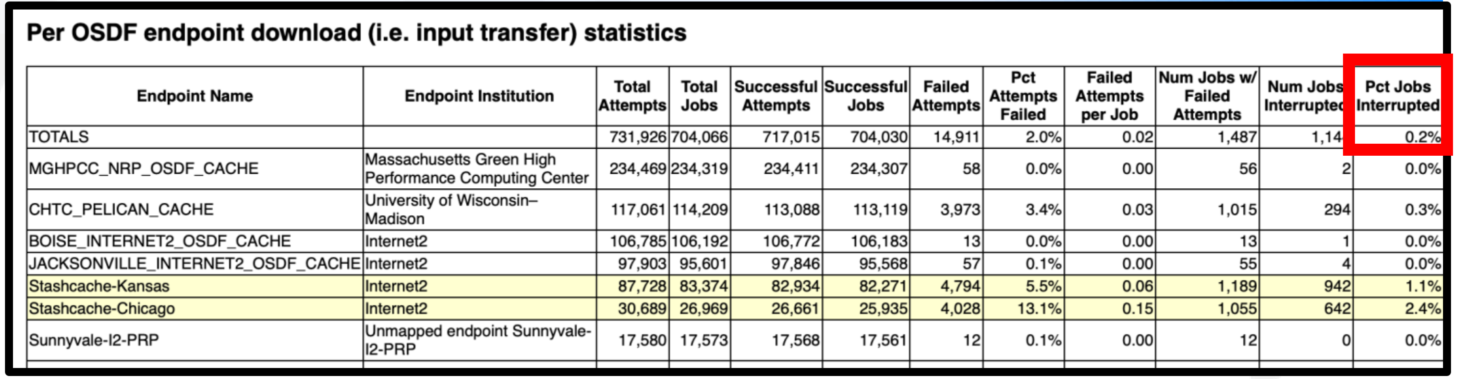
For a deeper dive in monitoring, [check out Patrick's talk](#) on Wednesday.





We've historically drowned in monitoring data – most of it not useful for operations.

- We leverage reports from the HTCondor plugin to understand the "typical user experience" for the OSPool.
- The OSPool APs aggregate these per-file documents and we can turn these into reports or charts.
- **Assumption**: The OSPool is distributed enough that it provides a "good proxy" for a random user.
  - Has been essential for spotting common failure cases which have identified ~half dozen serious bugs.
- **TODO**: Working to better separate "infrastructure problems" (random EOF) from "user problems" (404 file not found).



**Per OSDF endpoint download (i.e. input transfer) statistics**

| Endpoint Name | Endpoint Institution | Total Attempts | Total Jobs | Successful Attempts | Successful Jobs | Failed Attempts | Pct Attempts Failed | Failed Attempts per Job | Num Jobs w/ Failed Attempts | Num Jobs Interrupte | Pct Jobs Interrupted |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTALS | | 731,926 | 704,066 | 717,015 | 704,030 | 14,911 | 2.0% | 0.02 | 1,487 | 1,14 | 0.2% |
| MGHPCC_NRP_OSDF_CACHE | Massachusetts Green High Performance Computing Center | 234,469 | 234,319 | 234,411 | 234,307 | 58 | 0.0% | 0.00 | 56 | 2 | 0.0% |
| CHTC_PELICAN_CACHE | University of Wisconsin–Madison | 117,061 | 114,209 | 113,088 | 113,119 | 3,973 | 3.4% | 0.03 | 1,015 | 294 | 0.3% |
| BOISE_INTERNET2_OSDF_CACHE | Internet2 | 106,785 | 106,192 | 106,772 | 106,183 | 13 | 0.0% | 0.00 | 13 | 1 | 0.0% |
| JACKSONVILLE_INTERNET2_OSDF_CACHE | Internet2 | 97,903 | 95,601 | 97,846 | 95,568 | 57 | 0.1% | 0.00 | 55 | 4 | 0.0% |
| Stashcache-Kansas | Internet2 | 87,728 | 83,374 | 82,934 | 82,271 | 4,794 | 5.5% | 0.06 | 1,189 | 942 | 1.1% |
| Stashcache-Chicago | Internet2 | 30,689 | 26,969 | 26,661 | 25,935 | 4,028 | 13.1% | 0.15 | 1,055 | 642 | 2.4% |
| Sunnyvale-I2-PRP | Unmapped endpoint Sunnyvale-I2-PRP | 17,580 | 17,573 | 17,568 | 17,561 | 12 | 0.1% | 0.00 | 12 | 0 | 0.0% |

# Keeping a Close Eye on You

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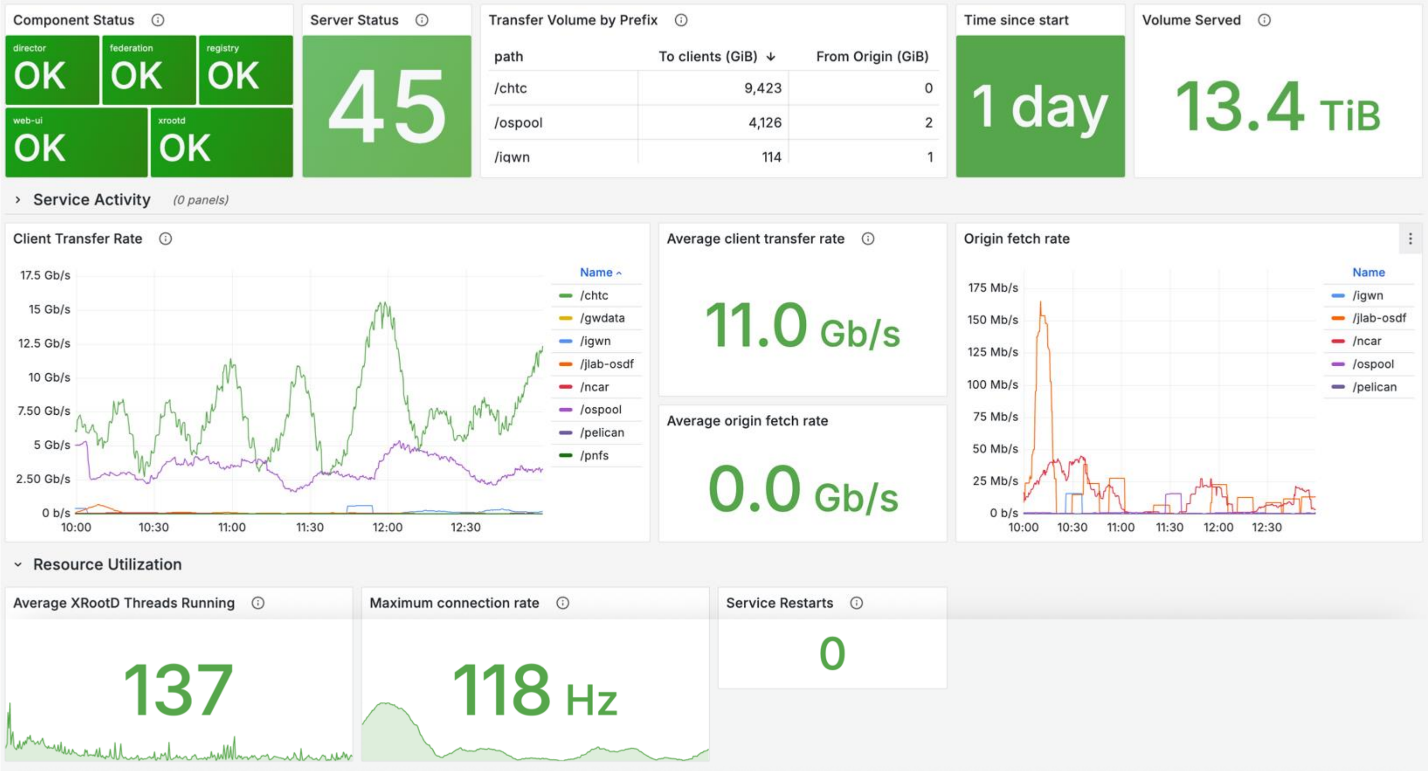


Component Status

director OK
federation OK
registry OK
web-ui OK
xrootd OK

Server Status

45

Transfer Volume by Prefix

| path | To clients (GiB) ↓ | From Origin (GiB) |
|---|---|---|
| /chtc | 9,423 | 0 |
| /ospool | 4,126 | 2 |
| /igwn | 114 | 1 |

Time since start

1 day

Volume Served

13.4 TiB

› Service Activity *(0 panels)*

Client Transfer Rate

Average client transfer rate

11.0 Gb/s

Average origin fetch rate

0.0 Gb/s

Origin fetch rate

⌄ Resource Utilization

Average XRootD Threads Running

137

Maximum connection rate

118 Hz

Service Restarts

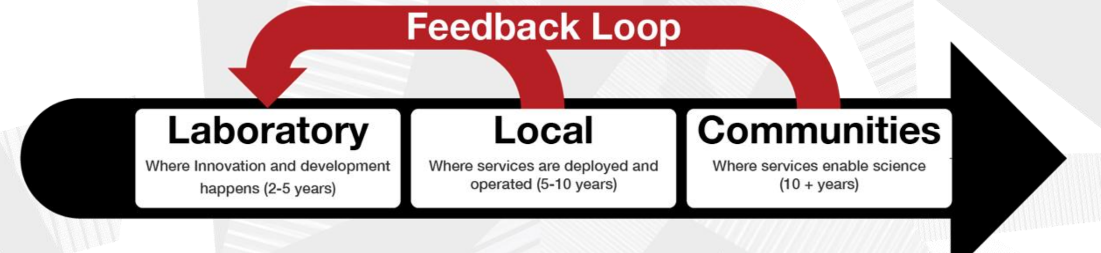
0

We still maintain various internal dashboards, typically Grafana-based.

Pushing more toward identifying errors and problems – less "big pretty numbers".

# NDC Pathfinders

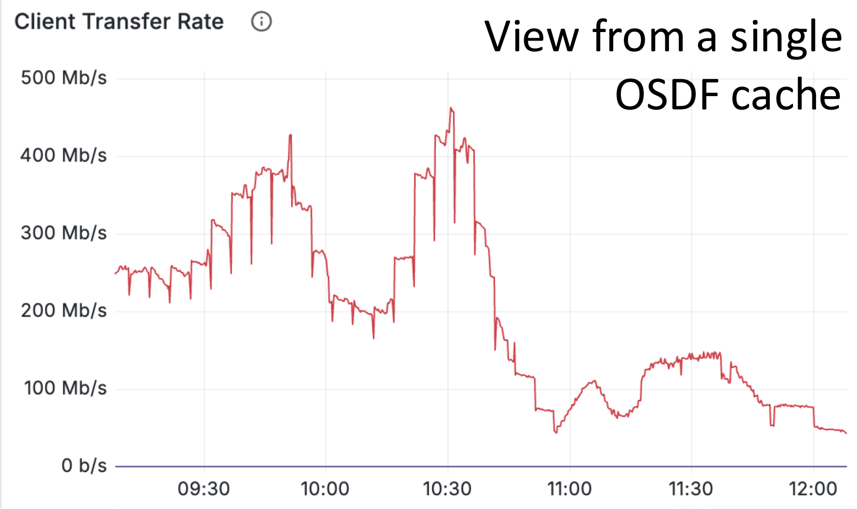
- Pelican was funded as part of NSF's "National Data Cloud" for Climate initiative in 2023.
  - The NDC brings together a broad set of domain science and cyberinfrastructure projects, allowing one to assemble end-to-end approaches spanning the vertical stack of expertise.
- The NDC Pathfinders collaboration consists of Pelican and 4 earth science-driven projects that aim to show potential approaches ("paths") through the NSF-funded cyberinfrastructure.


Feedback Loop
Laboratory
Where Innovation and development happens (2-5 years)
Local
Where services are deployed and operated (5-10 years)
Communities
Where services enable science (10 + years)

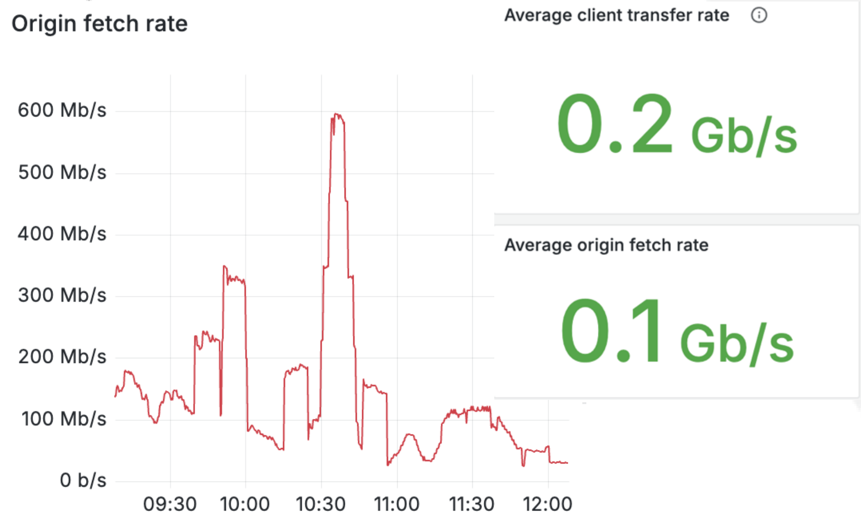
NDC Pathfinders Collaboration at Madison in 2024.
[https://ndc-pathfinders.org/](https://ndc-pathfinders.org/)

# NCAR Research Data Archive

To learn more about using the NCAR data via OSDF, [see Harsha's talk tomorrow](#).

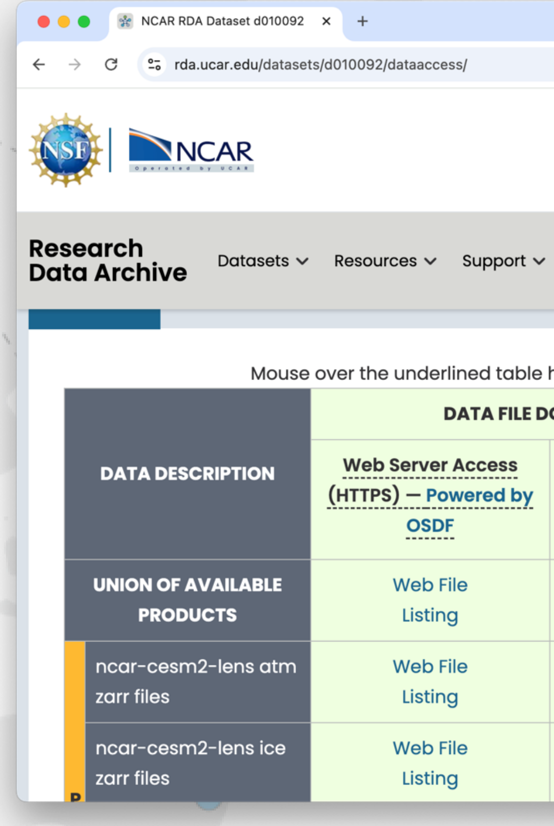


View from a single OSDF cache



NCAR's part in the NDC Pathfinders is to make its data available through the OSDF and to inspire its community on how to leverage it.

- In May 2025, NCAR's Research Data Archive (RDA) switched all its HTTP-based download links to use the OSDF.
- More importantly, Harsha Hampapura has been developing material for the community demonstrating [how the OSDF can be leveraged](#) via environments including Jupyter, OSPool, and Dask.



Mouse over the underlined table h

| DATA DESCRIPTION | DATA FILE DO |
|---|---|
| | Web Server Access (HTTPS) — Powered by OSDF |
| UNION OF AVAILABLE PRODUCTS | Web File Listing |
| ncar-cesm2-lens atm zarr files | Web File Listing |
| ncar-cesm2-lens ice zarr files | Web File Listing |

# NAIRR

For an NDP / OSDF / Pelican example, check out Curt Dodd's talk on Friday.

Pelican is one of the data-centric projects of the National AI Research Resource (NAIRR) Pilot. We collaborate with the National Data Platform, which builds out data analysis services on top of the NRP.

Our plans:

- Provide technology (Python FSSpec library) to allow common AI tools (PyTorch) to stream from the OSDF.
- Ensure NAIRR datasets are available via the OSDF.
- With PATh, show the the vision of Throughput machine learning to train ensembles of models and high throughput inference.

Watch this space!

# Retiring the old OSDF

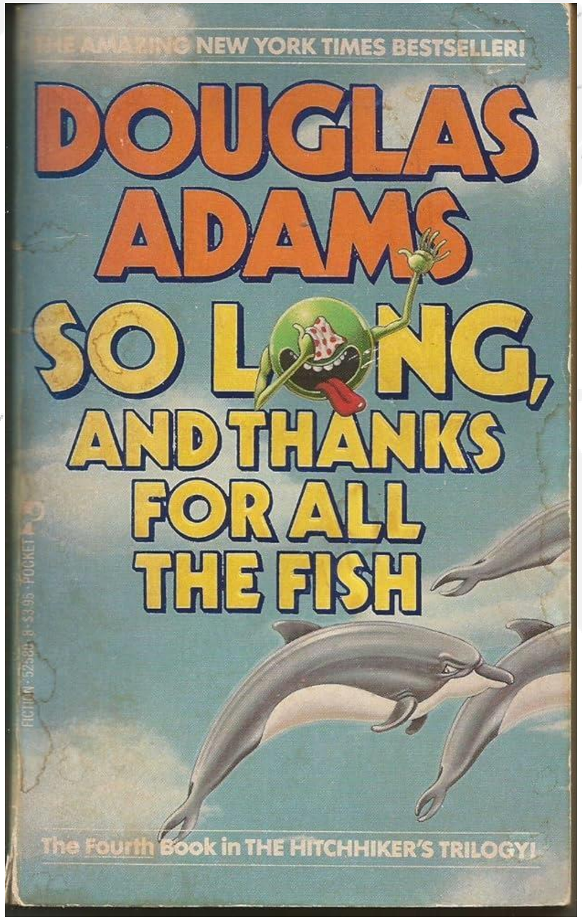

THE AMAZING NEW YORK TIMES BESTSELLER!
DOUGLAS ADAMS
SO LONG, AND THANKS FOR ALL THE FISH
The Fourth Book in THE HITCHHIKER'S TRILOGY!

Image from https://www.amazon.com/So-Long-Thanks-all-Fish/dp/0671525808

Before the Pelican Project was funded, the OSDF was built "one patch at a time":

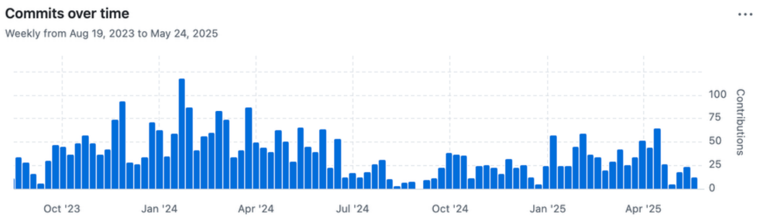
- 2011: The AAA project (NSF #1104664) developed a file cache based on the XRootD software.
- 2015: Started by deploying XRootD-based caches for the Stash filesystem @ UChicago.
- 2020: Grew into a generic system for multiple origins. Leveraged WLCG services for GeoIP and OSG Topology for cache discovery.
- 2023: Pelican Project started, re-engineering the federation components while keeping OSDF operational.
- **2025: Retired the pre-Pelican components in OSDF!**

# The View from Above

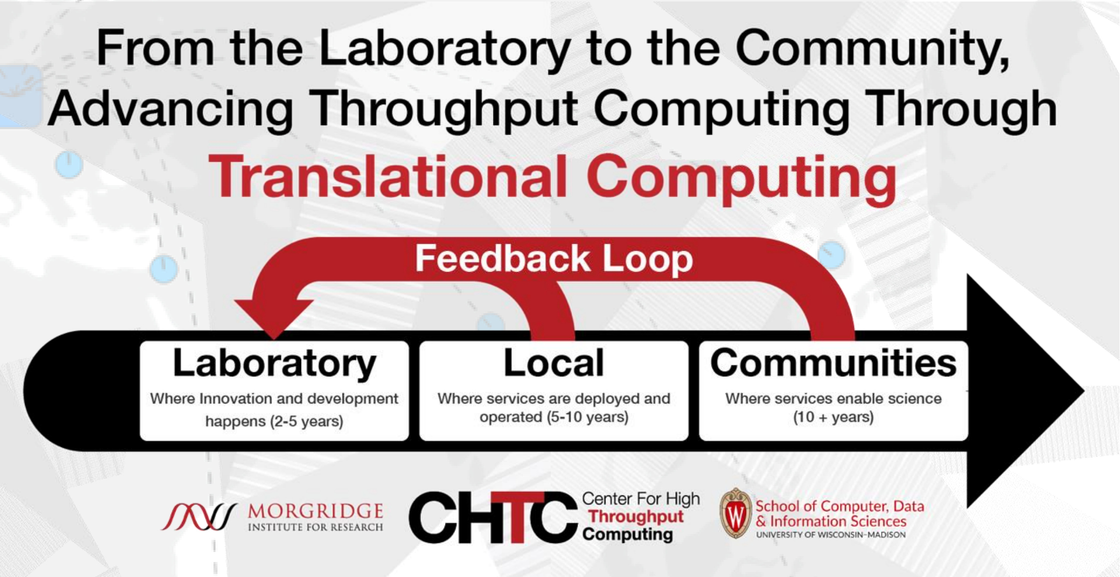
# 🎂Pelican is now >1 yr old🎂

The Condor Project is 40; the OSG Consortium is 20; the Pelican Project is 1.

- The “translational CS” loop is just starting!
  - The laboratory is churning out new ideas – still iterating on fundamental concepts.
  - The local – the OSDF – is now 100% Pelican.
  - We are rapidly building out the community.


Commits over time

Weekly from Aug 19, 2023 to May 24, 2025


From the Laboratory to the Community, Advancing Throughput Computing Through

**Translational Computing**

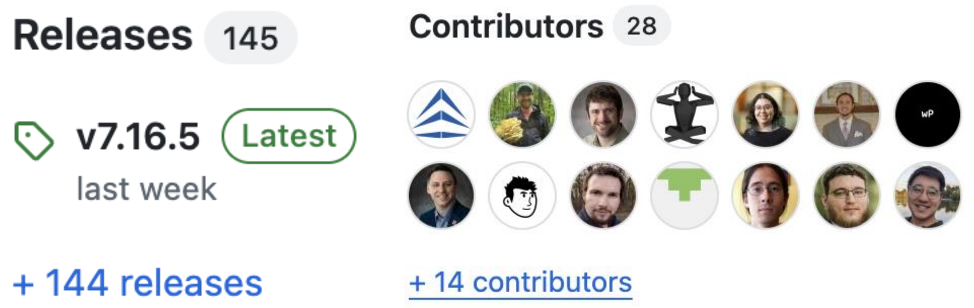
Feedback Loop

**Laboratory**
Where Innovation and development happens (2-5 years)

**Local**
Where services are deployed and operated (5-10 years)

**Communities**
Where services enable science (10 + years)

MORGRIDGE INSTITUTE FOR RESEARCH
CHTC Center For High Throughput Computing
School of Computer, Data & Information Sciences
UNIVERSITY OF WISCONSIN–MADISON


Releases 145

v7.16.5 Latest

last week

+ 144 releases

Contributors 28

+ 14 contributors

# Who is the Community?

The “locale” is the data federation.  Who is the community?

- **OSPool users** leveraging the OSDF for powering computational workflows across the nation.
- **UW-Madison researchers** using the ‘UWDF’ for on-campus data.
- **Collaborations**, like LIGO, distributing data to large-scale workloads.
- **Individual PIs** publishing & sharing their own datasets.
- Scientists reading out **community datasets** (NCAR data).

You are an essential part of this project!
Broadening the community makes Pelican better!

**Alexander Tuna**
Computational Data Scientist and Researcher
University of California-San Diego

**Andrew Owen**
Research Computing Facilitator
University of Wisconsin-Madison

**Austin Schneider**
Student Web Developer
Morgridge Institute For Resea

**Brian Aydemir**
Systems Integration Developer
University of Wisconsin-Madison

**Patrick Brophy**
Student Research Software Engineer
Morgridge Institute for Research

**Brian Bockelman**
Principal Investigator
Morgridge Institute for Research

**Miron Livny**
Co-Principal Investigator
University of Wisconsin–Madison

**Frank Wuerthwein**
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**Tae Kidd**
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**Cannon Lock**
Web Developer
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**Emma Turetsky**
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Morgridge Institute for Research

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**Mátyás Selmeci**
Software Integration Developer
University of Wisconsin–Madison

**William Swanson**
Research Cyberinfrastructure Specialist
University of Wisconsin–Madison

# We Love Feedback!

Pelican sits at the “infrastructure layer” and is not always visible to the user.

We value your participation in events like HTC25 – please strike up a conversation with a Pelican!

# 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.

# Backup – Things Coming Up in 2025!

As you meet with us in the coffee breaks this week, ask about any of these upcoming development topics for the next year:

- Improved cache storage management as part of the Kingfisher project.
- Deployment of high-availability central components.
- Origins behind firewalls – no incoming connectivity.
- User-shareable "collections".
- Write-through caches
- Cache integration with S3 storage
- Finish Globus integration