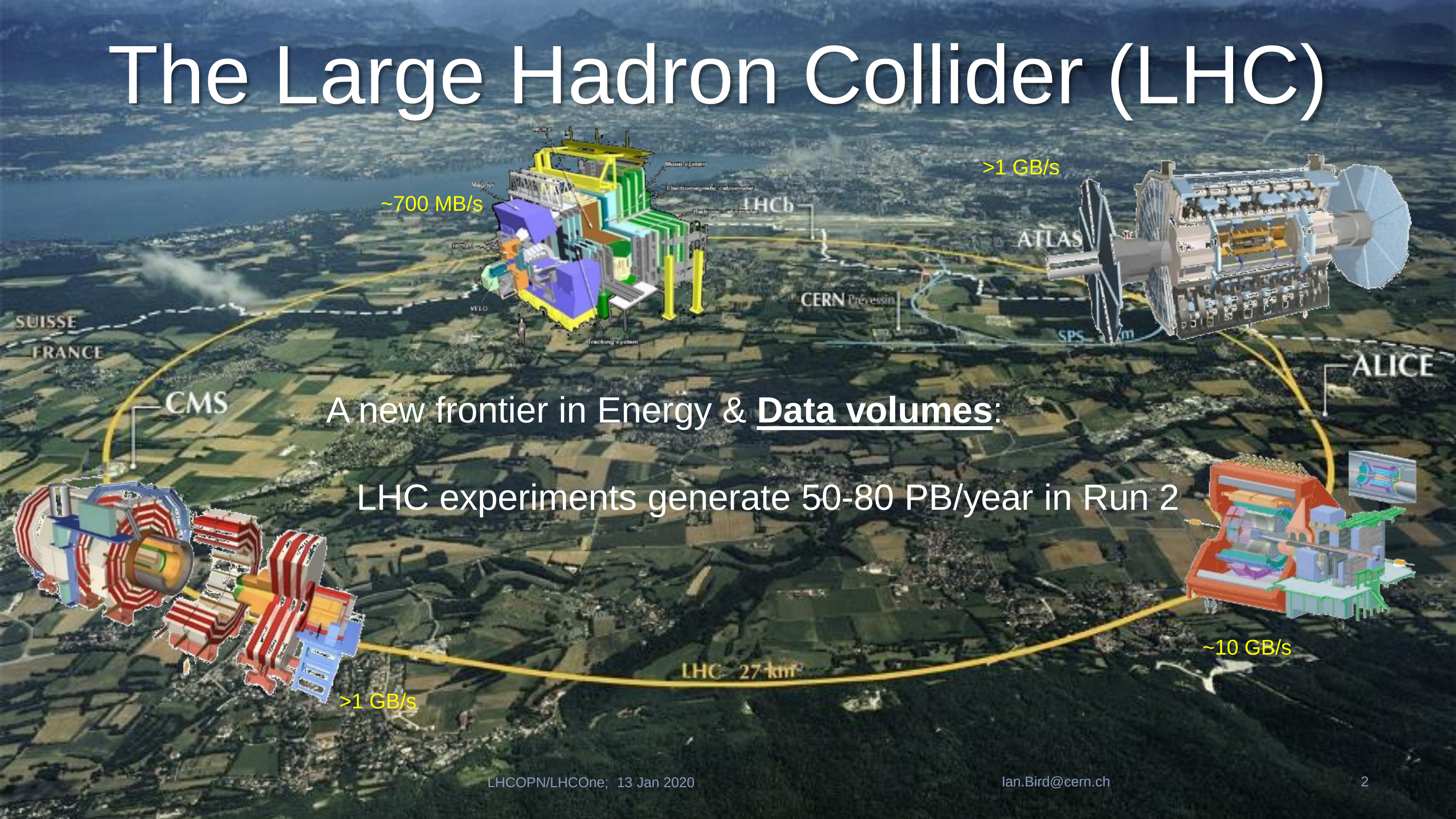
Ian Bird
CERN

LHCOPN/LHCOne Meeting;
CERN, 13th January 2020

WLCG Challenges and Collaborations

The Large Hadron Collider (LHC)

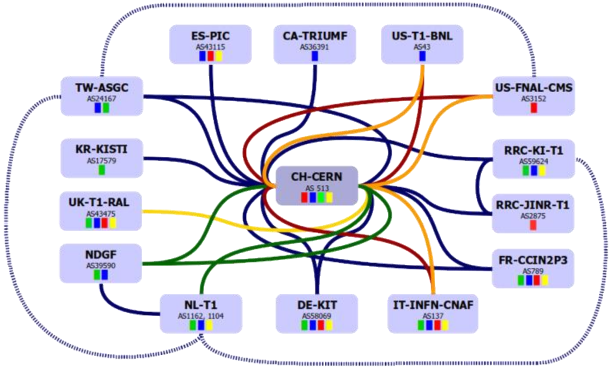


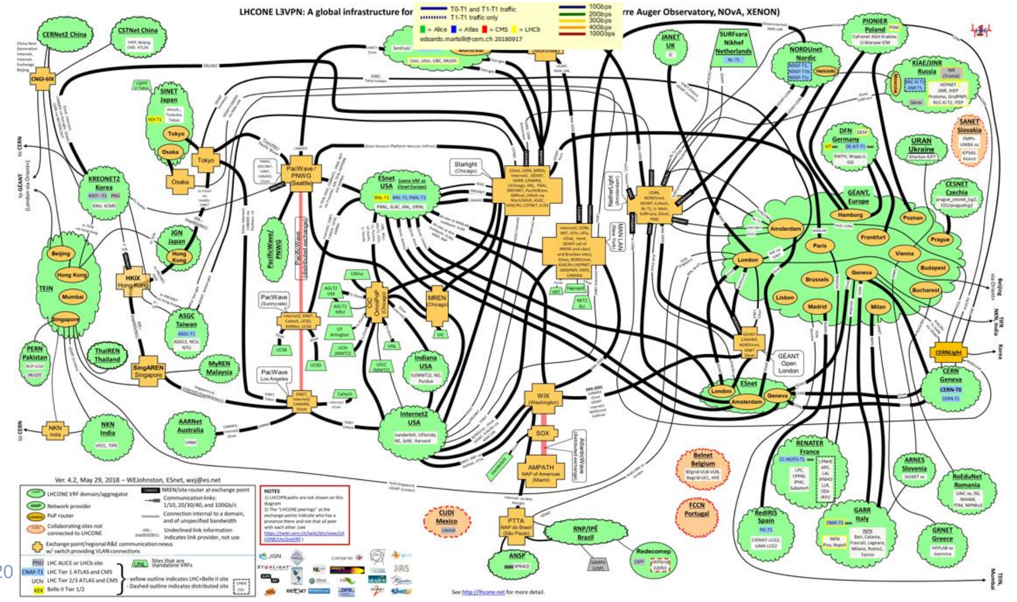
A new frontier in Energy & **Data volumes**:

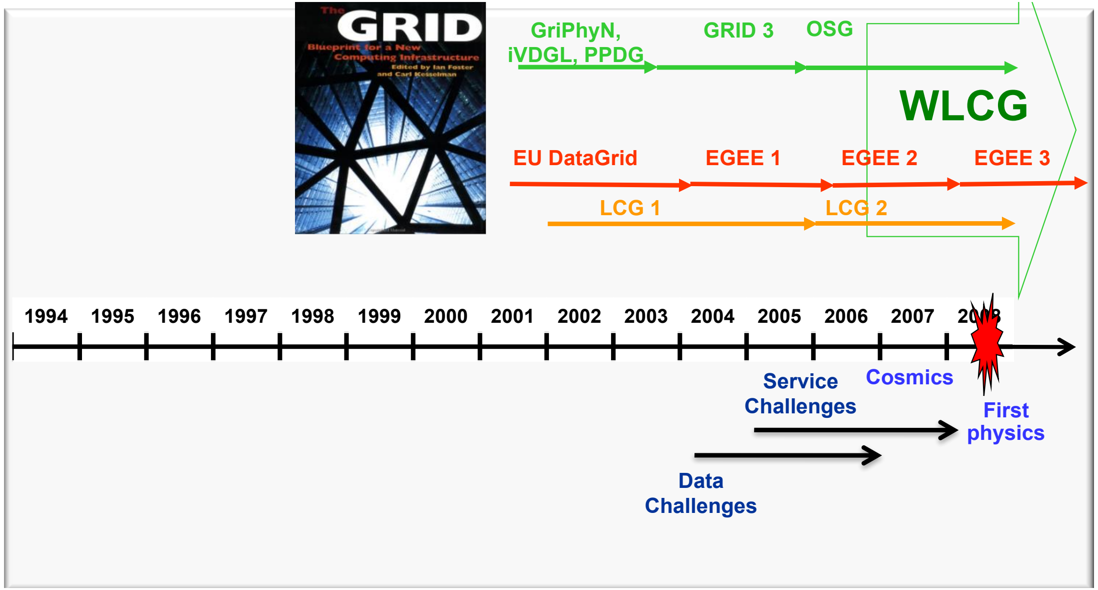
LHC experiments generate 50-80 PB/year in Run 2

Scale of computing needs today

- CPU:
  - ~ 1 million cores fully occupied (“x86”)
- Storage
  - ~ 1 EB (~500 PB disk, >500 PB tape)
- Global networking
  - Some private 10-100 Gbps
  - LHCOne – overlay

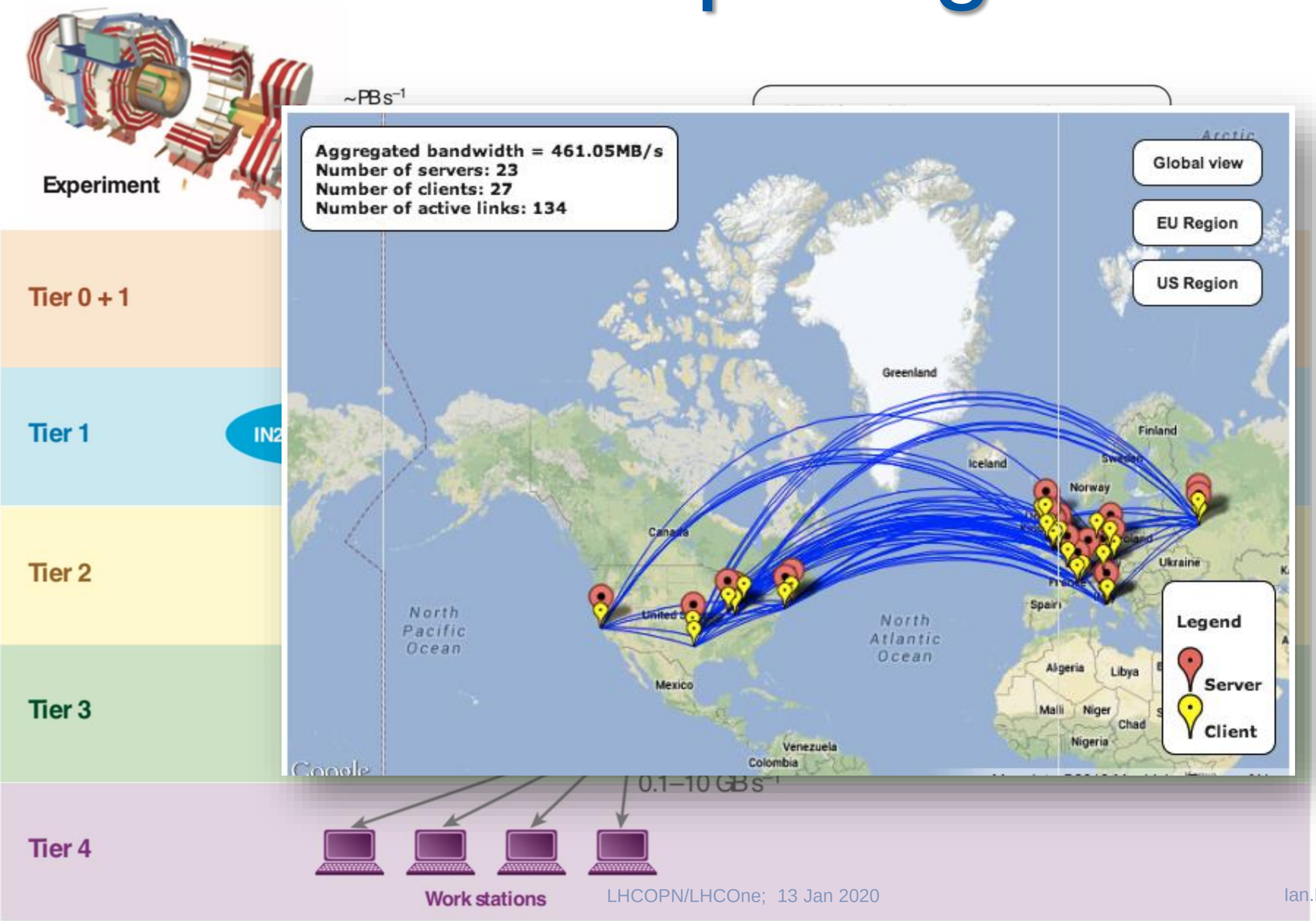






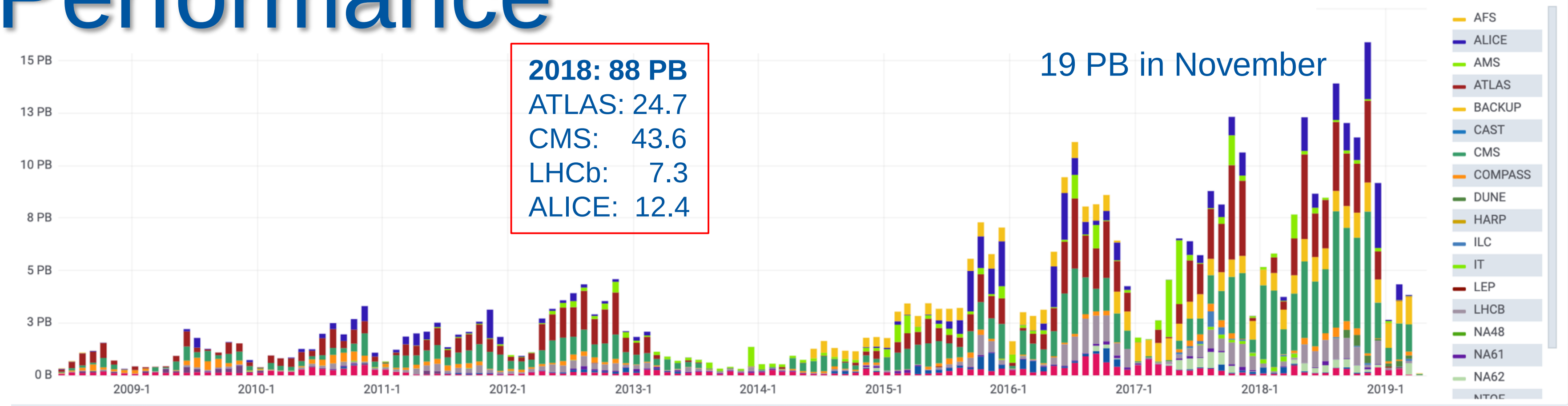
- When we started LHC computing (~2001)
  - There were no internet companies, no cloud computing – Google was a search engine, Amazon, etc. did not exist
- We had to invent all of the tools from scratch
  - At CERN we had no tools to manage a data centre at the scale we thought was needed (no commercial or OS tools existed)
    - Initial tools developed through EU Data Grid
- Grid ideas from computer science did not work in the real world at any reasonable scale
  - We (EU, US, LHC grid projects) had to make them work at scale
  - We had to invent trust networks to convince funding agencies to open their resources to federated users
- Our users were not convinced that any of this was needed ;-)

Evolved computing model



- ❑ Model from 1999
- ❑ Uncertainty over network performance, reliability
- ❑ Focus on distributing data *globally* to compute resources
- ❑ No concept of data remote from compute
- ❑ Quickly evolved

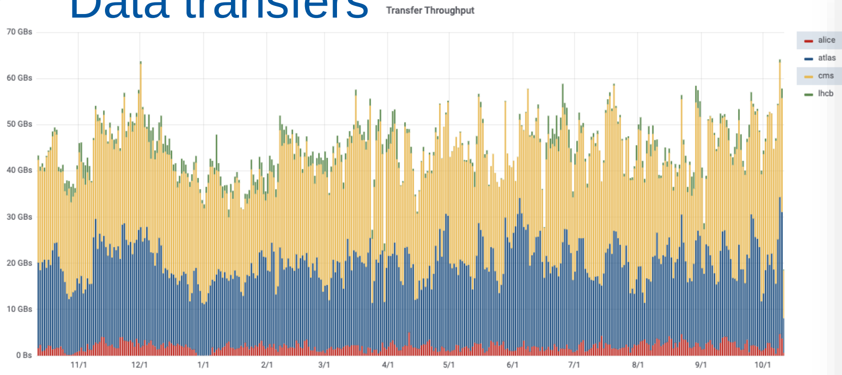
Performance

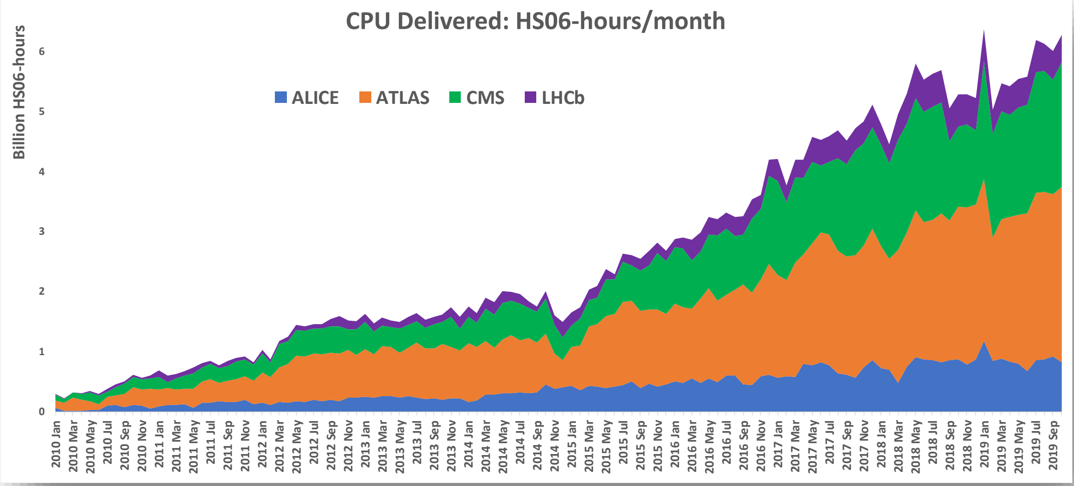


2018: 88 PB
ATLAS: 24.7
CMS: 43.6
LHCb: 7.3
ALICE: 12.4

19 PB in November

Data transfers





Some lessons and comments

- A federated infrastructure is of tremendous value and importance
  - This is the *key* feature that identifies our collaborative distributed infrastructure
  - Even though the X.509 model was difficult to use and manage
  - Security coordination; policies, incident response, vulnerability & threat intelligence is of huge value
  - Sociological – inclusivity

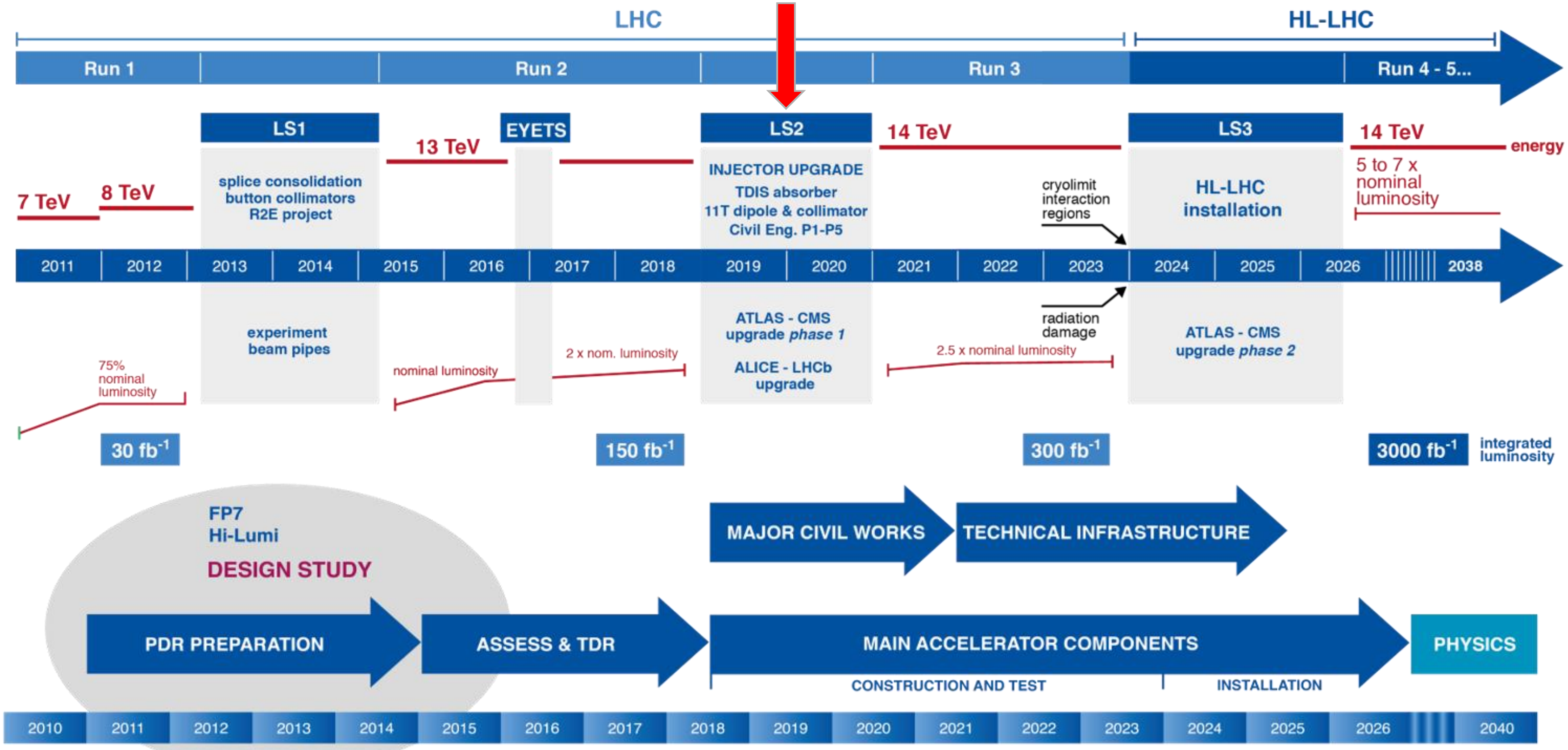
- The network is a fundamental resource and opportunity, not a problem to be solved
  - Redundancy and distribution of services as originally foreseen was unnecessary, complex, and expensive
  - Today service model is much simplified and streamlined

- Today's operational structure is very simple – coordination at a high level, no need for the heavyweight operations centres
  - Integrated global ticketing system was essential

- Distributed data management and storage is expensive – hardware and operations
  - Data pre-placement is not an optimal strategy (it is a complex problem)

- Hardware and cost evolution is becoming a serious concern –
  - "Moore's law" as we assumed it is broken
  - Future of storage technology is a concern – tape and disk
  - The future computational resources are very heterogenous

LHC / HL-LHC Plan



The HL-LHC computing challenge

2017:

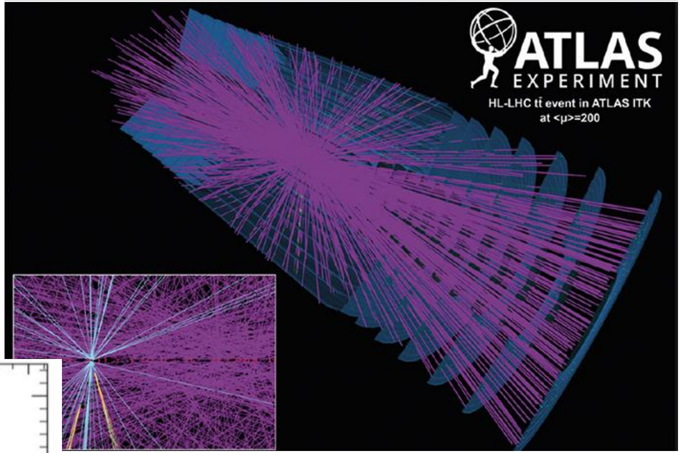
- ❑ HL-LHC needs for ATLAS and CMS are above the expected hardware technology evolution (15% /yr) and funding (flat)
- ❑ The main challenge is storage, but computing requirements grow 20-50x

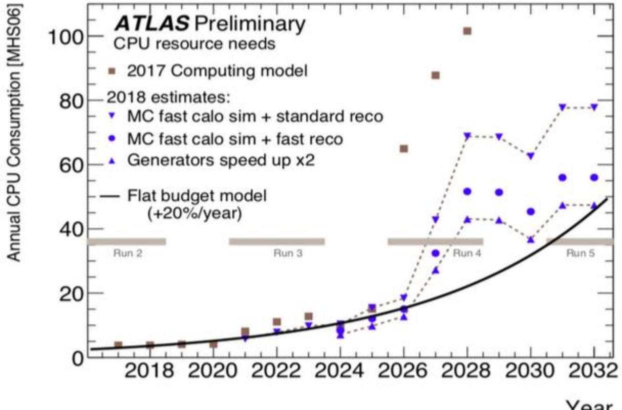
2019:

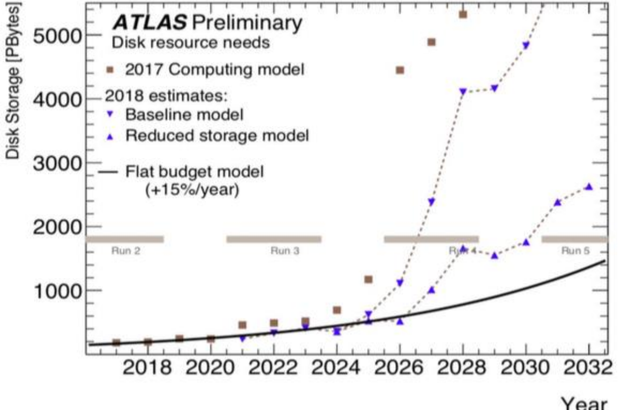
- ✓ Continually improving estimates – evolve computing model, software, infrastructure

Increased complexity due to much **higher pile-up** and higher trigger rates will bring several challenges to reconstruction algorithms

ATLAS: simulation for HL-LHC with 200 vertices







Evolution of HEP computing

HSF-CWP-2017-01
December 15, 2017

arXiv:1712.06982v5 [physics.comp-ph] 19 Dec 2018

A Roadmap for HEP Software and Computing R&D for the 2020s

HEP Software Foundation[1]

ABSTRACT: Particle physics has an ambitious and broad experimental programme for the coming decades. This programme requires large investments in detector hardware, either to build new facilities and experiments, or to upgrade existing ones. Similarly, it requires commensurate investment in the R&D of software to acquire, manage, process, and analyse the shear amounts of data to be recorded. In planning for the HL-LHC in particular, it is critical that all of the collaborating stakeholders agree on the software goals and priorities, and that the efforts complement each other. In this spirit, this white paper describes the R&D activities required to prepare for this software upgrade.

[1] Authors are listed at the end of this report.

https://doi.org/10.1007/s41781-018-0018-8

WLCG-LHCC-2018-001
05 April 2018

WLCG Strategy towards HL-LHC

Executive Summary

The goal of this document is to set out the path towards computing for HL-LHC in 2026/7. Initial estimates of the data volumes and computing requirements show that this will be a major step up from the current needs, even those anticipated at the end of Run 3. There is a strong desire to maximise the physics possibilities with HL-LHC, while at the same time maintaining a realistic and affordable budget envelope. The past 15 years of WLCG operation, from initial prototyping through to the significant requirements of Run 2, show that the community is very capable of building an adaptable and performant service, building on and integrating national and international structures. The WLCG and its stakeholders have continually delivered to the needs of the LHC during that time, such that computing has not been a limiting factor. However, in the HL-LHC era that could be very different unless there are some significant changes that will help to moderate computing and storage needs, while maintaining physics goals. The aim of this document is to point out where we see the main opportunities for improvement and the work that will be necessary to achieve them.

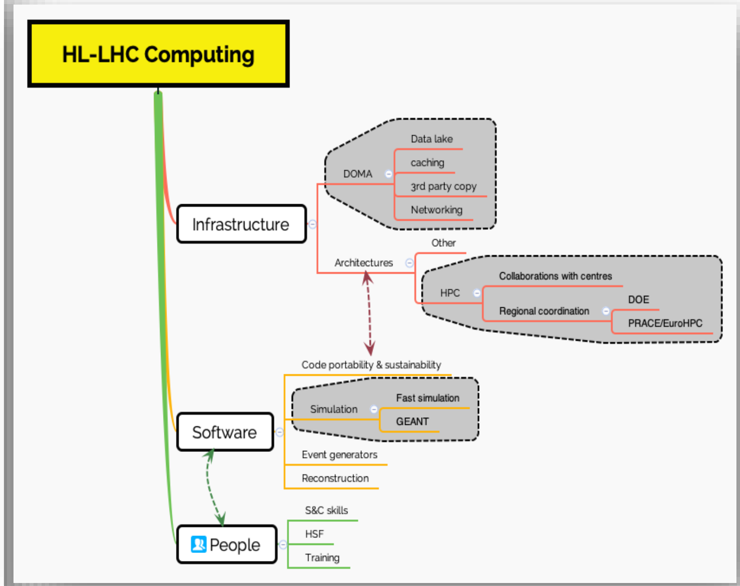
During 2017, the global HEP community has produced a white paper - the Community White Paper (CWP), under the aegis of the HEP Software Foundation (HSF). The CWP is a ground-up gathering of input from the HEP community on opportunities for improving computing models, computing and storage infrastructures, software, and technologies. It covers the entire spectrum of activities that are part of HEP computing. While not specific to LHC, the WLCG gave a charge to the CWP activity to address the needs for HL-LHC along the lines noted above. The CWP is a compendium of ideas that can help to address the concerns for HL-LHC, but by construction the directions set out are not all mutually consistent, not are they prioritised. That is the role of the present document - to prioritise a program of work from the WLCG point of view, with a focus on HL-LHC, building on all of the background work provided in the CWP, and the experience of the past.

At a high level there are a few areas that clearly must be addressed, that we believe will improve the performance and cost effectiveness of the WLCG and experiments:

- **Software:** With today's code the performance is often very far from what modern CPUs can deliver. This is due to a number of factors, ranging from the construction of the code, not being able to use vector or other hardware units, layout of data in memory, and end-end I/O performance. With some level of code re-engineering, it might be expected to gain a moderate factor (x2) in overall performance. This activity was the driver behind setting up the HSF, and remains one of the highest priority activities. It also requires the appropriate support and tools, for example to satisfy the need to fully automate the ability to often perform physics validation of software. This is essential as we must be adaptable to many hardware types and frequent changes and optimisations to make the best use of opportunities. It also requires that the community develops a level of understanding of how to best write code for performance, again a function of the HSF.

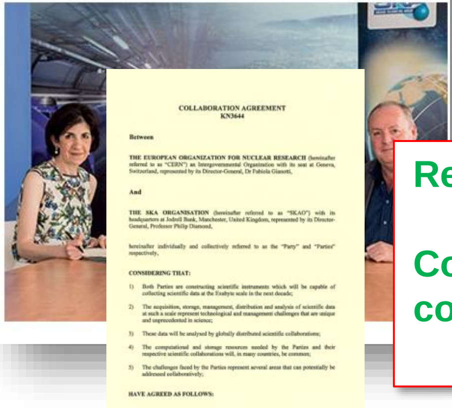
1

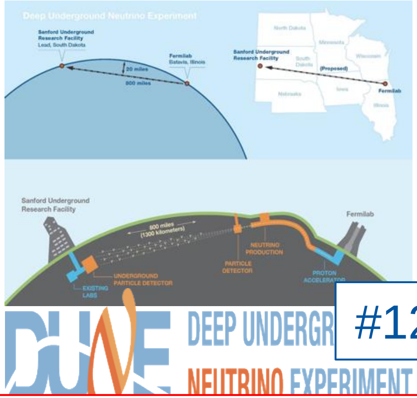
https://cds.cern.ch/record/2621698



Synergies

CERN COURIER
Aug 11, 2017
SKA and CERN co-operate on extreme computing





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Joint Gravitational Waves and CERN Meeting
Friday 1 Sep 2017, 09:00 → 20:00 Europe/Zurich
500-1-001 - Main Auditorium (CERN)
Federico Ferrini (INFN Sezione di Pisa (INFN)), Francesco Fide

09:00 → 09:20 Welcome and introduction to the meeting
Speakers: Eckhard Elsen (CERN), Federico Ferrini (EGO)
09:20 → 09:45 GW from a particle physics perspective
Speaker: Gian Giudice (CERN)
09:45 → 10:10 The New Era of Precision Gravitational-Wave (astro)
Speaker: Alessandra Buonanno
10:10 → 10:30 Discussion

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Recent European Strategy for Particle Physics

Common theme in many contributions is the desire to collaborate with LHC R&D work
➔ implies governance evolution

...ticle Physics European Consortium (APPEC)
APPEC Contribution to the European Particle Physics Strategy
December 17, 2018
Editorial Board:
S. Katsanevas, A. Masiero, T. Montaruli, J. de Kleuver, A. Haungs
Contact Person:
T. Montaruli (APPEC Chair from Jan. 1, 2019)
Email: teresa.montaruli@unige.ch
Website: http://www.appec.org

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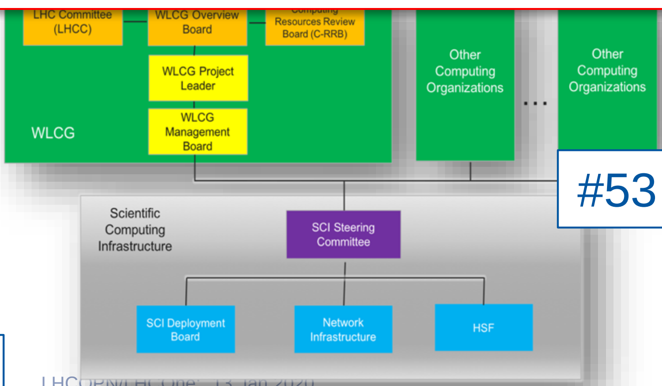

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The International Linear Collider
A Global Project

APS Division of Particles and Fields Response to European Strategy Group Call for White Papers:
Tools for Particle Physics
DPF Executive Committee and Strategy Whitepaper Editing Grou...
dpfstrategy@fnal.gov
December 18, 2018
Abstract
The U.S. particle physics strategy process is summarized in a companion white paper that also describes U.S. activities related to the five P5 science drivers. Additional activities within the U.S. particle physics program that are critical to progress in our field are described here.

#150

Statement of the Pierre Auger Collaboration as input for the European Particle Physics Strategy Update 2018 – 2020
Ralph Engel (auger_spokespersons@fnal.gov),
on behalf of the Pierre Auger Collaboration

#117

Common challenges

- Management of Exabyte- scale science data
  - And associated tools, networks, infrastructure
- Move from "simple" x86-like clusters to very heterogenous resources
  - Use of HPC and Exascale computing resources
- Infrastructures & centres likely to be common between HEP & Astronomy, Astroparticle, GW, etc.
- Software challenge – associated with the above
  - How to easily move code between various compute resources, validate correctness, adapt to new architectures, etc.
- Develop and retain skills in software and computing
  - In the scientific community – as well as with specialists
  - Issue of recognition in academic environments

ESFRI Science Projects

HL-LHC	SKA
FAIR	CTA
KM3Net	JIVE-ERIC
ELT	EST
EURO-VO	EGO-VIRGO
(LSST)	(CERN,ESO)

ESCAPE

European Science Cluster of Astronomy & Particle physics
ESFRI research infrastructures

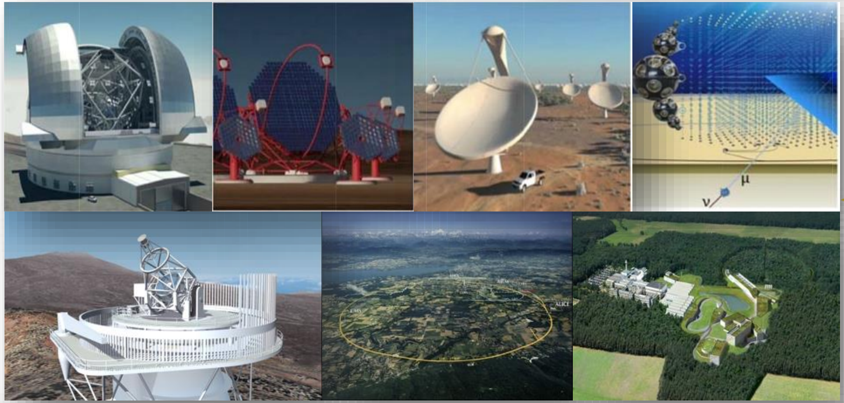
Horizon 2020 funded project

Goals:

Prototype an infrastructure for the EOSC that is adapted to the Exabyte-scale needs of the large ESFRI science projects.

Ensure that the science communities drive the development of the EOSC.

Has to address *FAIR* data management, long term preservation, open access, open science, and contribute to the EOSC catalogue of services.



EUROPEAN OPEN SCIENCE CLOUD

Work Packages

WP2 – Data Infrastructure for Open Science

WP3 – Open-source scientific Software and Service Repository

WP4 – Connecting ESFRI projects to EOSC through VO framework

WP5 – ESFRI Science Analysis Platform

Task 2.2 Content Delivering and Caching

Task 2.2 Storage Orchestration Service

Task 2.1 Storage Services

Task 2.1 Data transfer services

Task 2.3 Efficient Access to Compute

HTC/Grid

HPC

Cloud/ commercial

citizen

Task 2.4 Networking

Task 2.5 AAI

Data centres (funded in WP2)

CERN, INFN, DESY, GSI, Nikhef, SURFSara, RUG, CCIN2P3, PIC, LAPP, INAF

Data Infrastructure

DOMA project
(Data Organization, Management, Access)

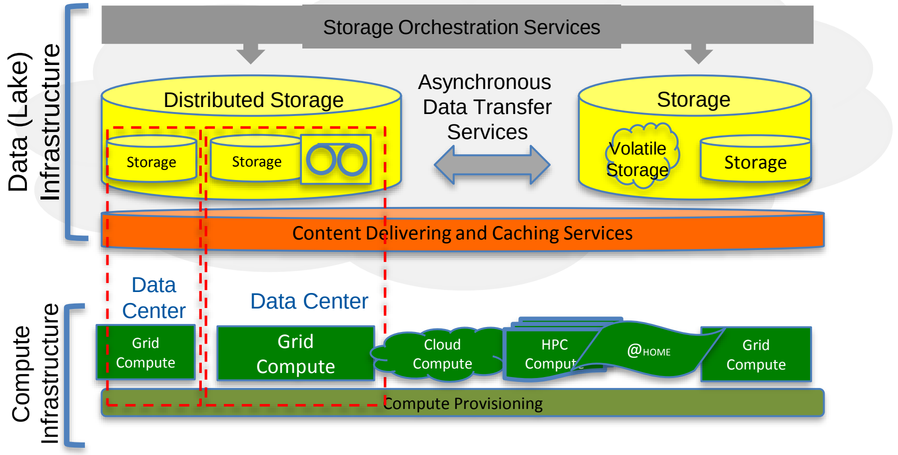
A set of R&D activities evaluating components and techniques to build a common HEP data cloud

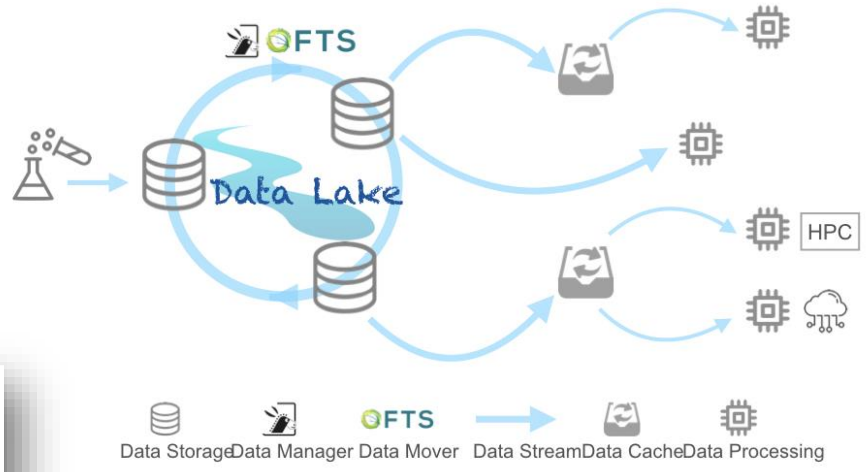
Idea is to localize bulk data in a cloud service (Tier 1's ➔ data lake):
minimize replication, assure availability; policy driven

Serve data to remote (or local) compute – grid, cloud, HPC, etc.
Simple caching is all that is needed at compute site

Works at national, regional, global scales

Model to integrate private and commercial storage – in a "RAID" configuration across sites



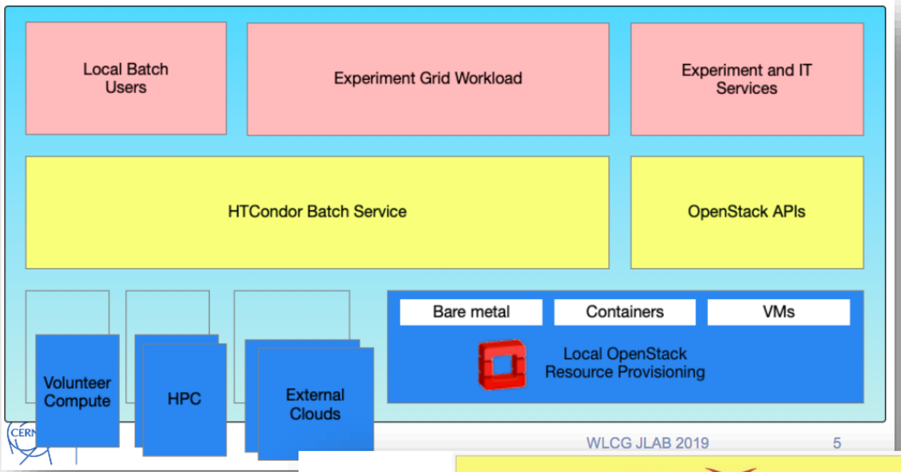


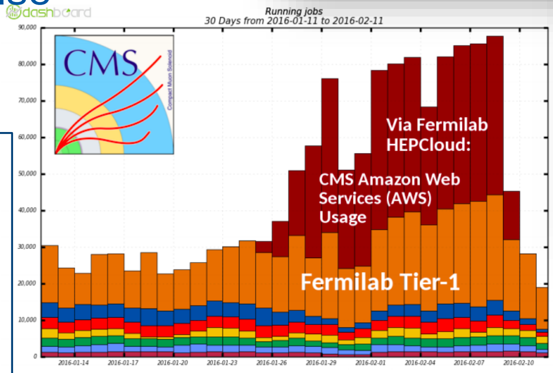
CERN | WLCG

ESCAPE
European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures

Heterogenous compute

- Requires:
  - Common provisioning mechanisms, transparent to users
  - Facilities able to control access (cost), appropriate use, etc
- HPC, Clouds, HLT will not have (affordable) local storage service (in the way we assume today)
  - Must be able to deliver data to them when they are in active use



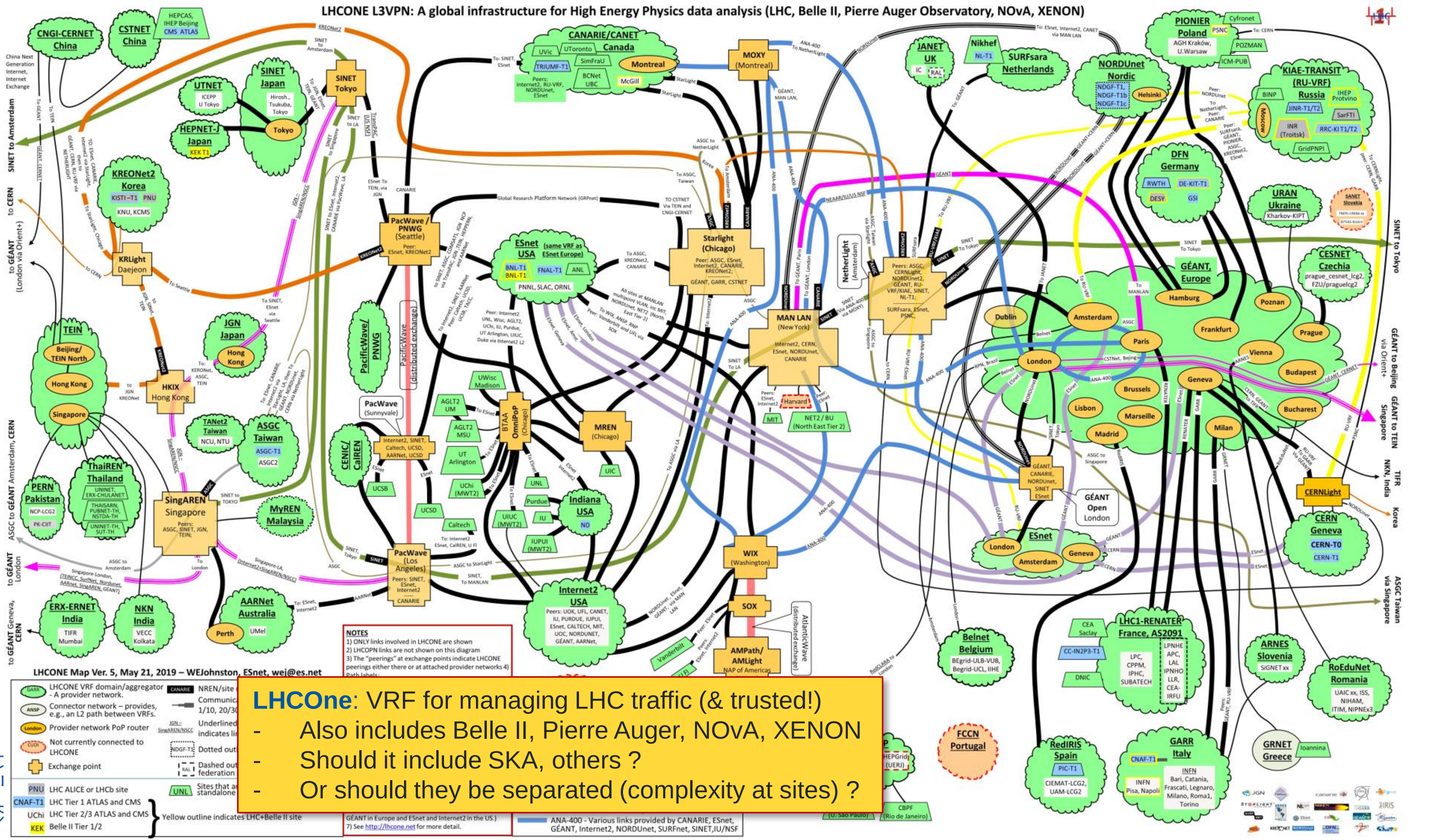


Deployed in a hybrid cloud mode:

- Procurers' data centres
- commercial cloud service providers
- GEANT network and EduGAIN Federated Identity Management

Infrastructure challenges

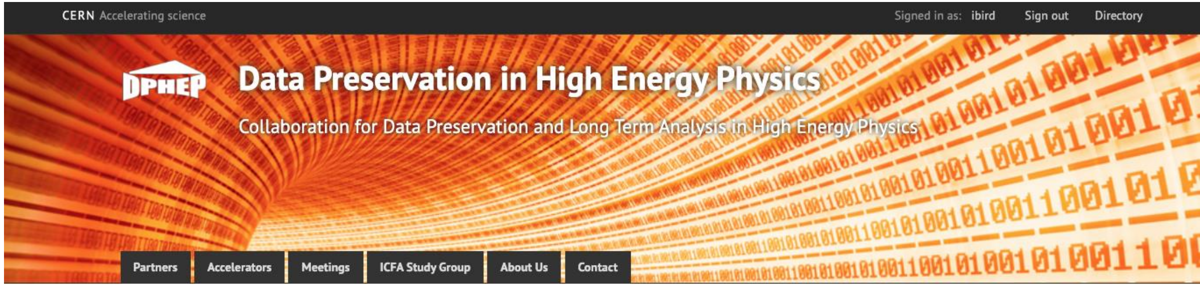
- A federated data infrastructure that:
  - Enables policy driven wide area data replication across a “virtual data centre”
    - == “Data Cloud” or “Data Lake”
    - Want it to appear as a single data repository although distributed
    - Avoid having small *managed* storage service everywhere
  - Is able to feed data to heterogenous compute resources distributed at processing centres
    - Traditional grid/HTC; HPC, Commercial cloud, citizen scientists
    - Streaming, latency hiding, caching, etc.
  - Can integrate owned and commercial resources
- Hopefully a lot in common between HEP and other related sciences with similar needs
- Avoid adding complexity to the system –
  - today it is much simpler than original design; this has decreased the operational cost significantly



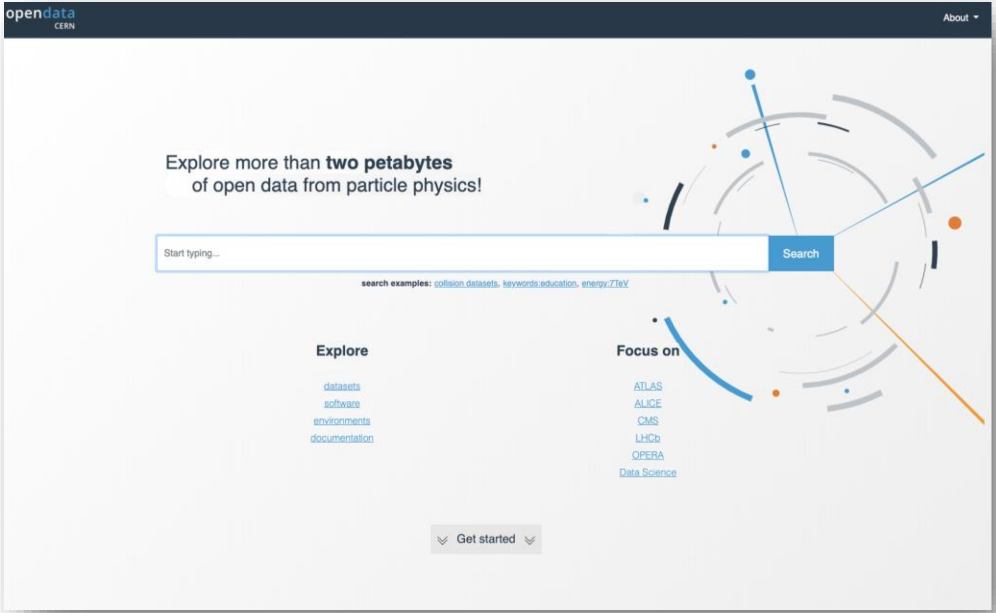
LHCOne: VRF for managing LHC traffic (& trusted!)

- Also includes Belle II, Pierre Auger, NOvA, XENON
- Should it include SKA, others ?
- Or should they be separated (complexity at sites) ?

Open Data

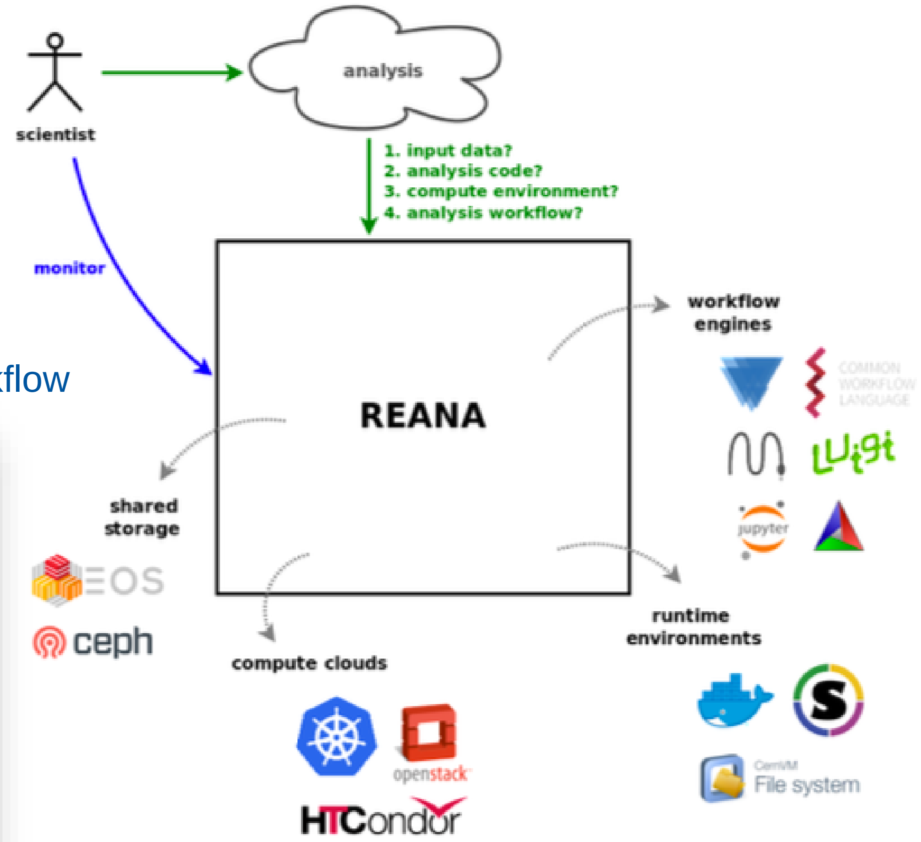


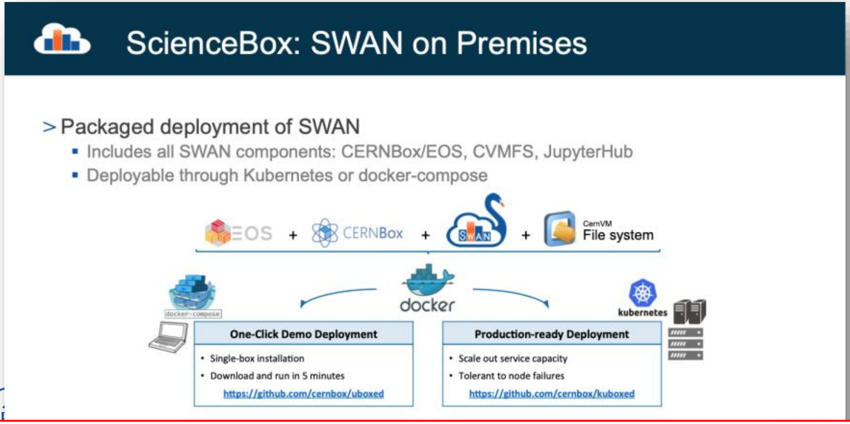
- Launched in November 2014
- Rich content
  - Collision and simulated datasets for research
  - Derived datasets for education
  - Configuration files and documentation
  - Virtual machines and container images
  - Software tools and analysis examples
- Total size in November 2019
  - Over 7000 bibliographic records
  - Over 800,000 files
  - Over 2 Petabytes of data



Scientific workloads on containerized clouds

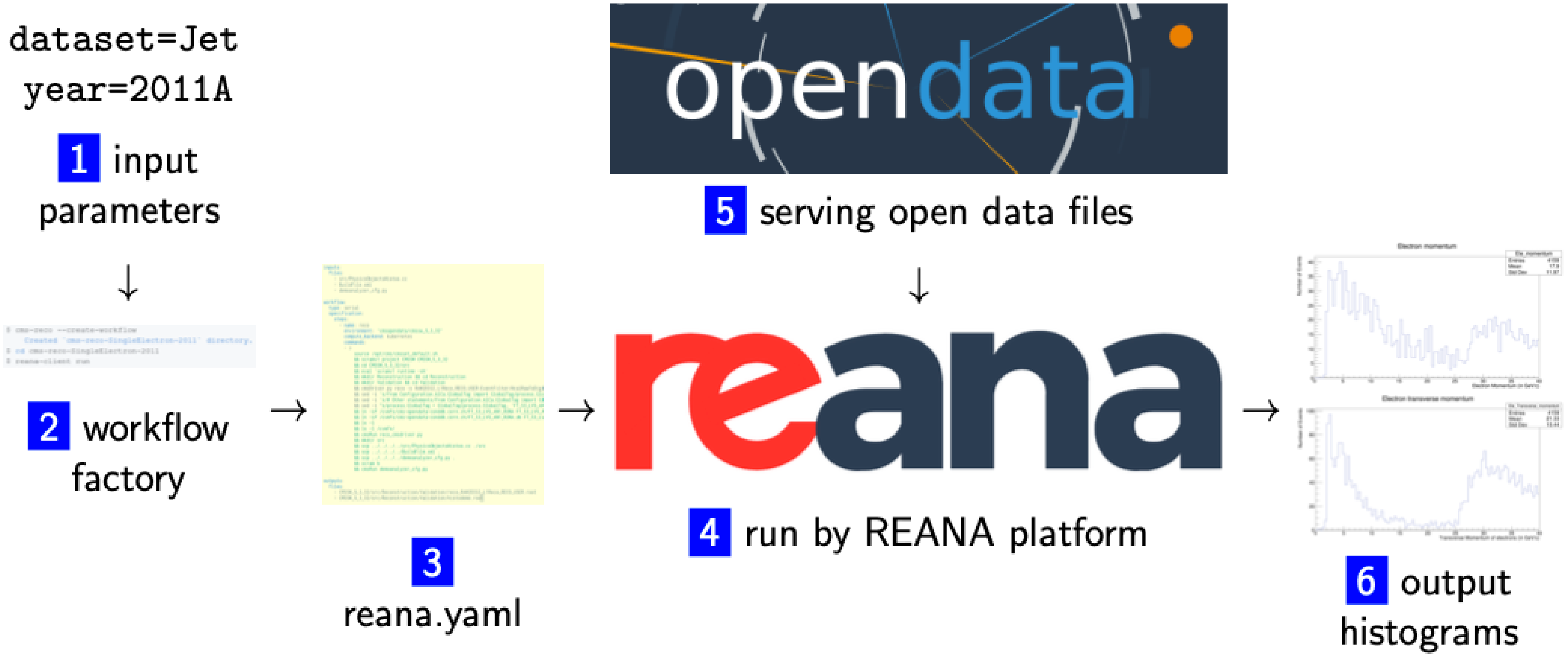
- REANA – reproducible analysis platform
  - https://www.reana.io
- Multiple workflow systems
  - CWL, Serial, Yadage
- Multiple compute backends
  - Kubernetes, HTCondor, SLURM
- Diverse shared storage
  - ceph, EOS, NFS
- Reproducibility: code+data+environment+workflow





SWAN: Notebook on demand; scale-out compute; full analysis environment

Automated reconstruction workflows

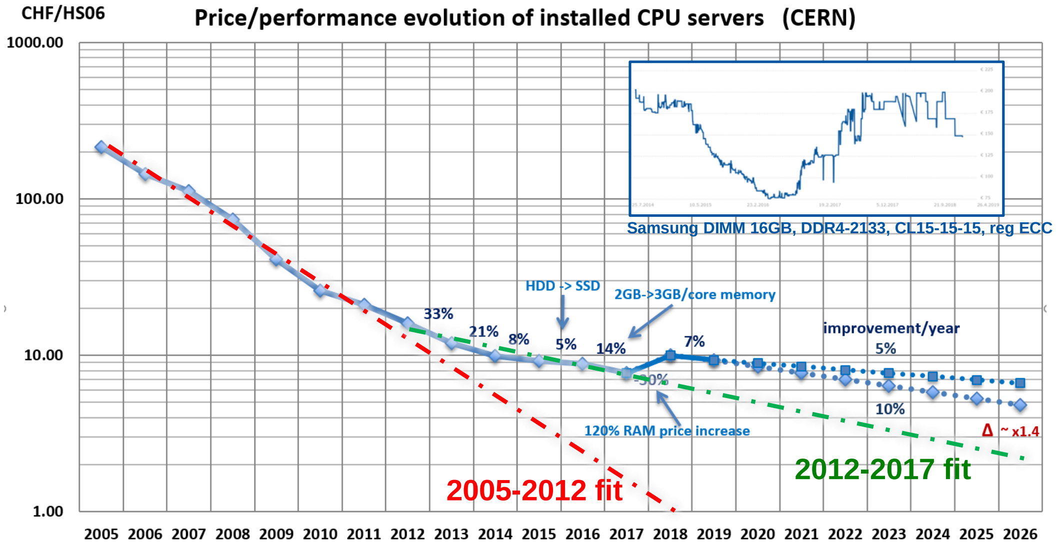


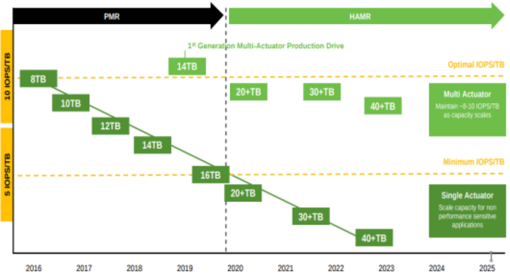
Parametrised workflow runnable on REANA reproducible analysis platform

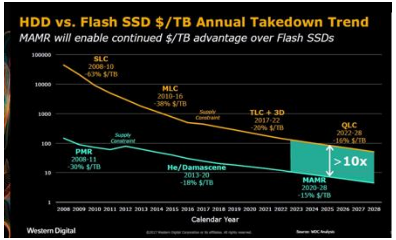
Hardware cost evolution

- Previous assumptions of ~20%/year effective cost improvement for CPU & storage no longer true
- *Market-driven* rather than technology
- Science has no influence on these markets

- We have serious risks:
- Our budget outlooks are constrained (flat!)
- Risk of technologies disappearing
  - e.g. tape due to market forces
  - disk technology future not clear – costs not obvious








The Register®

Biting the hand that feeds IT

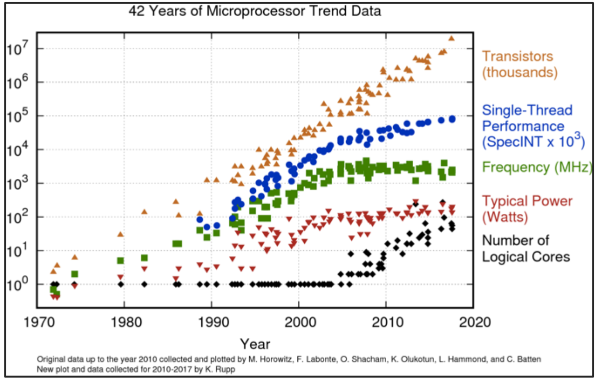
Data Centre ▸ Storage

Did Oracle just sign tape's death warrant? Depends what 'no comment' means

Big Red keeps schtum over the status of StreamLine

By Chris Mellor 17 Feb 2017 at 10:44 29 SHARE ▾

Oracle's StorageTek (StreamLine) tape library product range will be end-of-lifed, *El Reg* has learned.



Software

HSF Set up in response to recognition that software will be key to success for HL-LHC and the future

HEP Software Foundation

The HEP Software Foundation (HSF) facilitates coordination and common efforts in high energy physics (HEP) software and computing internationally.

The HSF is now beginning community process to develop a consensus roadmap for HEP Software and Computing R&D for the 2020s. More infomation about this can be found on the Community White Paper (CWP) page on the HSF site.

Meetings

All our activities and ideas are discussed weekly in our HSF meeting. Feel free to participate!

- HSF Weekly Meeting #71, November 3, 2016
- HSF Weekly Meeting #69, September 15, 2016
- HSF Weekly Meeting #68, September 8, 2016

Full list of meetings »

Newsletter

If you would like to stay updated, please subscribe to our newsletter:

- Third HSF Workshop
- Sharing ideas and code
- HSF Newsletter - Logo Contest and Packaging Working Group

Older newsletters »

Activities

Our plenty of activities span from our working groups, organizing events to supporting projects as HSF projects, and channeling communication within the community with discussion forums, technical notes and a knowledge base.

How to get involved »

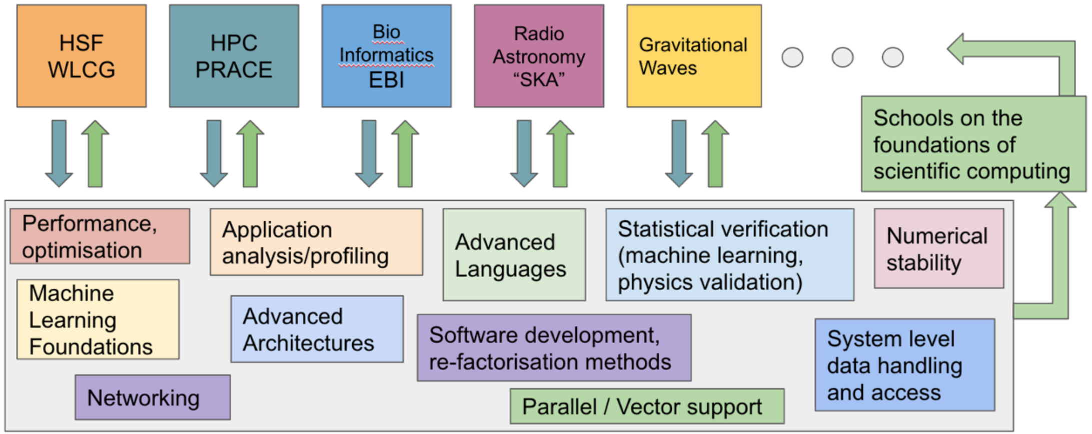
We have discussed this problem with SKA and PRACE

Some national initiatives have started

Much more is needed

Ideas for a software initiative

- Propose a strong collaboration among European research institutions, Universities, and scientific collaborations on software R&D, engineering and sustainability to tackle future challenges
  - Leverage and complement national initiatives
- Focus on
  - Focus on fundamental, transferable aspects – data structures, methods, best practices
  - Application software – data intensive and complex algorithms
  - Distributed computing – data management, analysis, exploitation of modern architectures
- Software and computing as a valid scientific career specialism
- Essential for all modern science and other disciplines
- Lobby for investment in software skills
- Interest from other communities



Conclusions

- HL-LHC and others facing Exabyte scale data challenges in the next 5-10 years
- Prototyping an infrastructure to enable FAIR data preservation, open access, reproducibility
  - As well as performance, scalability
- Projects such as ESCAPE should help shape the EOSC and next generation e-infrastructures for science