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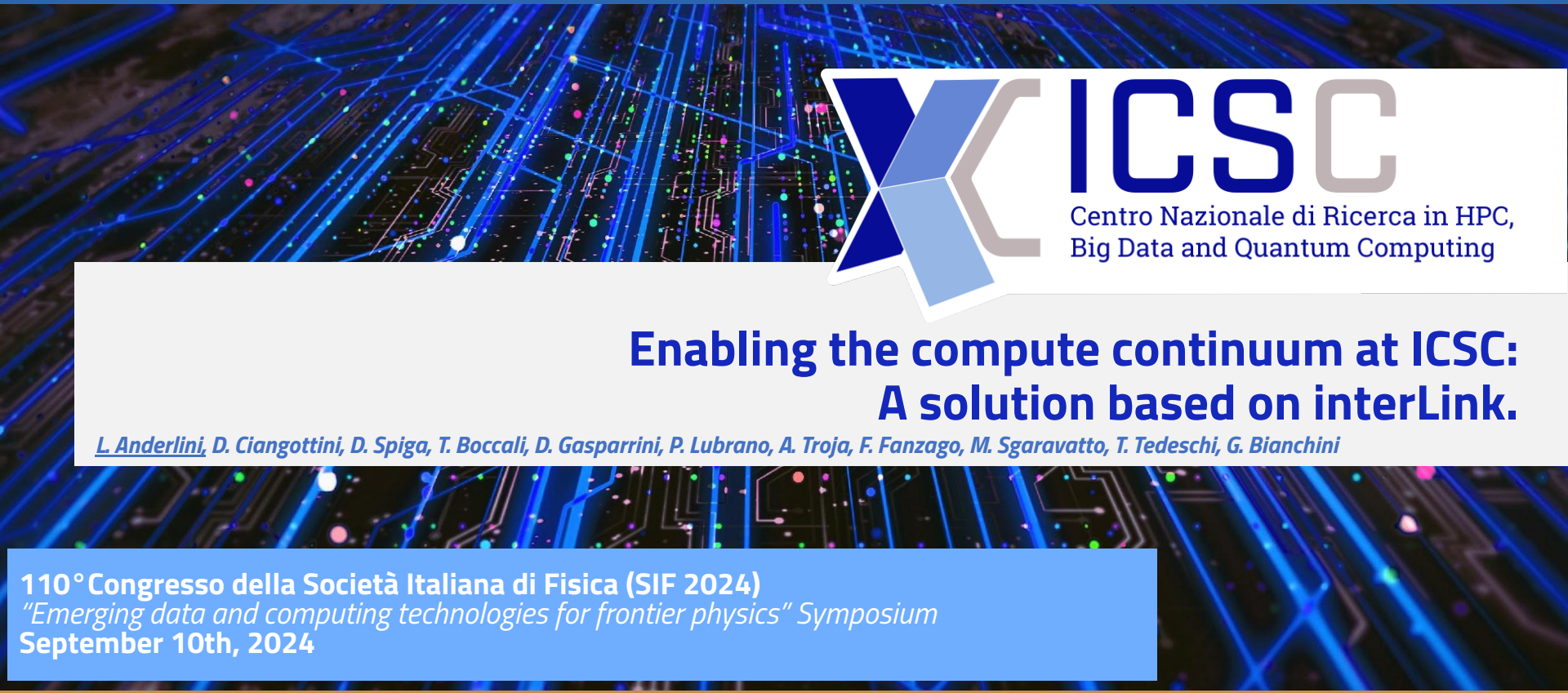
PIANO NAZIONALE DI RIPRESA E RESILIENZA

ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing



Enabling the compute continuum at ICSC: A solution based on interLink.

L. Anderlini, D. Ciangottini, D. Spiga, T. Boccali, D. Gasparrini, P. Lubrano, A. Troja, F. Fanzago, M. Sgaravatto, T. Tedeschi, G. Bianchini

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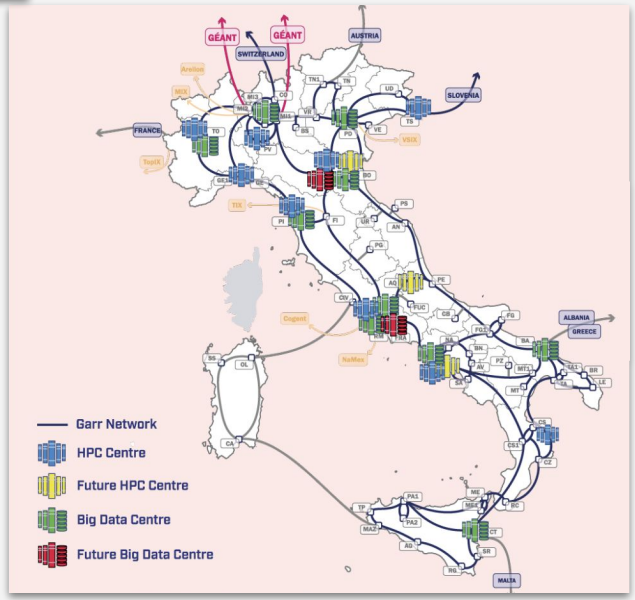
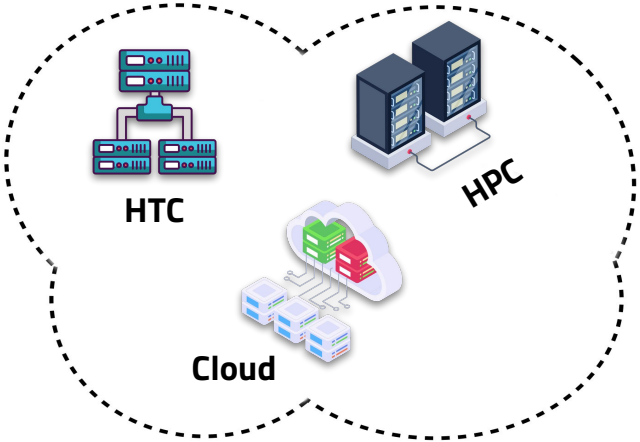
"Emerging data and computing technologies for frontier physics" Symposium
September 10th, 2024

ICSC and Terabit: *towards a highly heterogeneous, geographically distributed computing infrastructure*

Cutting-edge computing infrastructure connecting highly specialized centers (HPC, BigData and Cloud) providing a comprehensive overview of the existing resources and integrating emerging technologies.





High-Performance Computing (**HPC**), High-Throughput Computing (**HTC**), and **Cloud computing** … different resource providers, different backends, different authN/Z workflows, different network policies…

Scope: *Support complex workflows by distributing payloads throughout the network of computing centers, effectively mapping resource requests to compute backends while hiding the underlying heterogeneity and complexity from the user.*

Kubernetes *as the emerged standard for distributed applications (cloud-native)*

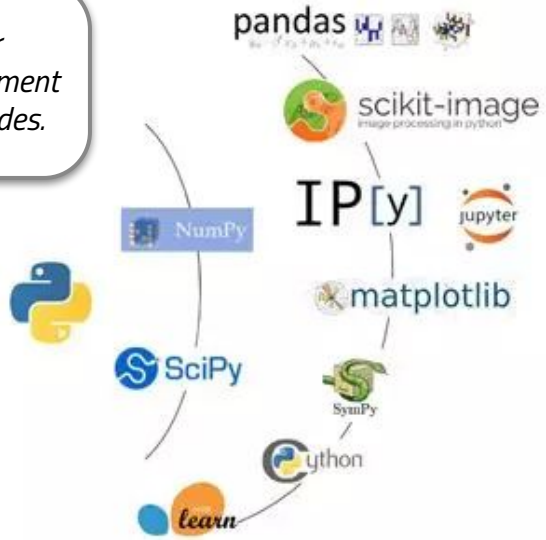
As Python+NumPy emerged as *de facto* standard for Data Science applications in early 2000s, the **Kubernetes APIs have been emerging as the standard for distributed applications**.

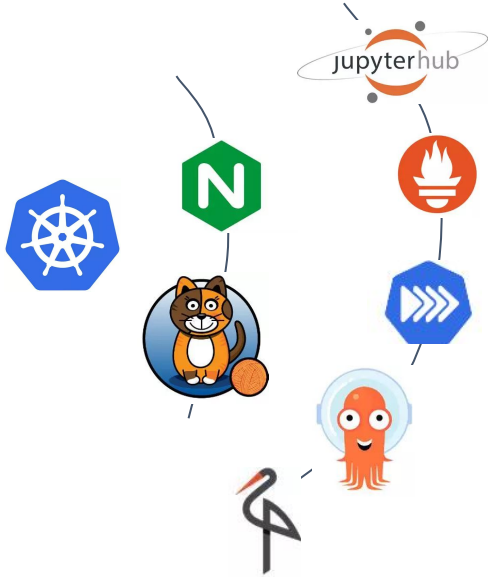
`pip install` ➡ `helm install`

Kubernetes *is an open-source system for automating deployment, scaling and management of* ***containerized*** *applications on multiple nodes.*

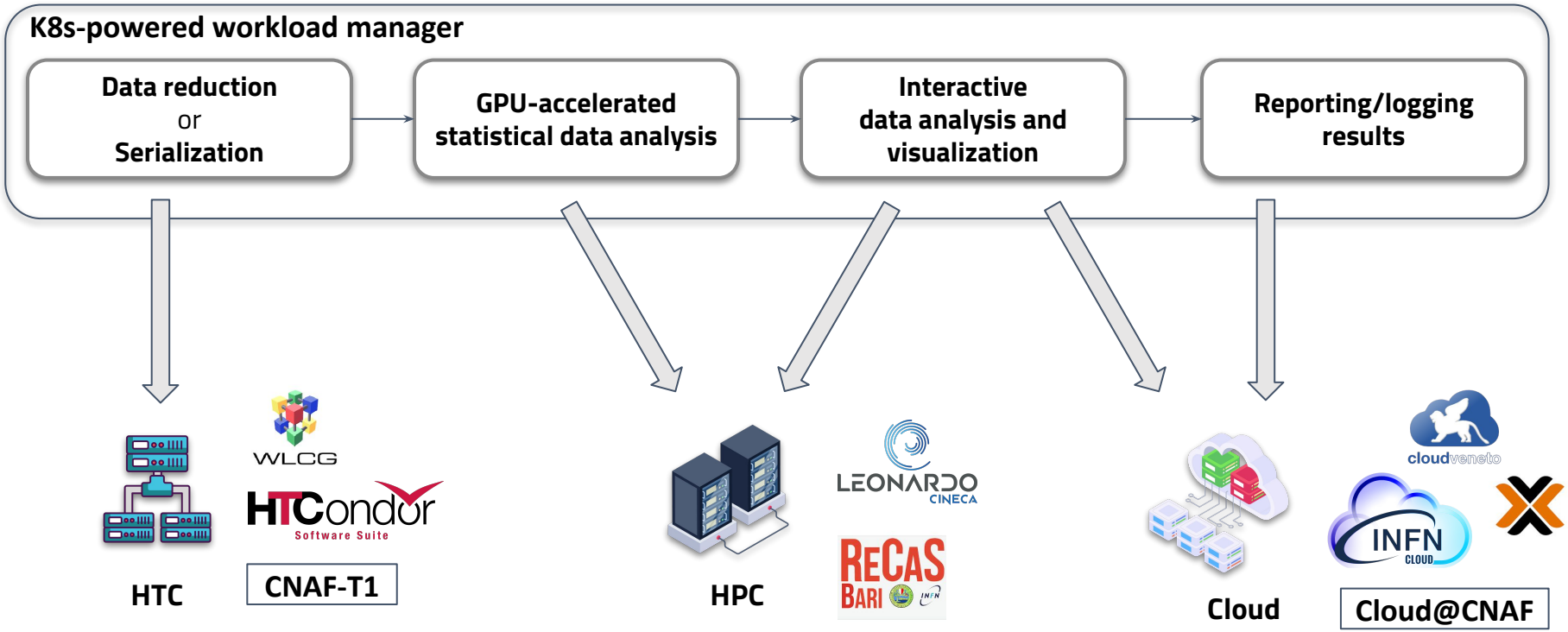
The [Cloud Native Computing Foundation](#) (CNCF) supports and coordinates the development of 200 k8s applications in more than 850 git repositories.

To benefit of K8s for compute-intensive applications, tasks can be organized in job queues and submitted to HPC/HTC centers.

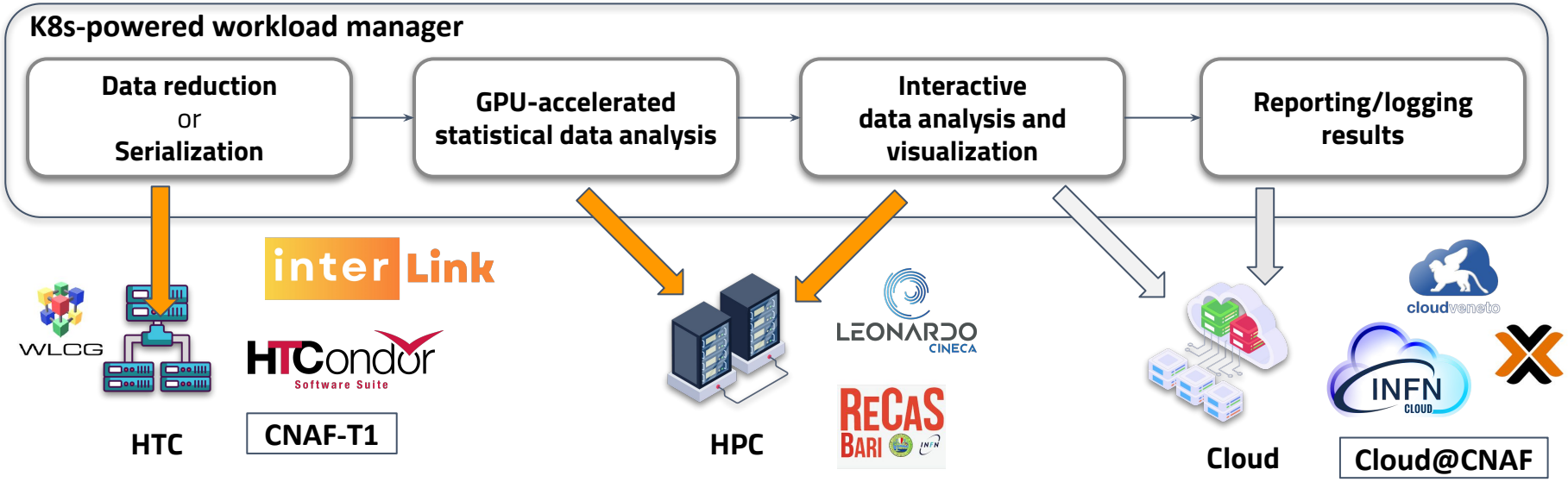




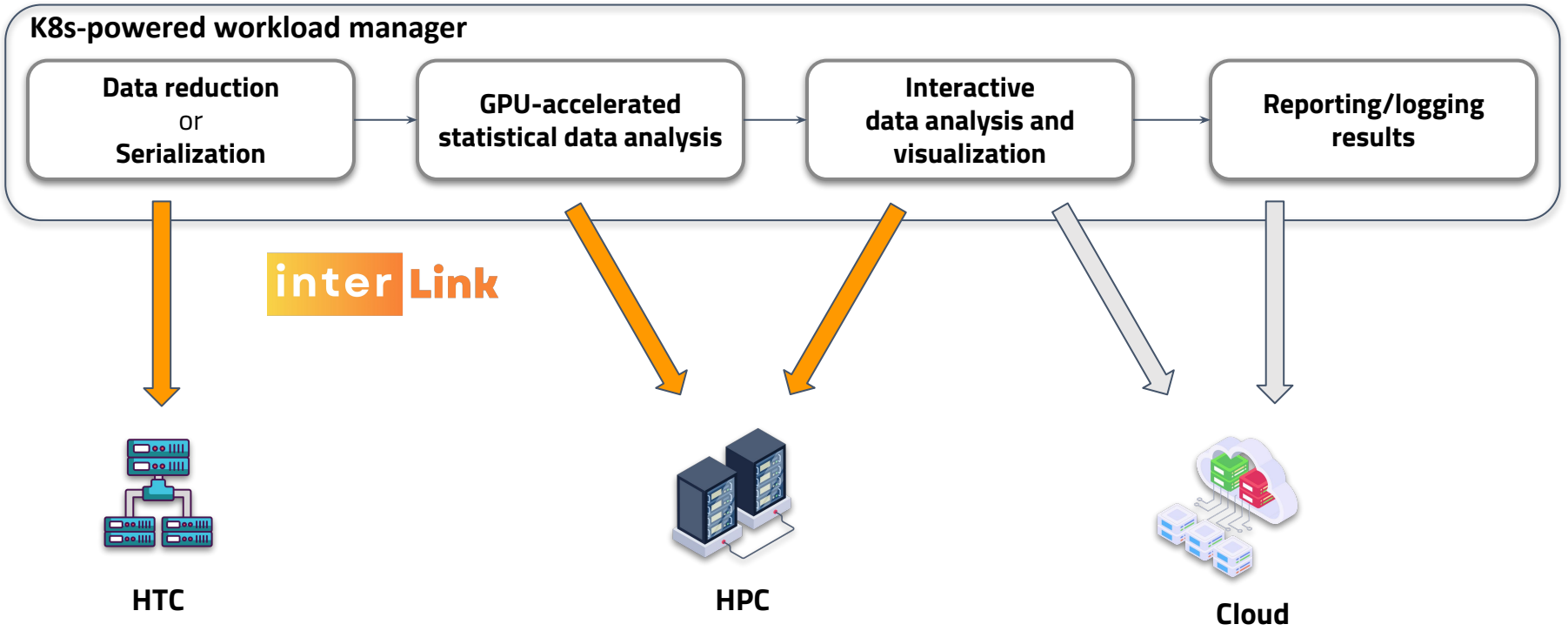
A typical workflow, offloaded



A typical workflow, offloaded



A typical workflow, offloaded



A typical workflow, offloaded

K8s-powered workload manager

Data reduction or **Serialization** → **GPU-accelerated statistical data analysis** → **Interactive data analysis and visualization** → **Reporting/logging results**

interLink

Submission of simple containerized applications.

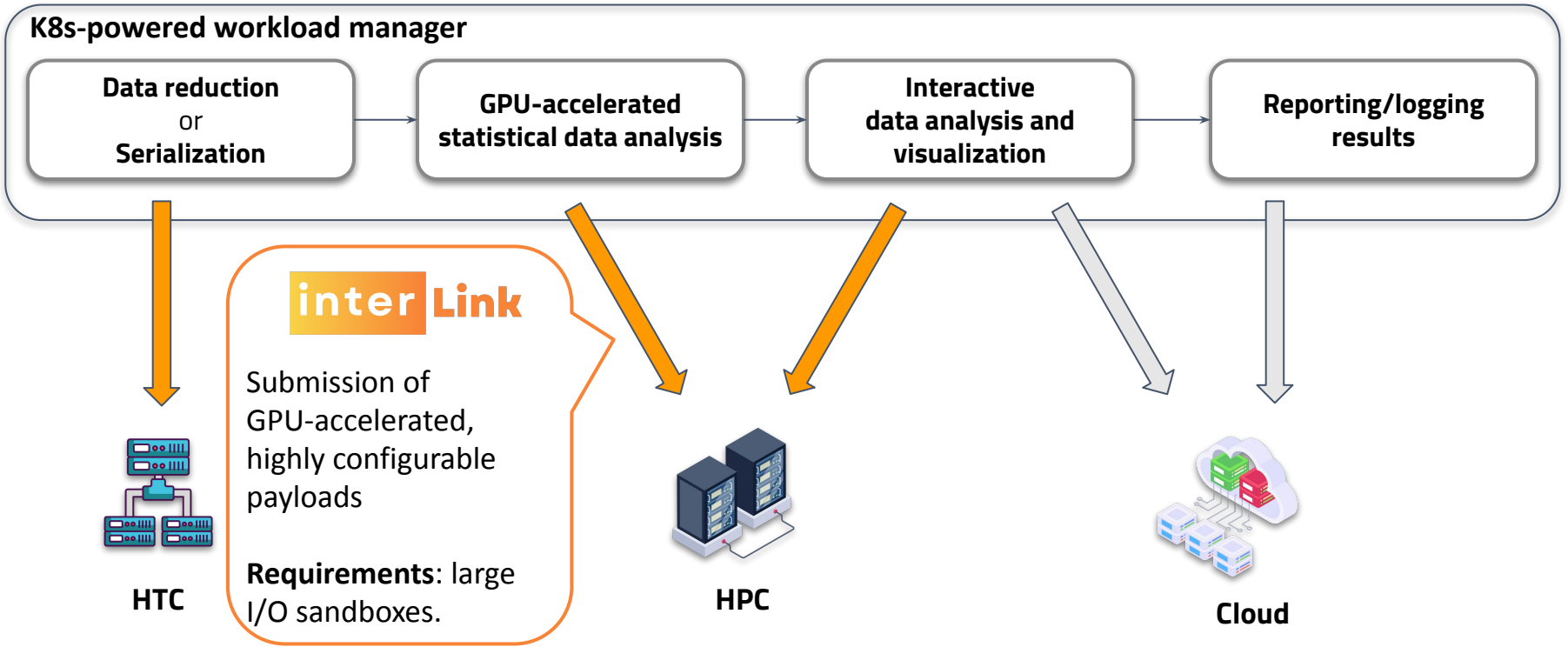
Requirements: scaling to thousands of jobs.

HTC

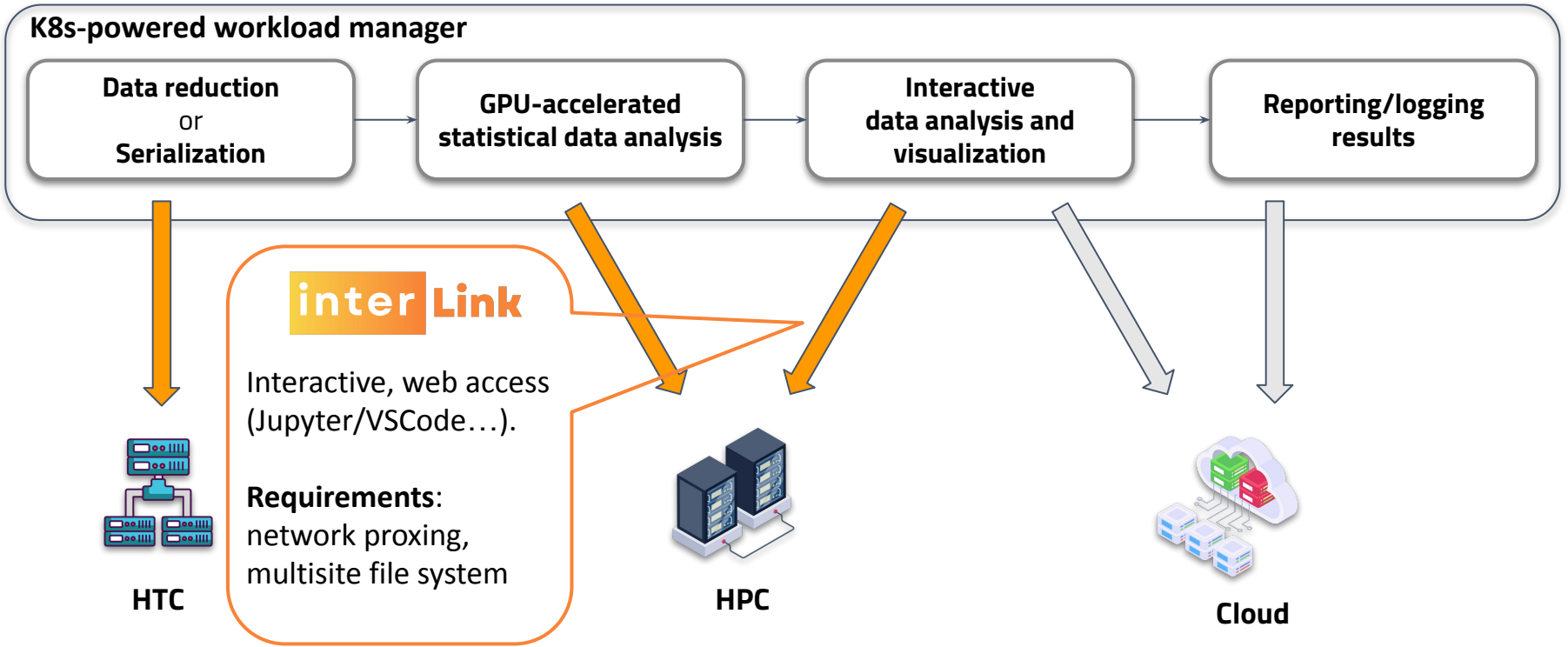
HPC

Cloud

A typical workflow, offloaded



A typical workflow, offloaded



How does it work?

Virtual Kubelet is an open-source project providing an interface between Kubernetes and serverless container platforms.

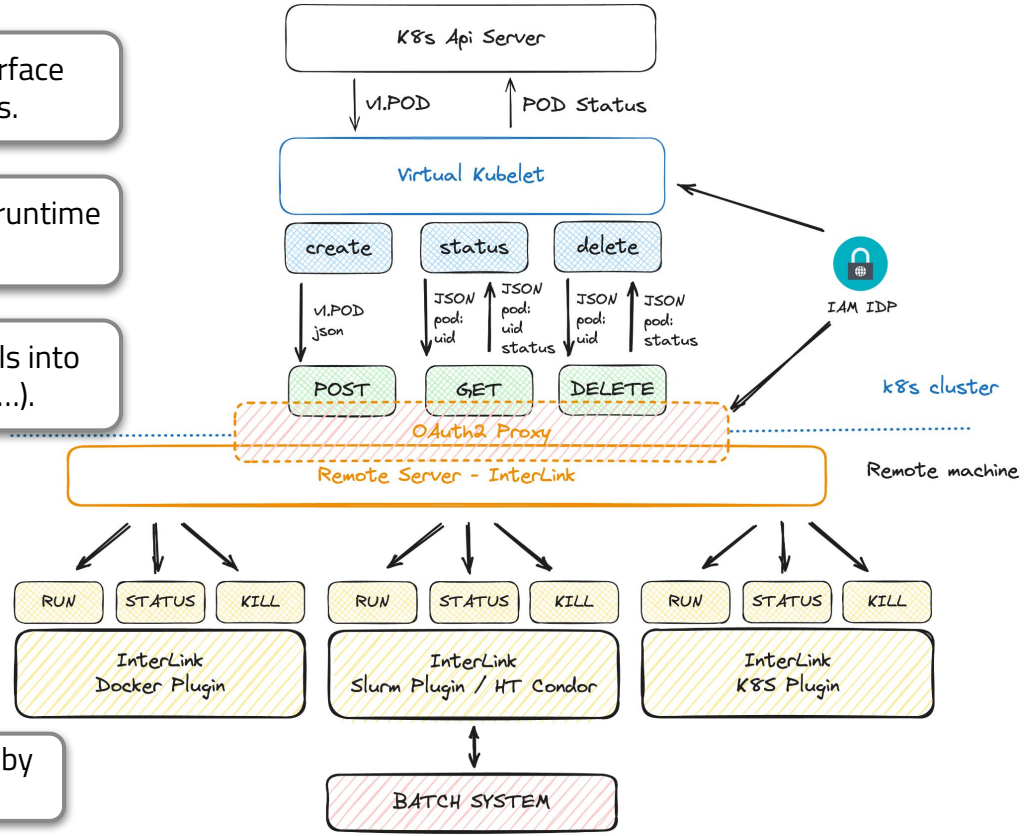
Interlink abstracts the interaction with the remote container runtime to few REST APIs: ***create, status, delete.***

Backend-specific plugins are developed to translate API calls into the "proper language" for each backend (CLI, REST, gRPC…).

OAuth2 and **OpenID Connect** are used to authenticate the Virtual Kubelet towards the remote backend.

The user submitting the job to the Kubernetes Workload manager is propagated as meta-data.

Data, accessed with remote protocols, can be **cached locally** by the compute backend (*e.g.* cvmfs)



Status of the development

	HTC	HPC	Cloud
Submission of self-contained applications	**Supported**	**Supported**	**Supported**
Remote volumes for I/O sandboxes	**PoC**	**PoC**	**Supported**
Network proxying for Jupyter access	**Supported**	**Supported**	**Supported**
Generic network proxying	**Ongoing**		
Multisite filesystem (*e.g. for scripts and notebooks*)	**Tech. Tracking**		
Monitoring and observability	**Supported**		

Scientific use-cases and their workflows

Flash Simulation for High Energy Physics experiments.
Workflow: Train models (HPC), Deploy models in grid-like simulation (HTC), Statistical validation (Cloud)

Quasi-interactive HEP data analysis for Analysis Facilities.
Workflow: An interactive application (Cloud) controls parallel, distributed data processing (HTC) and statistical interpretation (HPC)

Interactive **GPU algorithm optimization for astrophysical data analysis**.
Workflow: optimize code for astrophysical tasks on GPUs directly through interactive notebook sessions hosted on HPC.

Summary and next steps

- Kubernetes is the standard for distributed applications, including workload managers.
- Offloading compute-intensive containerized workloads to remote dedicated compute backends with a serverless-computing approach enables complex workflows combining:
  - custom services (cloud)
  - High Throughput Computing (data reduction and grid-like jobs)
  - High Performance Computing (statistical data analysis and machine learning)
- Interlink is being deployed as part of the ***Integration PoC*** of ICSC and TERABit to integrate:
  - INFN Cloud instances (docker, Kubernetes)
  - CINECA Leonardo (slurm)
  - HTC resources at CNAF (HTCondor)
- Development is progressing fast and use-cases have been identified in the context of ICSC-Spoke 2 and ICSC-Spoke 3 as demonstrators