How do you build a flagship supercomputer, and why would you like to do that?

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Outline

The story of LUMI (briefly)

LUMI's technical architecture

First scientific showcases of LUMI

LUMI Consortium

- Unique consortium of 10 countries with strong national HPC centers
- The resources of LUMI will be allocated per the investments
- The share of the EuroHPC JU (50%) will be allocated by a peer-review process and available for all European researchers
- The shares of the LUMI partner countries will be allocated by local considerations and policies – seen and handled as extensions to national resources

LUMI Datacenter in Kajaani

100% hydroelectric energy up to 200 MW

Very reliable power grid

100% free cooling available, PUE 1.03

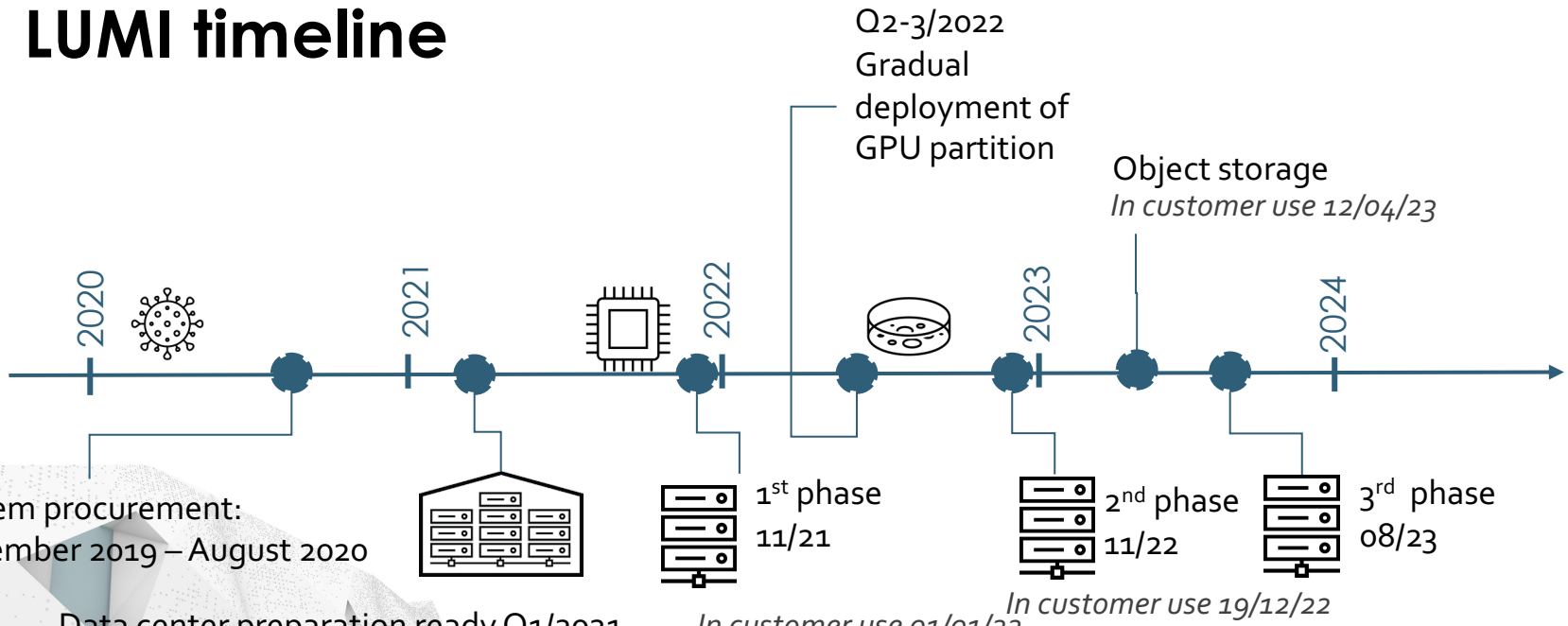
Waste heat reuse in district heating leads to thousands of tons CO_2 reduced every year and considerable financial savings

Extreme connectivity: Kajaani DC is a direct part of the Nordic backbone. 4x100 Gbit/s to GÉANT in place, can be easily scaled up to multi-terabit level

Elevated security standards guaranteed by ISO27001 compliancy


RENFORSIN RANTA
RATA
LUMI
KONE

LUMI timeline



Technical Architecture

LUMI: one of the fastest supercomputers in the world

- LUMI is an **HPE Cray EX** supercomputer manufactured by **Hewlett Packard Enterprise**
- HPL performance over **375 petaflop/s** makes the system one of the world's fastest
  - #3 in Top500 (#1 in Europe)
  - #3 HPCG, #2 HPL-MxP

1 system

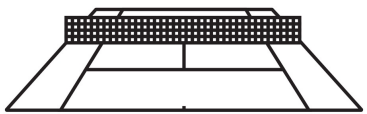
375 Pflop/s

Sustained performance

Computing power equivalent to

1 500 000

Modern laptop computers



Size of two tennis courts

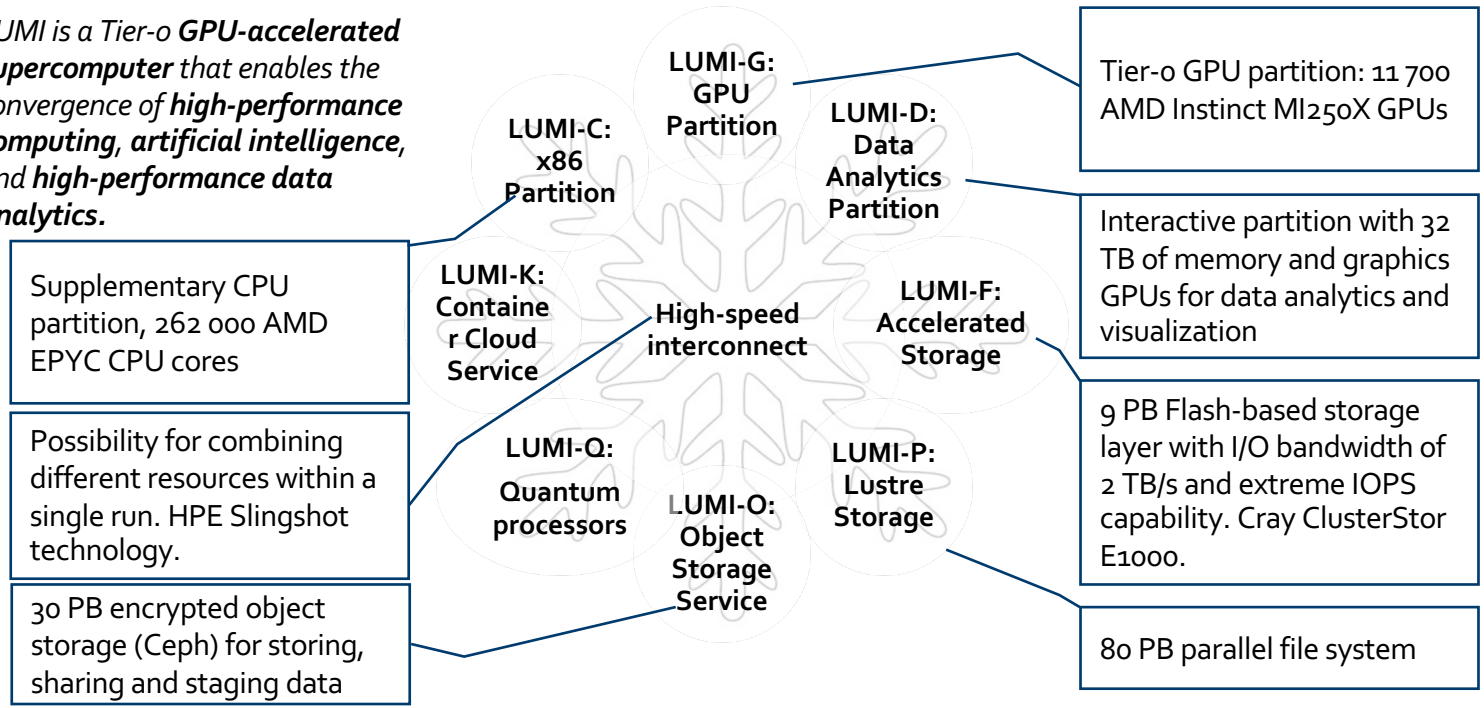
Modern platform for

High-performance computing, Artificial intelligence, Data analytics

Based on GPU technology

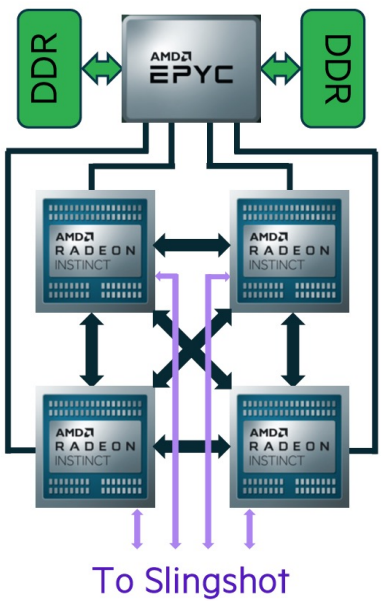
LUMI, the Queen of the North

LUMI is a Tier-0 ***GPU-accelerated supercomputer*** *that enables the convergence of* ***high-performance computing***, ***artificial intelligence***, *and* ***high-performance data analytics.***

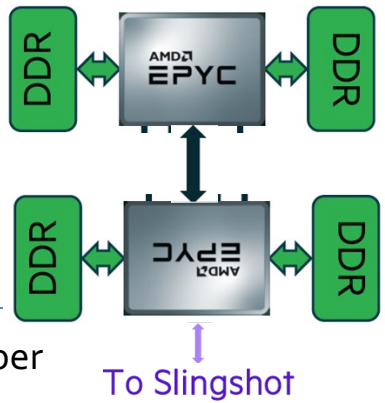


LUMI compute node configurations

LUMI-G



2928 nodes with 4 x MI250X + 1 x AMD Trento processor, 512 GB host memory and 512 GB device memory (HBM2)
4 x 200 Gbit/s NIC
Infinity Fabric



2x 64-core AMD Milan processors per node
1888 nodes with 256 GB, 128 with 512 GB and 32 with 1 TB
1 x 200 Gbit/s NIC

LUMI-C

LUMI

Enhanced user experience

- High-level interfaces on LUMI: Jupyter Notebooks, Rstudio and such to back-end to LUMI compute nodes (09/23)
- A rich stack of pre-installed software
- Datasets as a Service: curated large reference datasets made available and maintained
- Inference service for large ML models trained on LUMI (12/23)
- Support for handling data needing elevated security (GDPR subjected, IP-closed, etc) (12/23)

Early Scientific Showcases

Enabler of world-class scientific breakthroughs

LUMI is designed as a 'Swiss army knife' targeted for **a wide spectrum of use cases and user communities**.

- **Climate research:** More precise climate models and the interconnection of different climate models – digital twins of Earth ICON
- **Data science**: analyzing and re-analyzing large data sets (simulated and measured) e.g. in atmospheric science, environmental science, climate modelling, material science and linguistics.
- **Plasma physics**: Predicting and preparing for the societal effects of extreme space weather events. Multi-scale modeling of fusion reactors. Vlasiator, GENE
- **Life sciences:** enabling calculation of protein function, structural protein-protein interactions. Gromacs
- **Materials science:** quantum-mechanical simulations with global impact are development of better energy storage materials, more efficient solar cells, and better catalyst materials. CP2K, GPAW
- **Humanities and social sciences:** Natural language processing, large language models. Large-scale data analytics from social networks and the modelling of complex societal phenomena.
- Fast-track for **urgent computing** needs in time- and mission-critical simulations, e.g. related to national or EU security, or other major crisis e.g. pandemia.

Early Showcases: Large Language Models and Generative AI

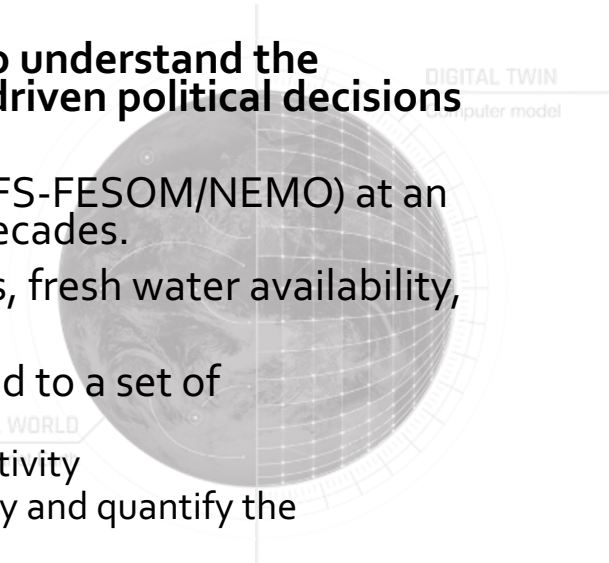
- **Objective: Democratization of generative AI**
- Several ongoing LUMI projects to train large language models of various European languages
  - Finnish, Swedish, Norwegian, Estonian, English,…
- One pilot project of LUMI pre-trained a 13B parameter GPT-3 and a 176B parameter Bloom model – by far the largest language model of Finnish to date
  - Exhausting all digital material in Finnish
- We are working on to provide an API for instructional LLM and open-source foundational LLMs

https://www.lumi-supercomputer.eu/research-group-created-the-largest-finnish-language-model-ever-with-the-lumi-supercomputer/

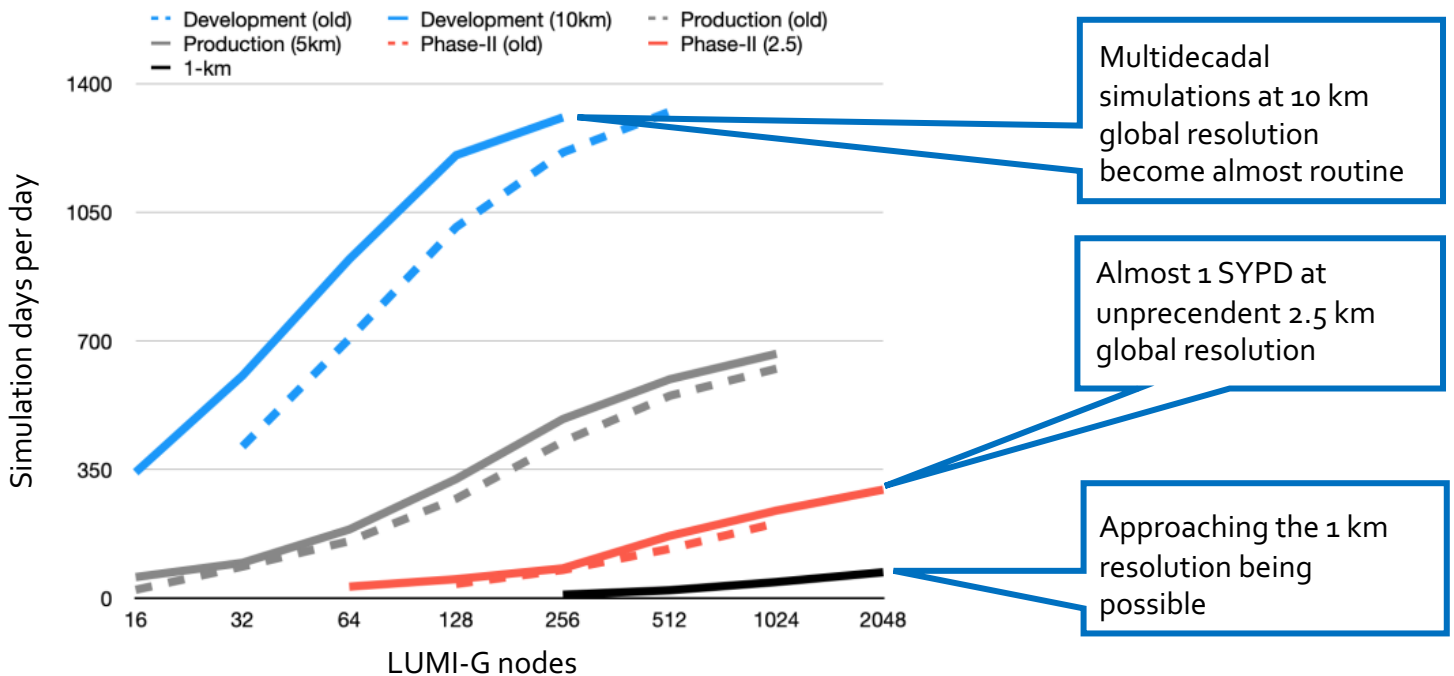
Early Showcases: Climate Adaptation Digital Twin

LUMI

- **Objective: To build a digital twin of Earth's climate to understand the impacts of climate change and help in making data-driven political decisions in their mitigation**
- Global climate simulations with two ESMs (ICON and IFS-FESOM/NEMO) at an unprecedented resolution (~5 – 10 km) over multiple decades.
- Six prototype impact models: Wind energy, river floods, fresh water availability, urban heat waves, wild fire risk and emissions
- With a novel approach, output of ESMs will be streamed to a set of applications, including impact models
  - timely delivery of climate information to users and interactivity
  - Earth observation data will be used to ensure model quality and quantify the uncertainties of impact assesments.
- Deployment on LUMI and MareNostrum 5

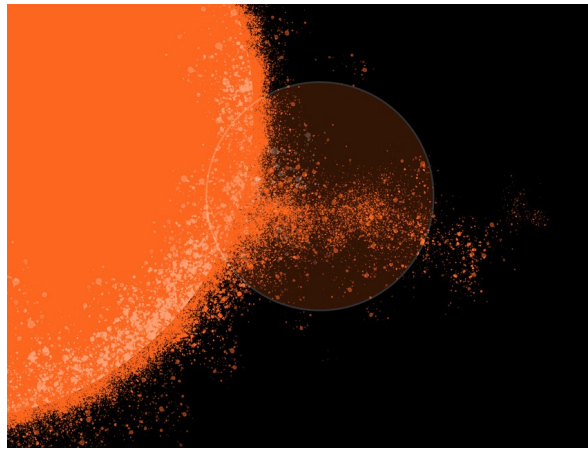


Global climate model ICON performance on LUMI-G



Early Showcases: Solar Astrophysics

- **Objective: Understand subsurface solar physics to improve forecasting of solar storms and therefore space weather**
- LUMI pilot project verified the existence of the fluctuating dynamo mechanism in the Sun

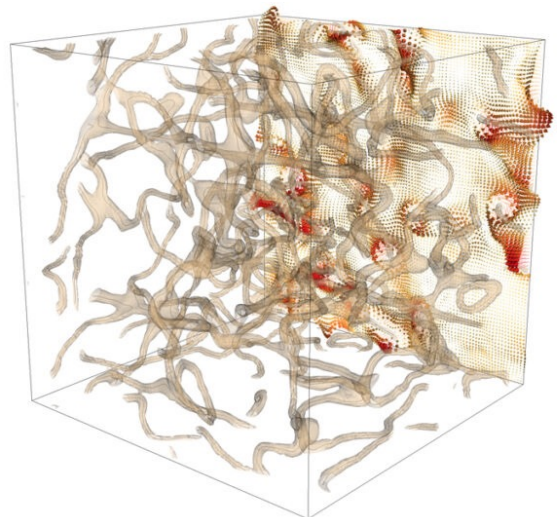


https://www.lumi-supercomputer.eu/researchers-discovered-information-from-under-the-suns-surface-about-the-emergence-of-solar-storms-using-the-lumi-supercomputer/

Early Showcases: Turbulent Dynamics in Superfluid Fermi Systems

LUMI

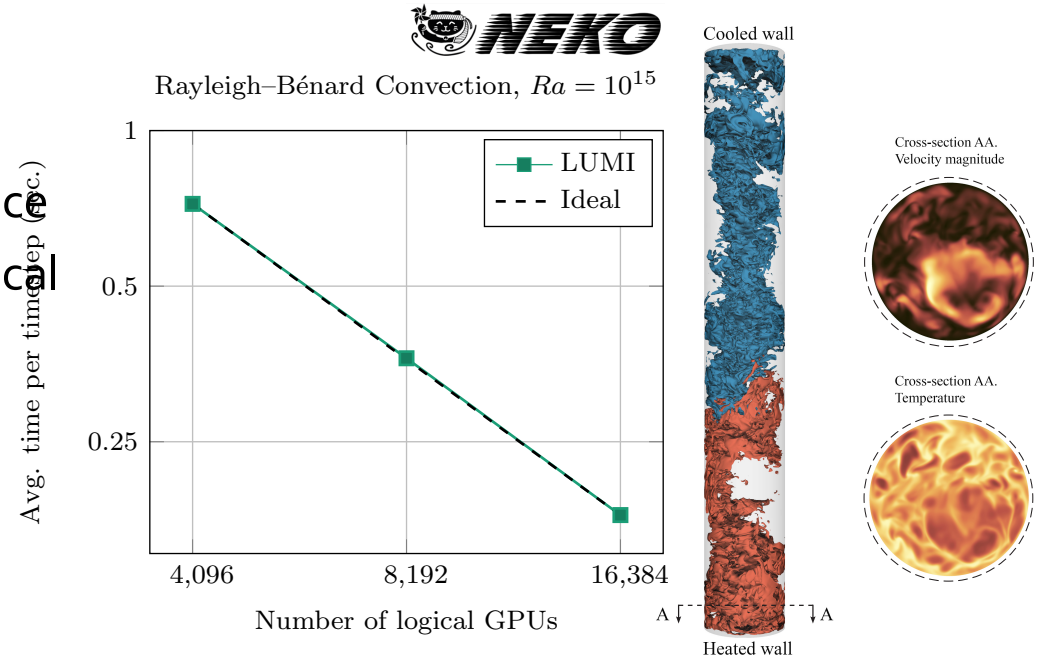
- Fermionic superfluids important in e.g. understanding neutron stars
- To model a fermion superfluid, one needs to track all quantum states
- A pilot project on LUMI performed eigenvalue problem solutions with matrix sizes of 3M
  - the largest direct eigenvalue solution to date



https://www.lumi-supercomputer.eu/successful-polish-lumi-pilot-project-in-the-field-of-quantum-mechanics/

Early Showcases: Extreme-scale high-fidelity turbulence simulations of convection

- Objective: High-fidelity Spectral-Element simulations for turbulence
- Rayleigh-Bénard canonical turbulent convection at extreme scale



Gordon-Bell Prize 2023 finalist

https://sc23.supercomputing.org/2023/08/a-look-at-the-2023-gordon-bell-prize-finalists/

Concluding remarks

New golden era in European HPC under the leadership of EuroHPC Joint Undertaking

LUMI, the Queen of the North: leadership-class resource designed for a broad range of user communities and workloads, with an enhanced user experience

In full customer use since December 2022

LUMI's capabilities already in use for societally important science initiatives - cracking previously intractable computing problems, every day!

LUMI

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EuroHPC Joint Undertaking

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Leverage from the EU 2014–2020

European Union European Regional Development Fund

Kainuun liitto