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Ocean Observatories Initiative

Data Cyberinfrastructure for End-to-end Science: Experiences from the Ocean Observatories Initiative

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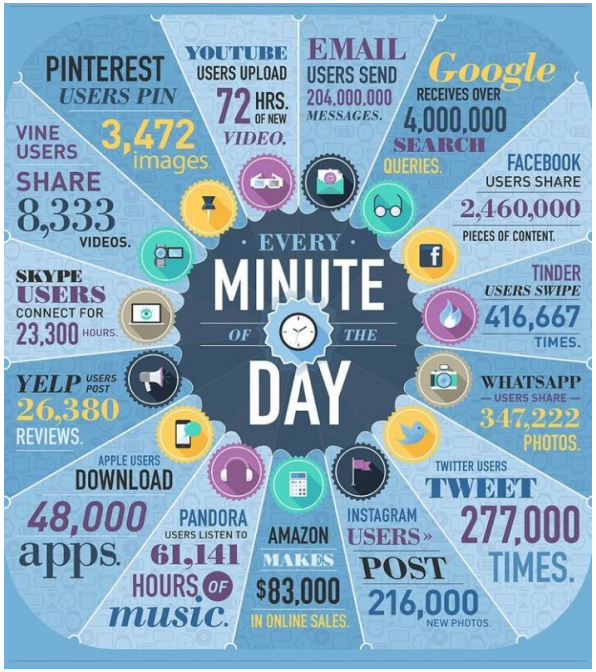
Outline

- Science transformed by computing and data
- Ocean Observatories Initiative (OOI)
- Towards end-to-end data-driven science
- Conclusion

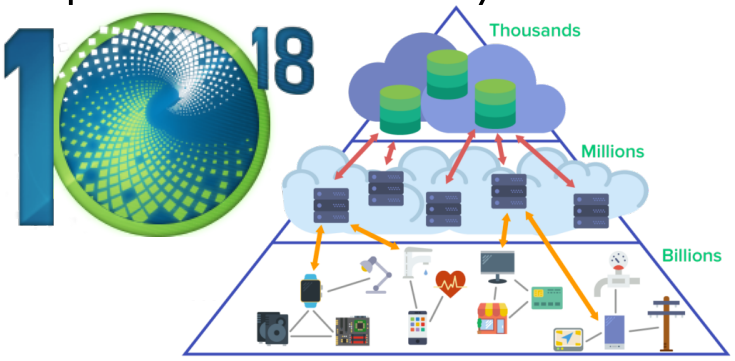
The Era of Big Data and Extreme Compute

- Data and computing data are pervasive
  - Extreme scales; extreme data volumes and rates
  - Novel paradigms: cloud services everywhere, cloud/fog/edge, in-transit, SDN/NFV, IoT, …
  - New technologies: accelerators, storage, communication, …
  - New concerns: correctness, energy, fault tolerance, security, etc.
- New paradigms and practices are essential
  - Multi-disciplinary
  - Collaborative



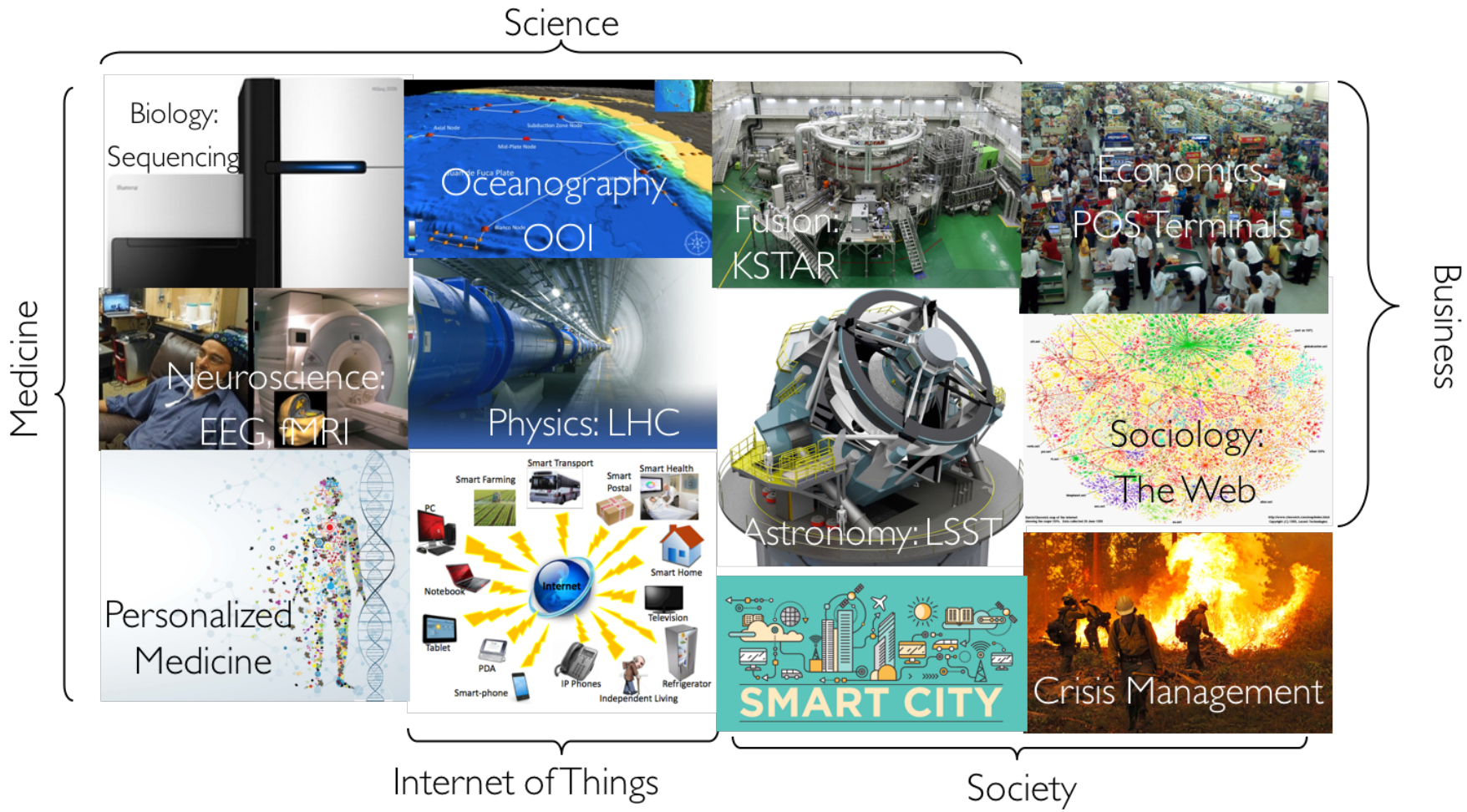
Entire printed collection of the US library of Congress is 10 Terabytes
1 Exabyte is 100,000 US Libraries of Congress

One BILLION BILLION operations per second by 2021!

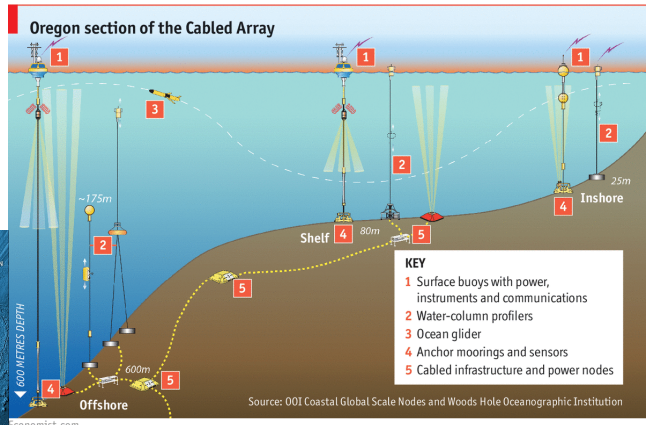


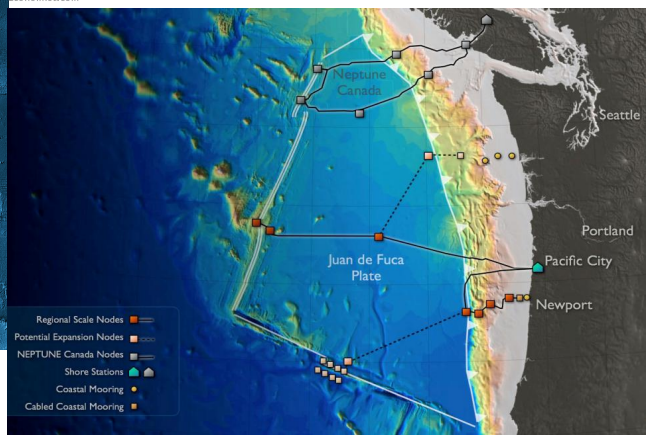
Science/Society Transformed by Data & Compute

- *The **scientific process** has evolved to include **computation** & **data***
  - New ***data rich*** reality in virtually every domain
- ***Convergence*** of opportunities and challenges



NSF Ocean Observatories Initiative (OOI)





ooinet.oceanobservatories.org

Credit: John Delaney, University of Washington

Select critical locations, of high science impact yet data sparse due to challenging nature

Deploy cutting edge platforms

Equip with multidisciplinary sensors

Provide as much real time data as possible

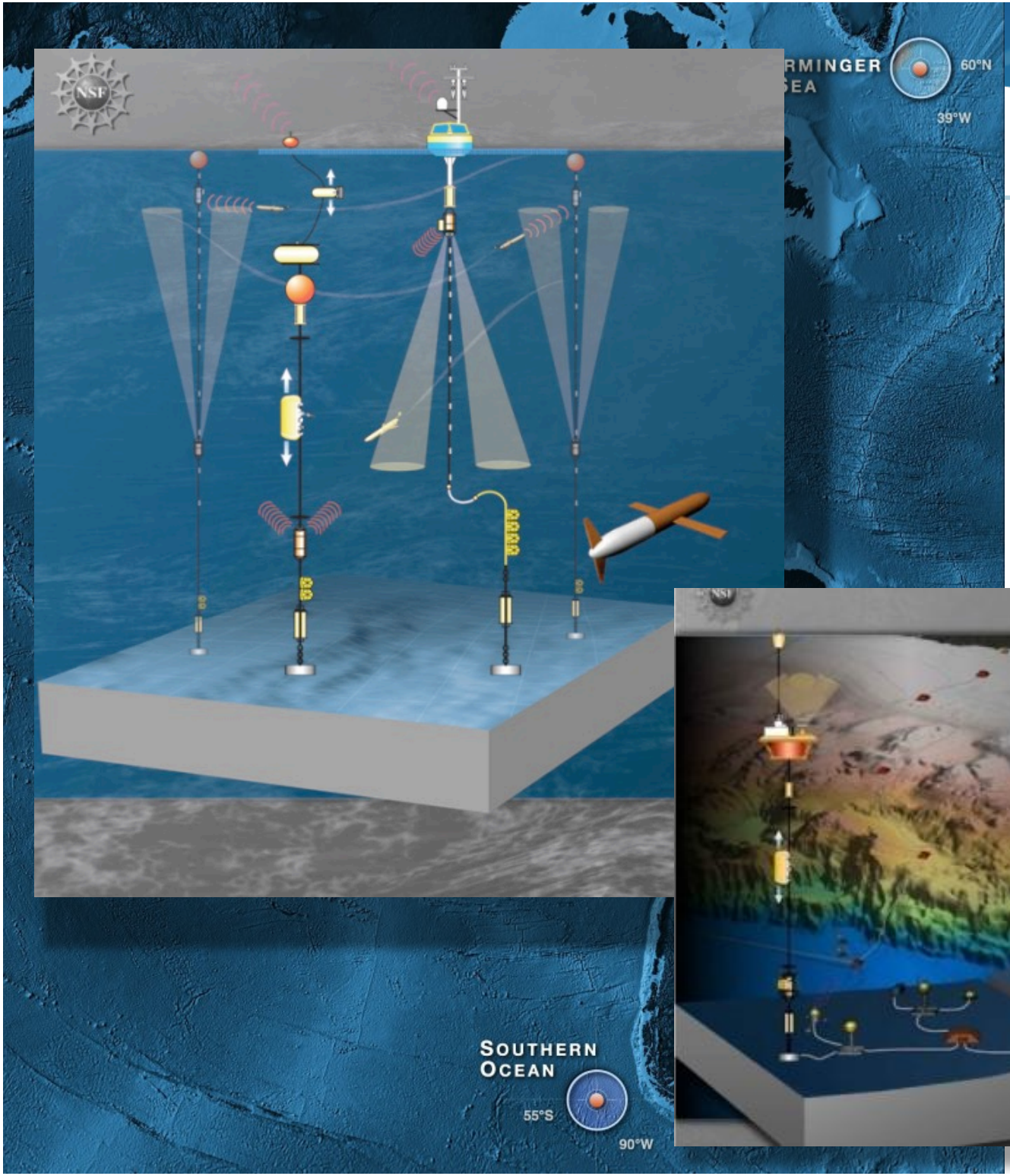
Provide as much interactive capability as possible

Provide additional bandwidth and carrying capacity

Launch crucial long-term measurements that resolve high frequencies and episodic events

Make all data available

OSU Oregon State University · RUTGERS UNIVERSITY · UNIVERSITY of WASHINGTON



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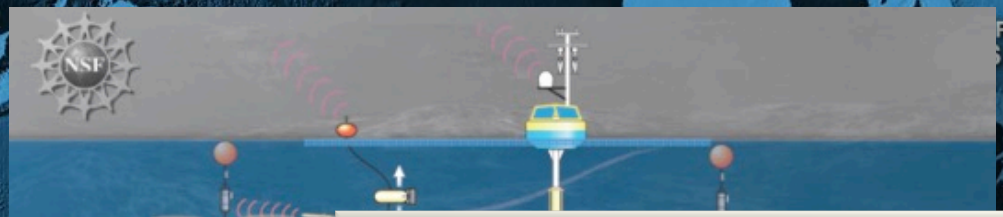

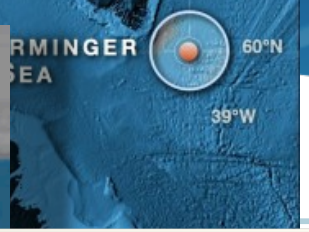

7	Arrays
57	Stable Platforms Moorings, Profilers, Nodes
31	Mobile Assets Gliders, AUVs
1227	Instruments (~850 deployed)
>2500	Science Data Products
>100K	Science/Engineering Data Products

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data

SOUTHERN
OCEAN

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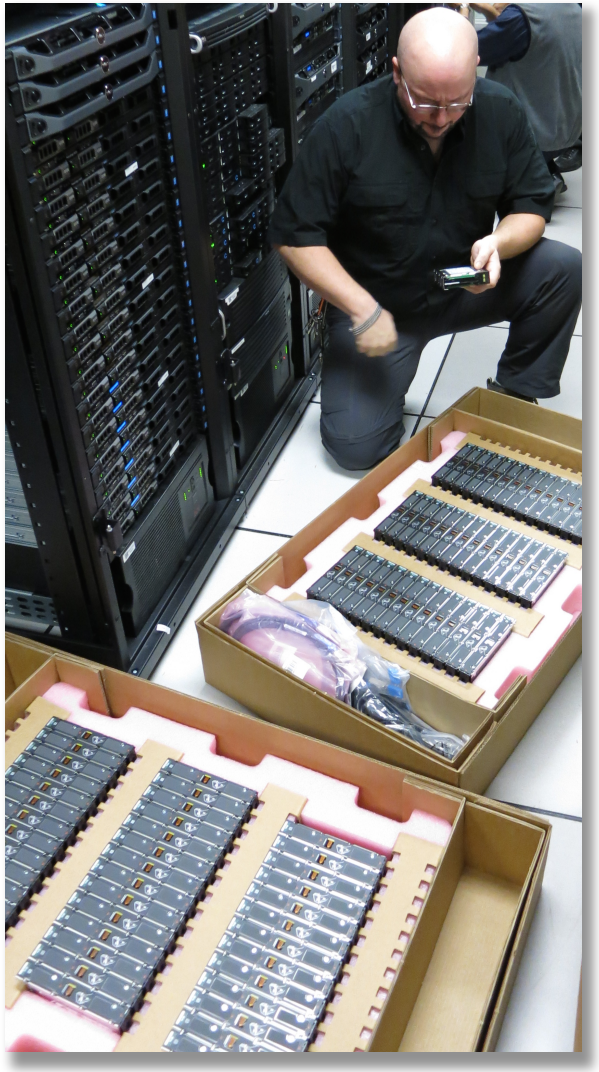
OOI CI Overall Architecture



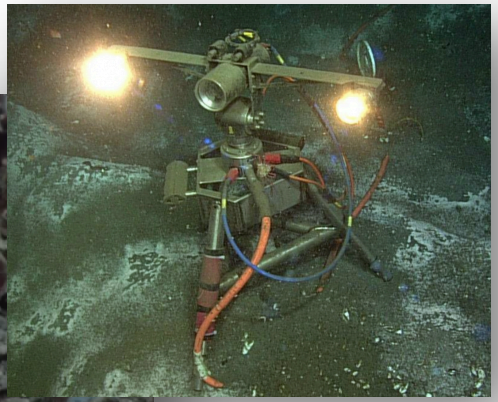
- Enterprise-level system and network architecture
- CI best practices
- Information lifecycle management
- 24/7 delivery of data & services
- Integrated software stack
- Configuration management
- Comprehensive monitoring and analytics
- Mirroring and fail-over
- Integrated cyber-security

Types of Data

Telemetered

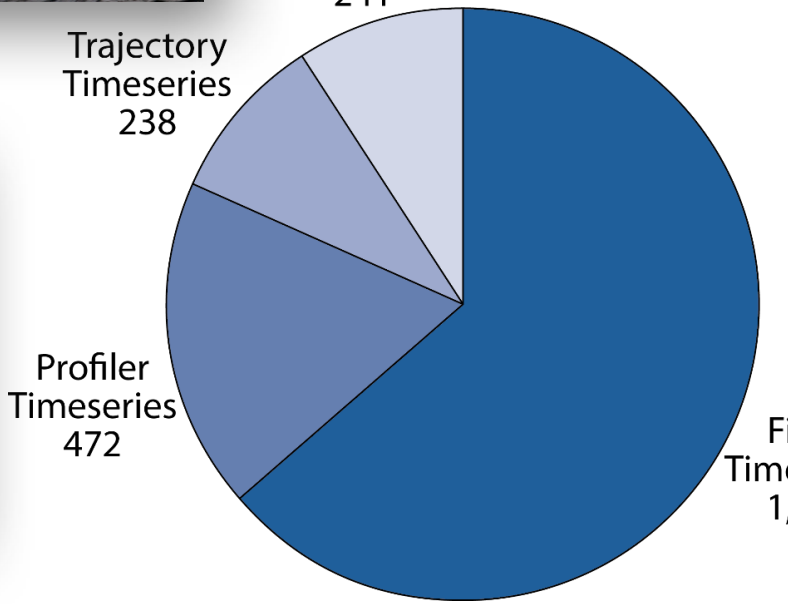
Recovered

Cabled

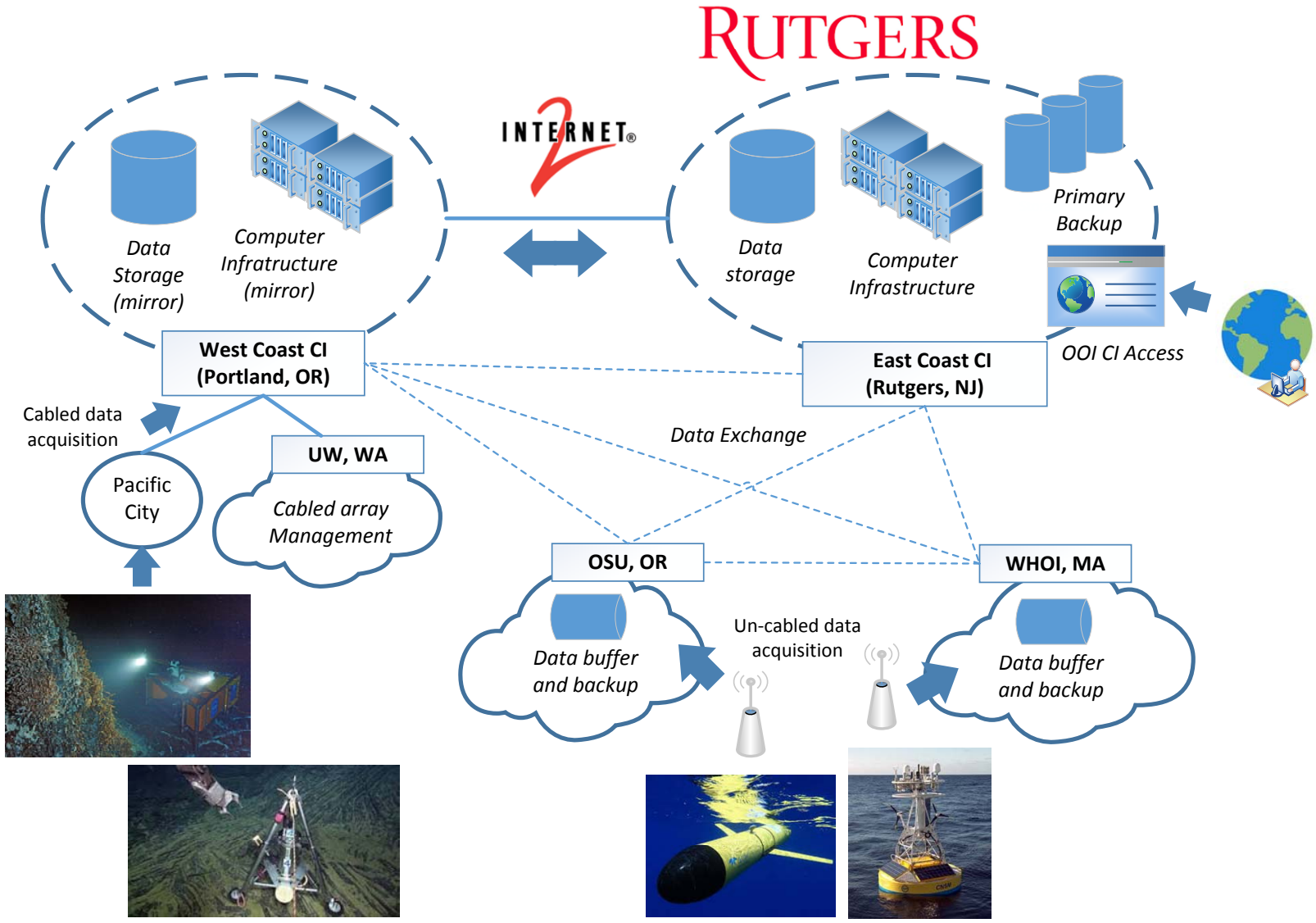


Data Product Types

approximate counts based on design

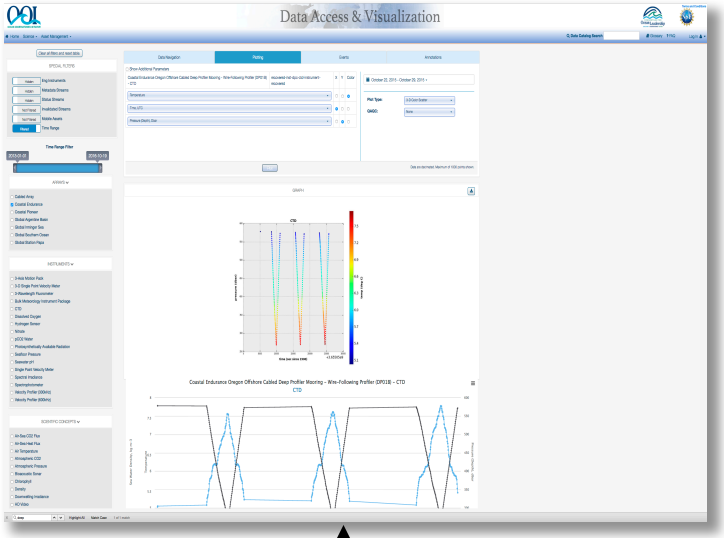


OOI CI Overall Architecture

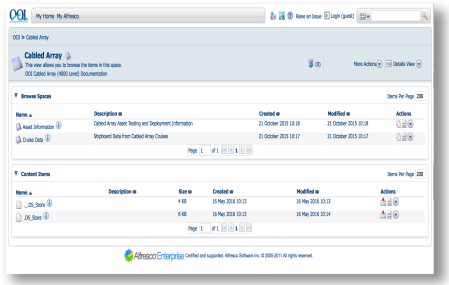


Integrated Software Stack

OOI Data Portal + M2M

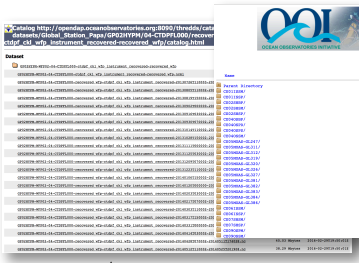


oceanobservatories.org

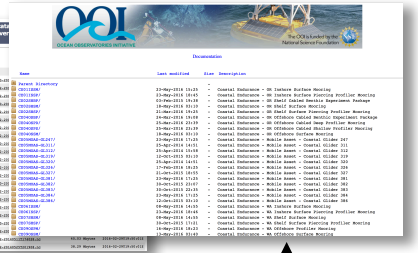


Alfresco (cruise and doc CM)

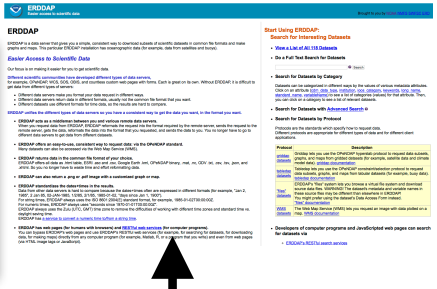
THREDDS



Raw data



ERDDAP



uFrame Service-Oriented Infrastructure

OOINet

OOI Data

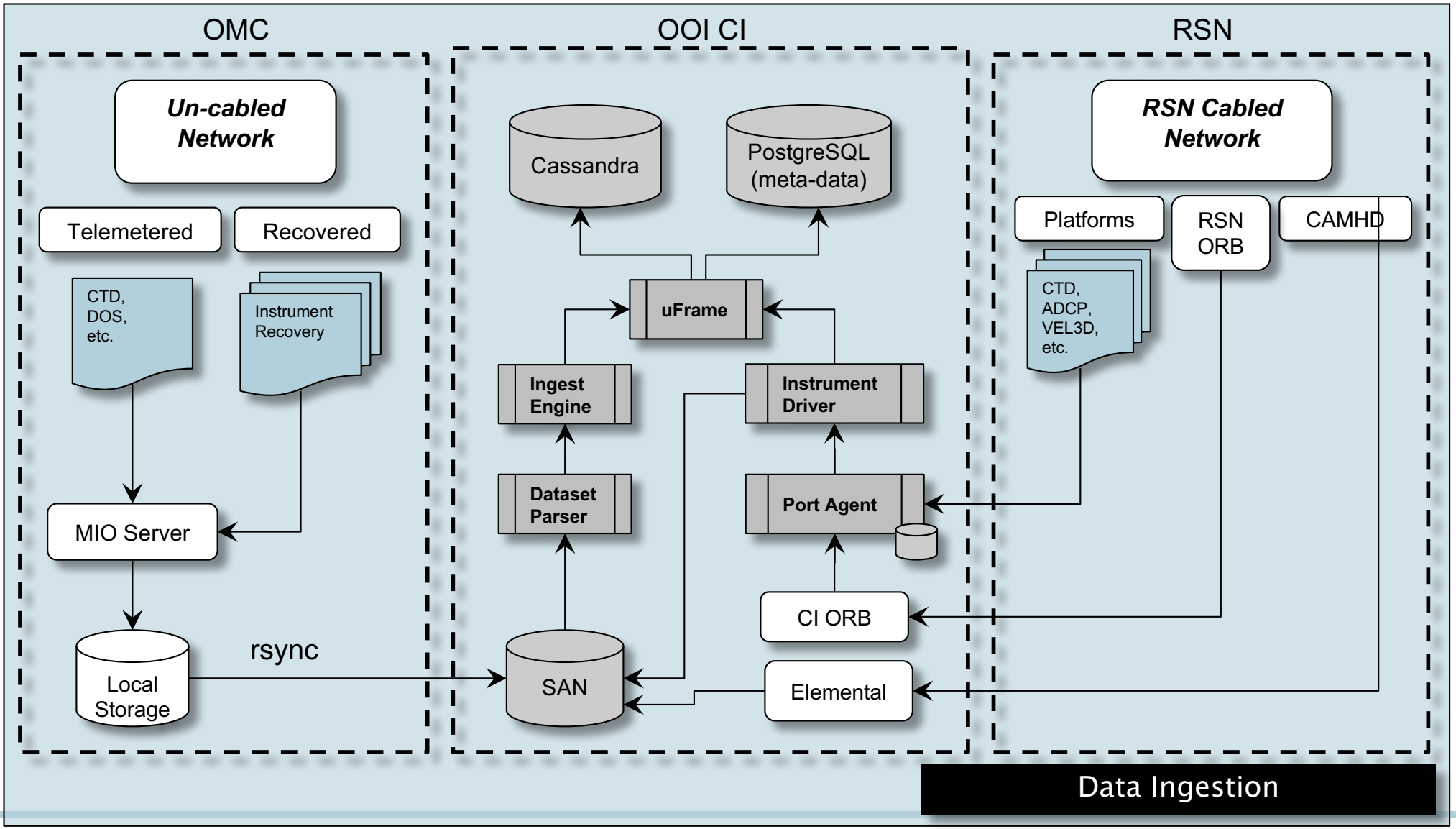
cassandra

PostgreSQL

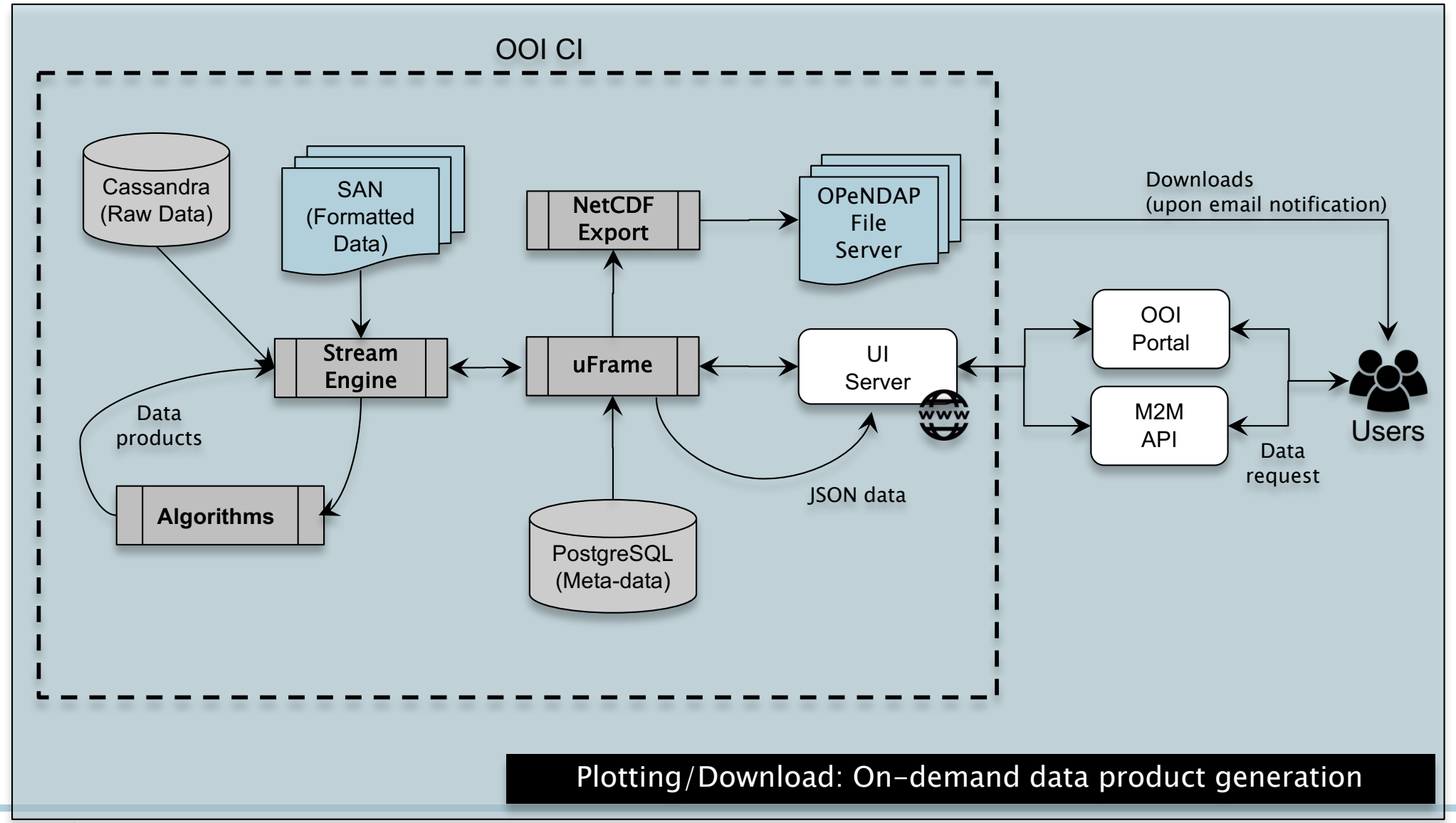
Qpid

RabbitMQ

uFrame-based OOINet – Data Ingest



uFrame-based OOINet – Plotting and download

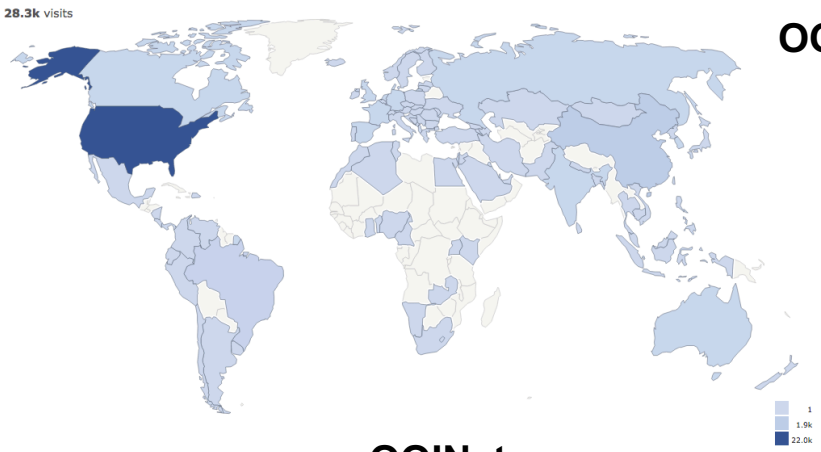


Cyber-security Overview

- Implementation
  - Redundant perimeter firewall appliances in all sites
  - VPN IPSec tunnels across all sites
  - Two-factor authentication
  - Federated Identity Management
- 1,250 attacks mitigated in first half of 2017
- Cyber-security Program
  - Engagement with NSF Center for Trustworthy Scientific Cyberinfrastructure (CTSC)
  - Maintains policies and procedures (12+ documents)
  - Cyber-security scans/audits
  - Leverage Rutgers' policies and protocols
  - Training activities

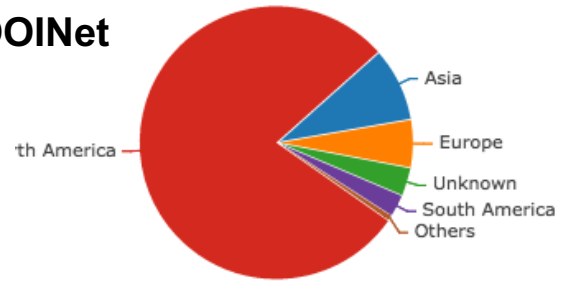
Data Download Statistics (Jun'16 – Jun'17)

	OOINet (UI Portal)	THREDDS Server	Raw Data Server
Visits	28,341	3,681	18,829
Distinct countries	104	36	57
Direct entries	22,446 (79%)	3,324 (90%)	17,021 (90%)
Search engines	227(1%)	51 (1%)	(<1%)
From websites	3,228 (26%)	306 (8%)	1,792 (10%)
Distinct websites	131 (540 distinct URLs)	17 (92 distinct URLs)	30 (158 distinct URLs)
Data transferred	**75.31 GB**	**923.3 GB**	**41.85 TB**



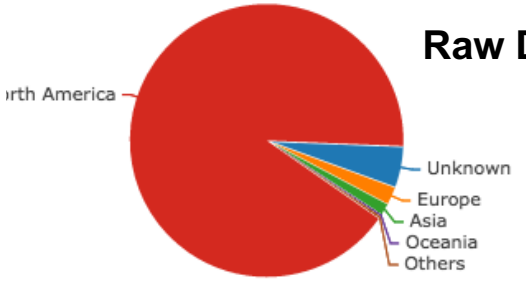
OOINet

OOINet



Country	Visits
United States	22,029
China	1,942
Unknown	965
Brazil	659
France	426
United Kingdom	297

Raw Data



Country	Visits
United States	16,989
Unknown	929
Germany	215
Canada	127
China	116
Israel	84

End-to-end Data-driven Workflows

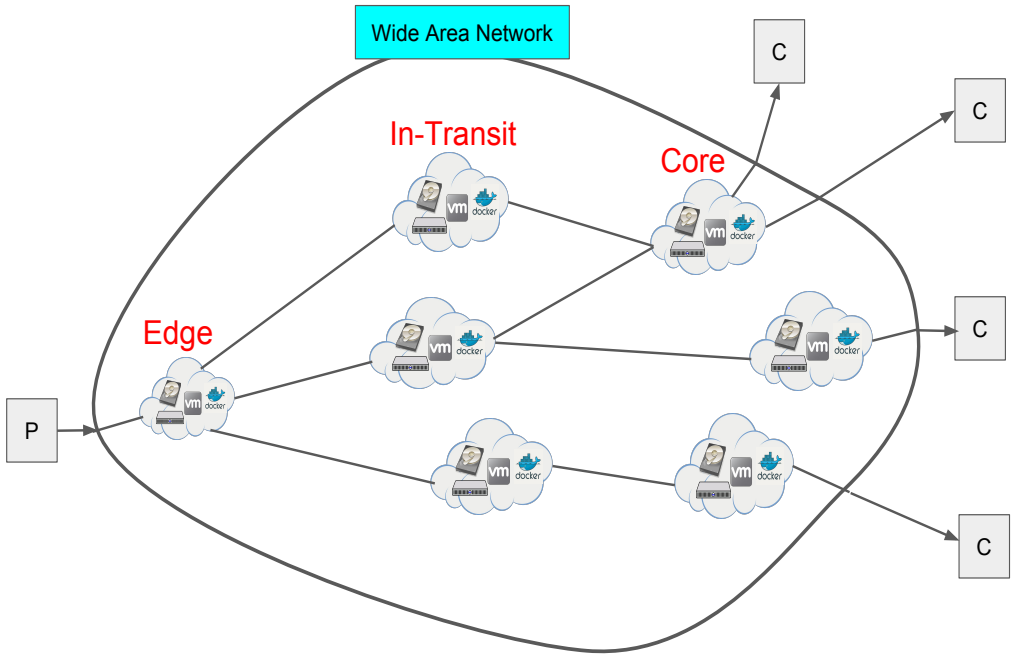
- Large-scale scientific facilities are an essential part of science and engineering enterprise
  - Provide open, real time access to data from geographically distributed sensors and instruments
- Increasing scale, heterogeneity, and richness of data
  - Data downloads and local processing no longer feasible
- Commercial/academic computing services remain largely disconnected from scientific facilities
- New delivery modes for data and data-products necessary

Re-examining Data Delivery

- Distributed content-delivery networks (CDNs) – publish/subscribe semantics for data and data products
- Data-driven (content, location, quality) workflows that seamlessly orchestrate the entire data-to-discovery pipeline
  - Automated processing of data
    - Users issue query for data to be transferred from large-scale scientific facilities and processed at national/commercial resources
  - Data-driven query and processing of data
    - Users register queries and workflows that automatically trigger computation when certain types of data are available or when certain results from previous queries are observed
  - Data-driven query, aggregation, and processing across multiple data-stores
    - Allow users to define and register complex queries to couple multiple sources of data, which can potentially be processed at different ACI facilities

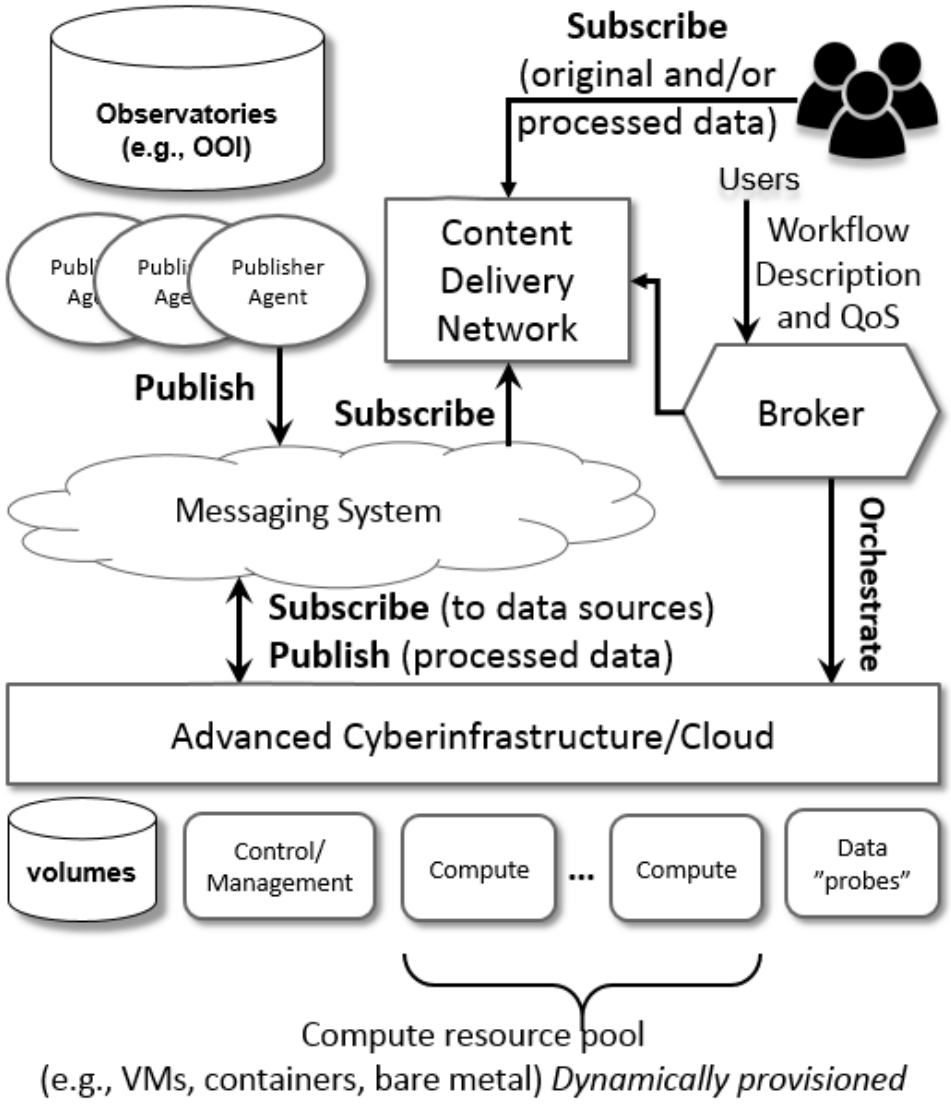
Edge/In-transit Data Processing

- Edge/In-transit processing
  - Integrates non-trivial resources and services along the data path
  - Transform/process data as it moves toward consumers
- Approximation and Content Delivery
  - Explore approximate computing and tradeoffs between quality, time, and resources
  - Disseminate data and data to multiple consumers more effectively
  - Using edge and in-transit resources to stage and process data
- Reducing Number of Streams
  - Streams combined based on content of data, users interests and workflow
  - In-transit resources leveraged for data aggregation/disaggregation



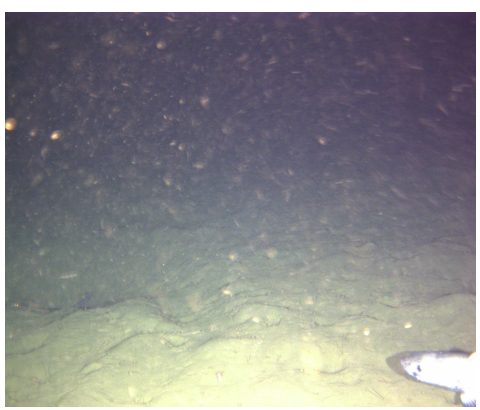
System Architecture

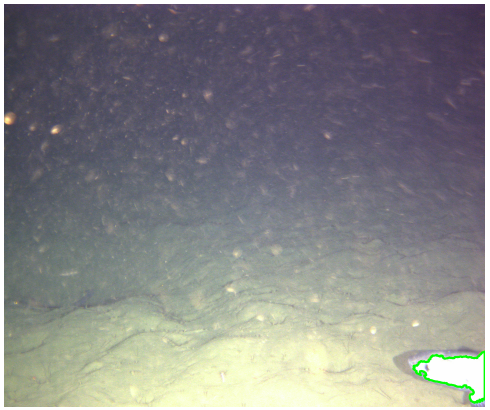
- Distributed streaming engine
  - Subscription based data delivery
- Data processing
  - Commercial/academic services (AWS, Azure, Jetstream)
- Content delivery network
  - Leverage network appliances close to users
- Broker
  - Provision services / map workflow to resources (in-transit, and at the ends)
- Builds on Kafka, Storm, …



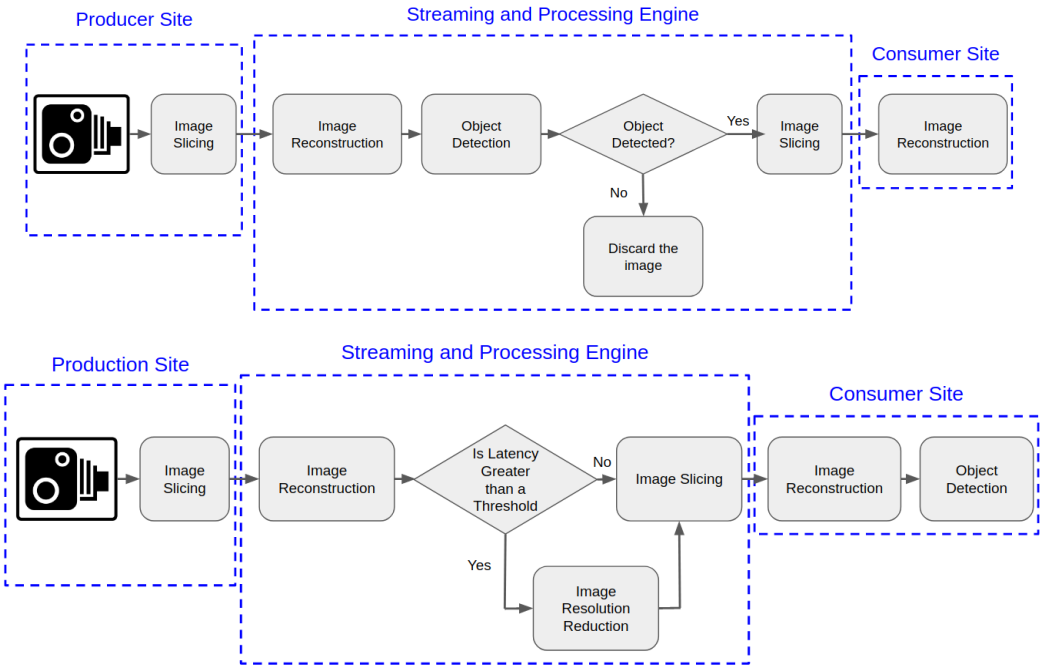
Usecase: Digital Still Camera Image Analysis

- Processing images from an ocean floor high resolution digital camera
- Total of 50 images
  - Rate: image every 7 seconds
  - Large images sizes
    - Image slicing at source
    - Image reconstruction at destination
  - Image processing algorithms applied to detect objects



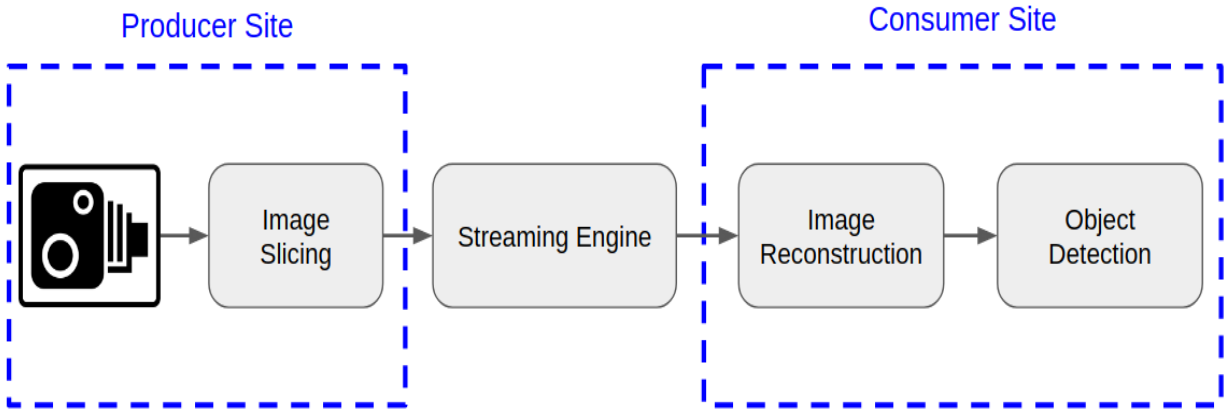


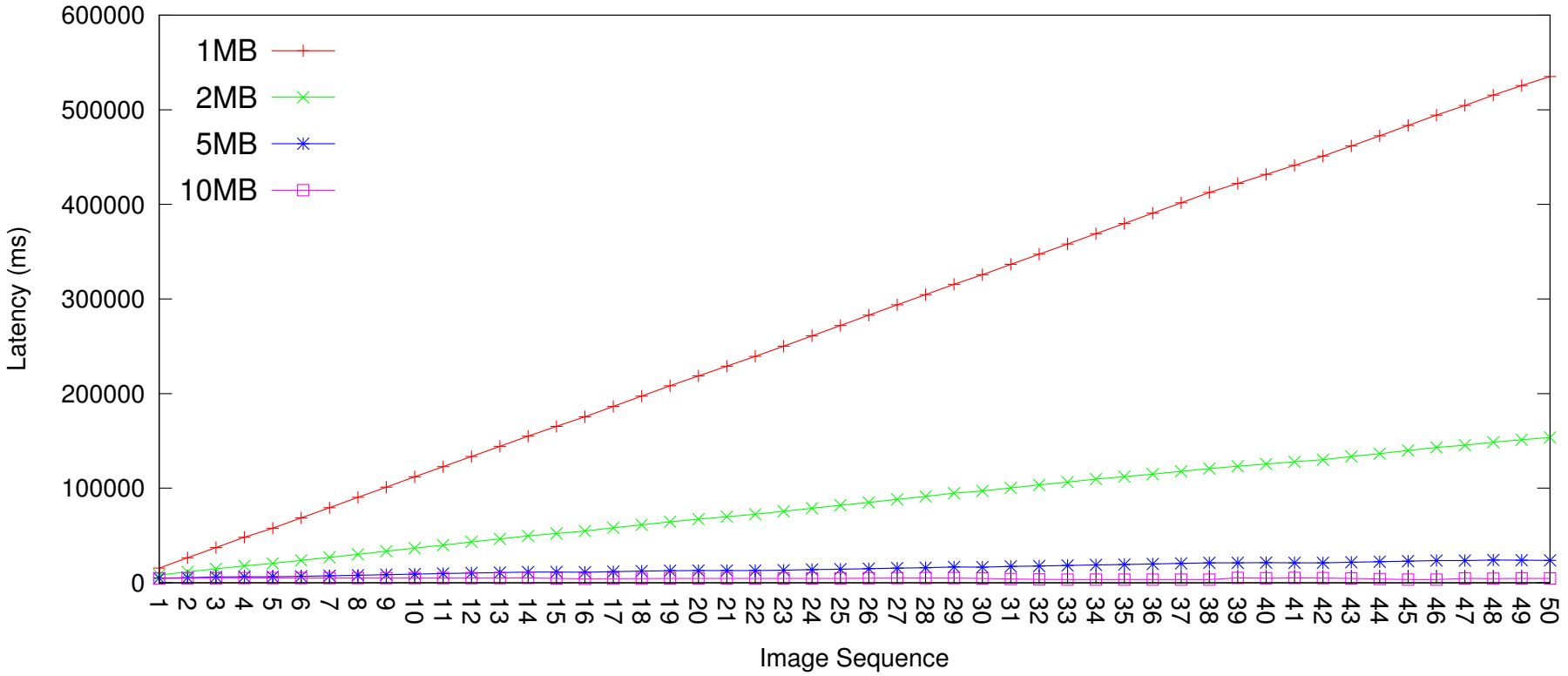
Implementations



Case Study – Base Data Streaming

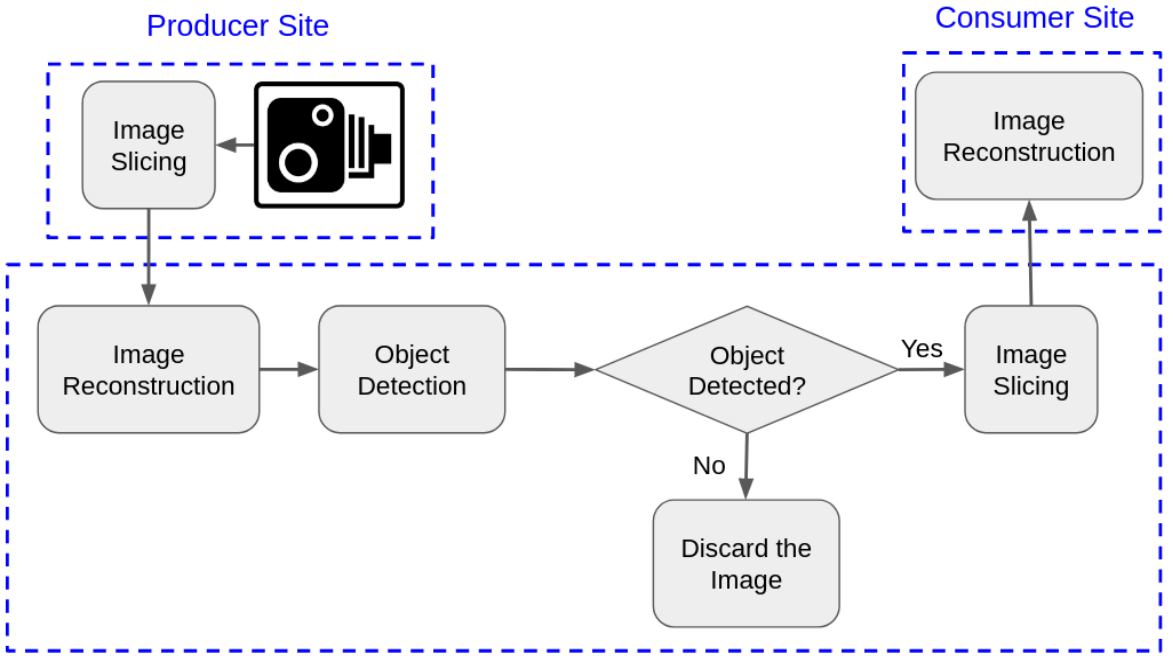
- Latency: Time to deliver all slices of an image to a consumer

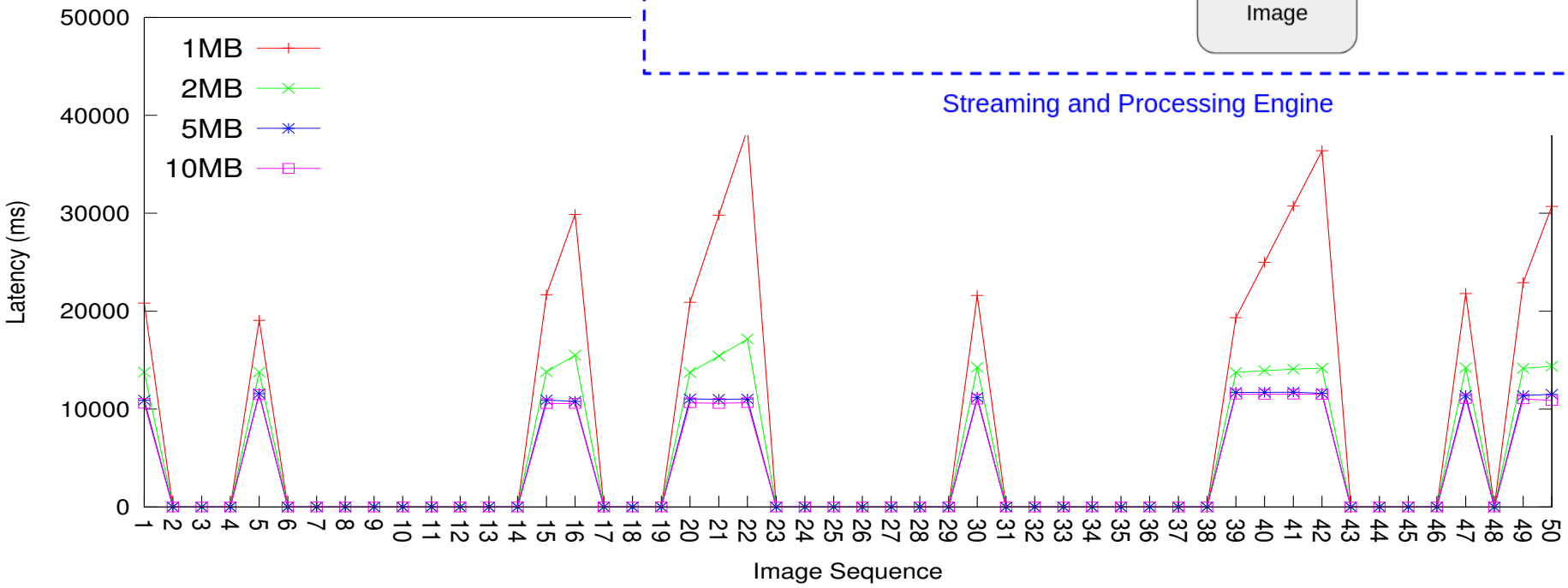




Case Study – Early Detection

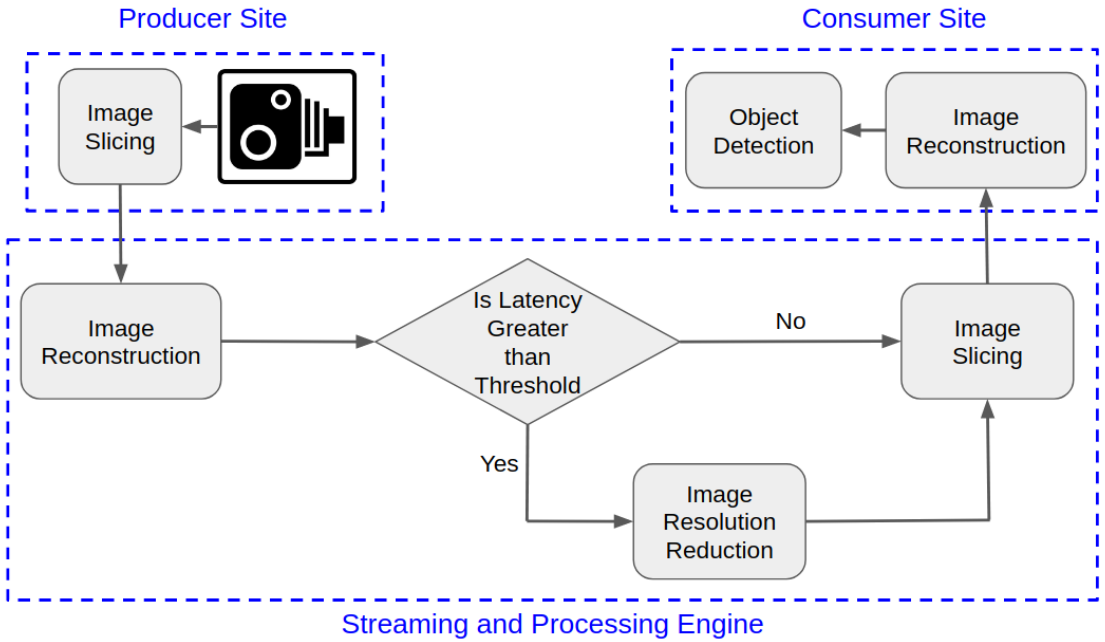
- Data processed as it moves toward the destination
- Data delivered to consumer based on its content
  - Only 13 images contain objects

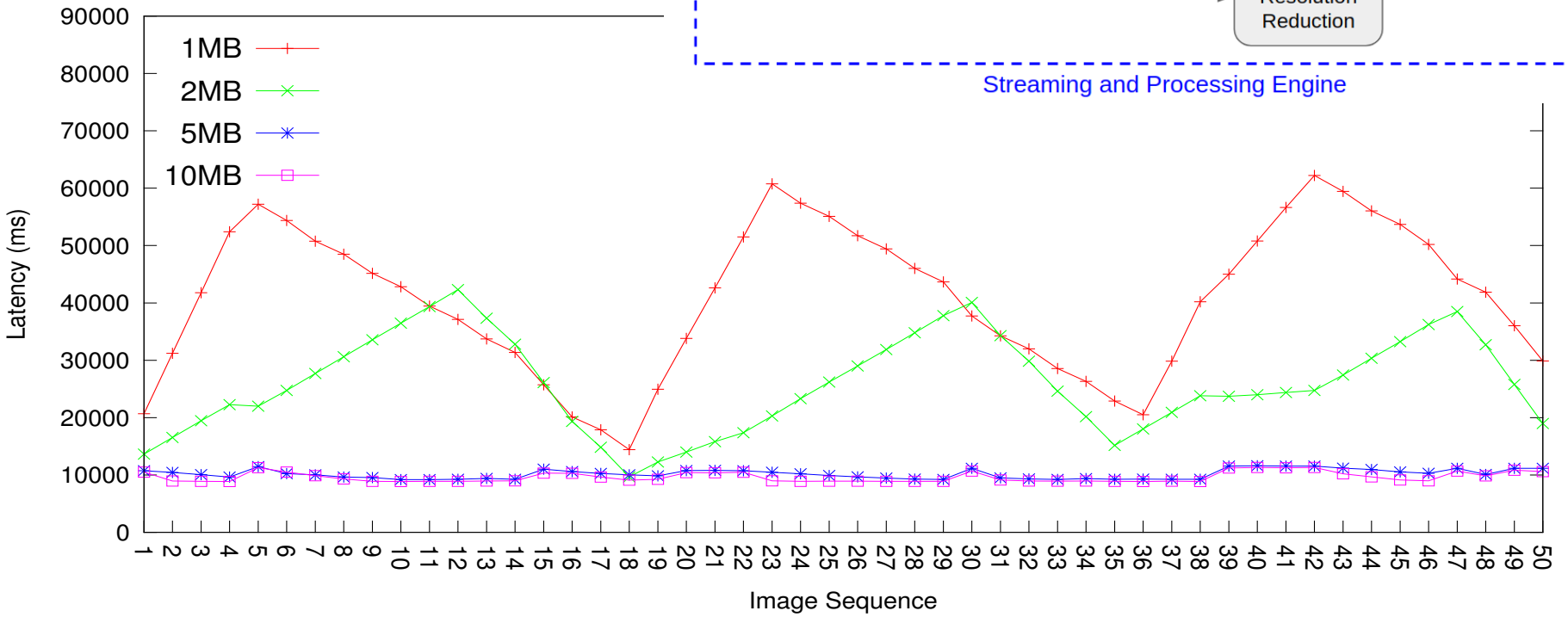




Case Study – Content Approximation

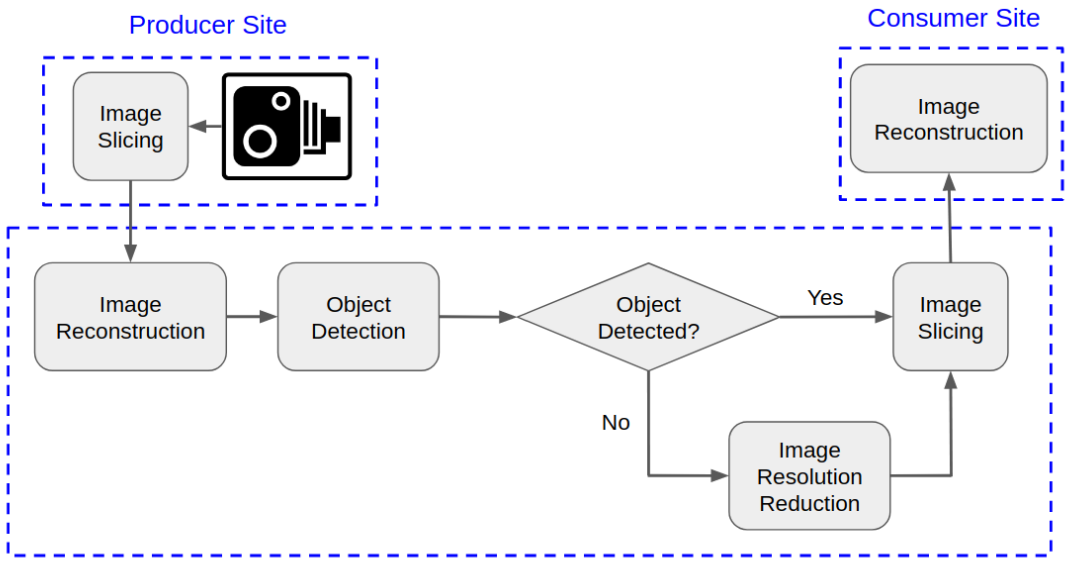
- Latency continuously monitoring
- Resolution reduced if latency is higher than a predefined threshold

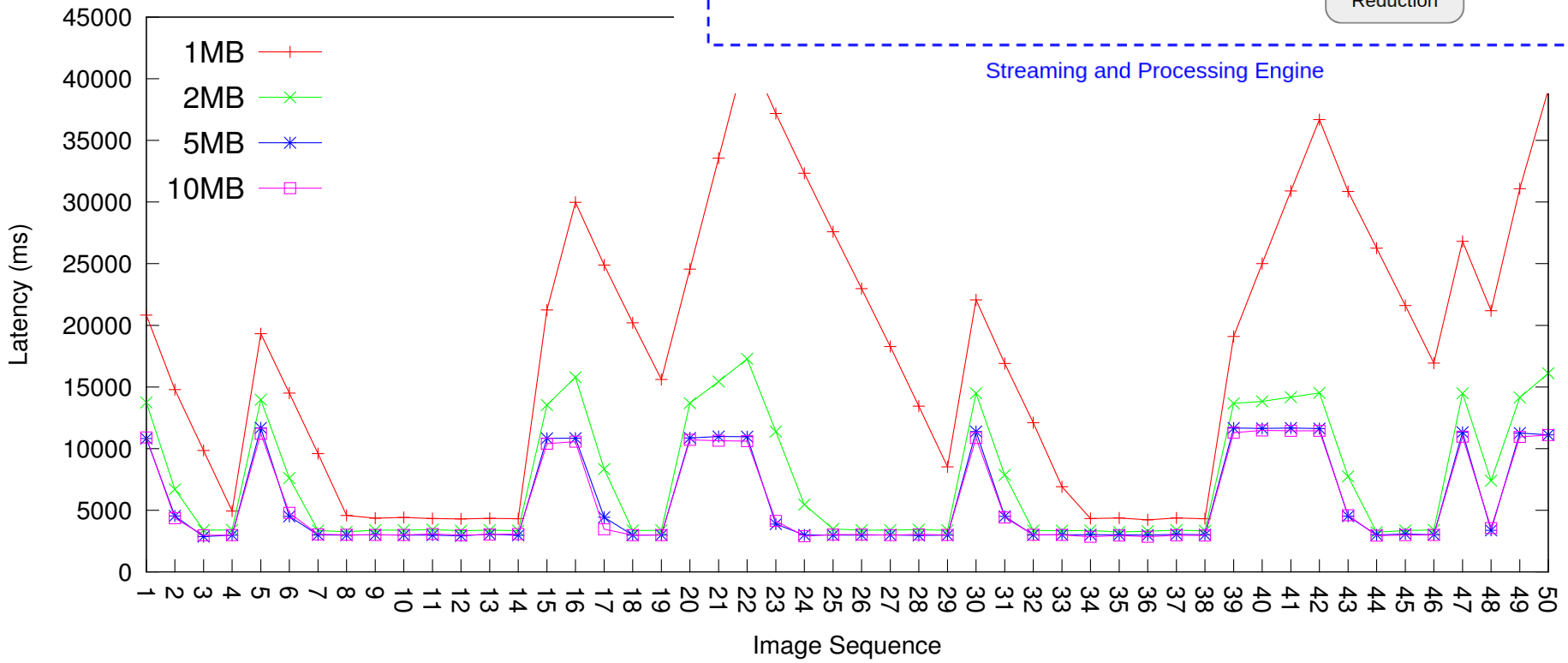




Case Study – Hybrid (Early Detection & Approximation)

- Image resolution reduced only if it contains object(s)

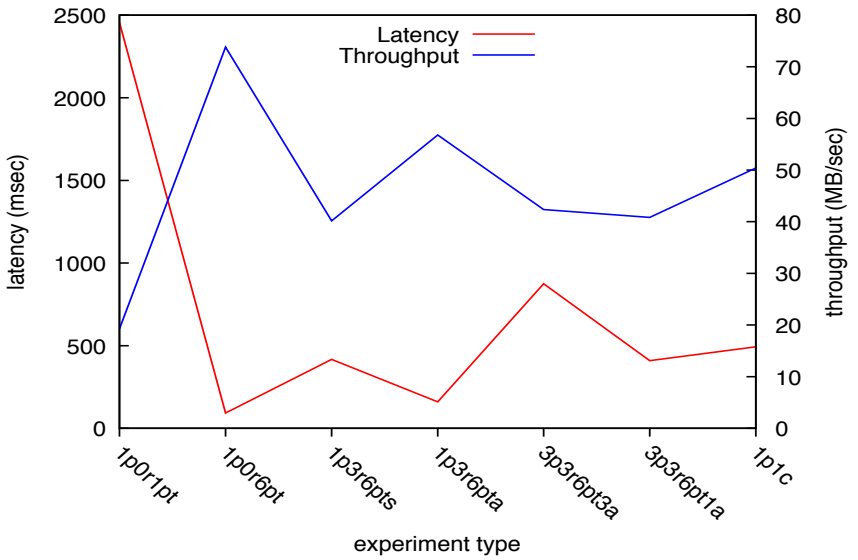


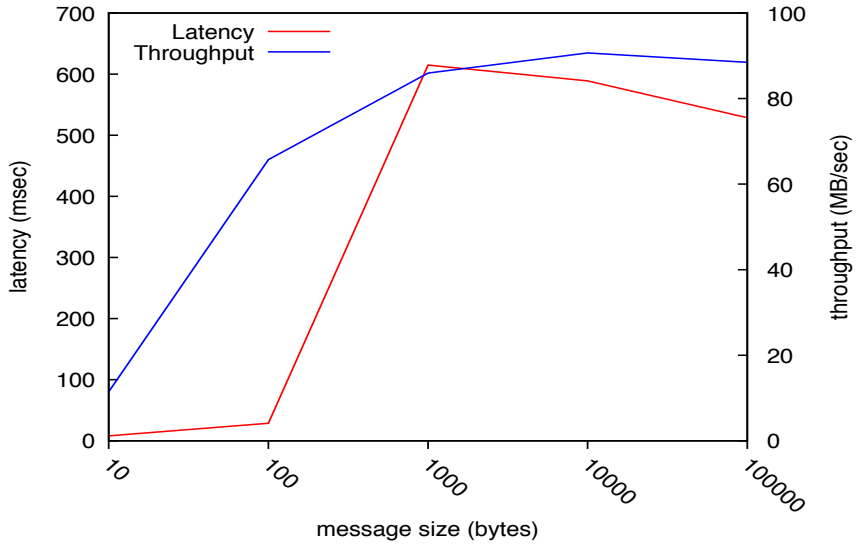


Bottom Pressure and Tilt (BOTPT) – System Performance

- 20 S/sec rate, millimeter resolution of water depth
- Real-time data access, e.g., volcanic eruption detection

- Proof-of-concept using AWS, NSF CloudLab, NSF JetStream
- System implementation based on Apache Kafka/Zookeeper
- Experiments
  - # producers
  - # partitions
  - Sync/Async replication





Concluding Remarks

- Large-scale scientific facilities are an essential part of science and engineering enterprise
  - Provide open, real time access to data from geographically distributed sensors and instruments
  - E.g., Ocean Observatories Initiative
- Increasing data volumes and heterogeneity, complexity of workflows provide new challenges
  - Data streaming and workflow automation mechanisms are essential
    - Publish/subscribe data delivery, in-transit data processing, approximation, etc.

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Ocean Observatories Initiative

Thank you

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