



# How do you build a leadership-class supercomputer, and why would you like to do that?

Dr. Pekka Manninen

Director, Science and Technology

# Outline



The story of LUMI



LUMI's technical architecture



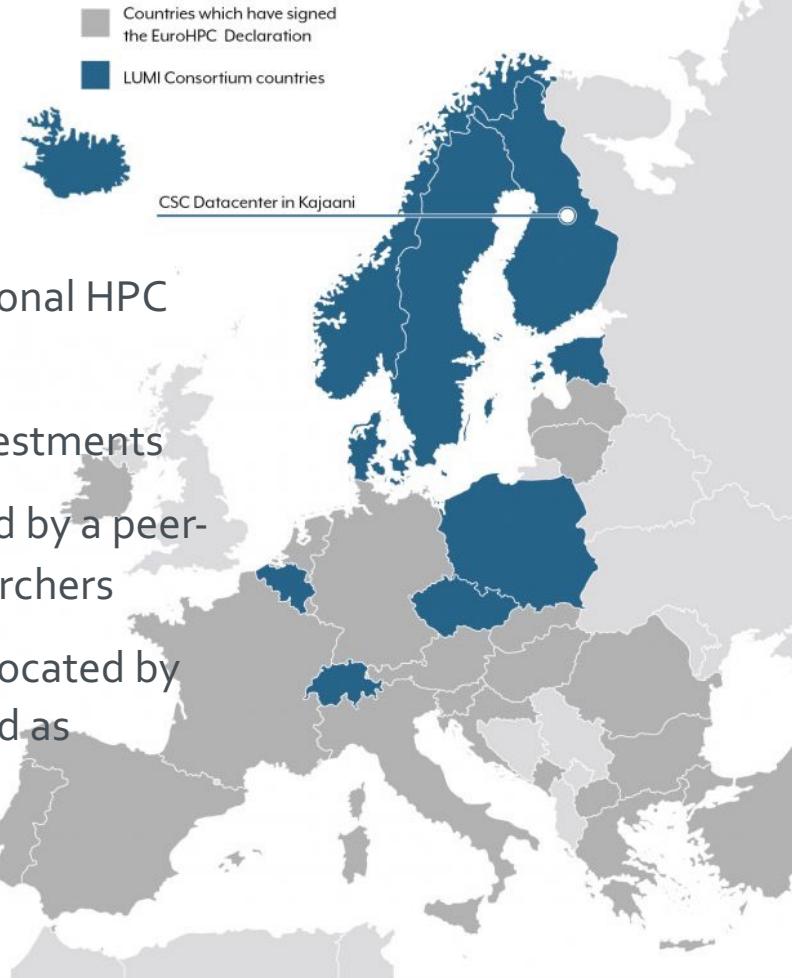
First scientific showcases of LUMI

# The EuroHPC Initiative

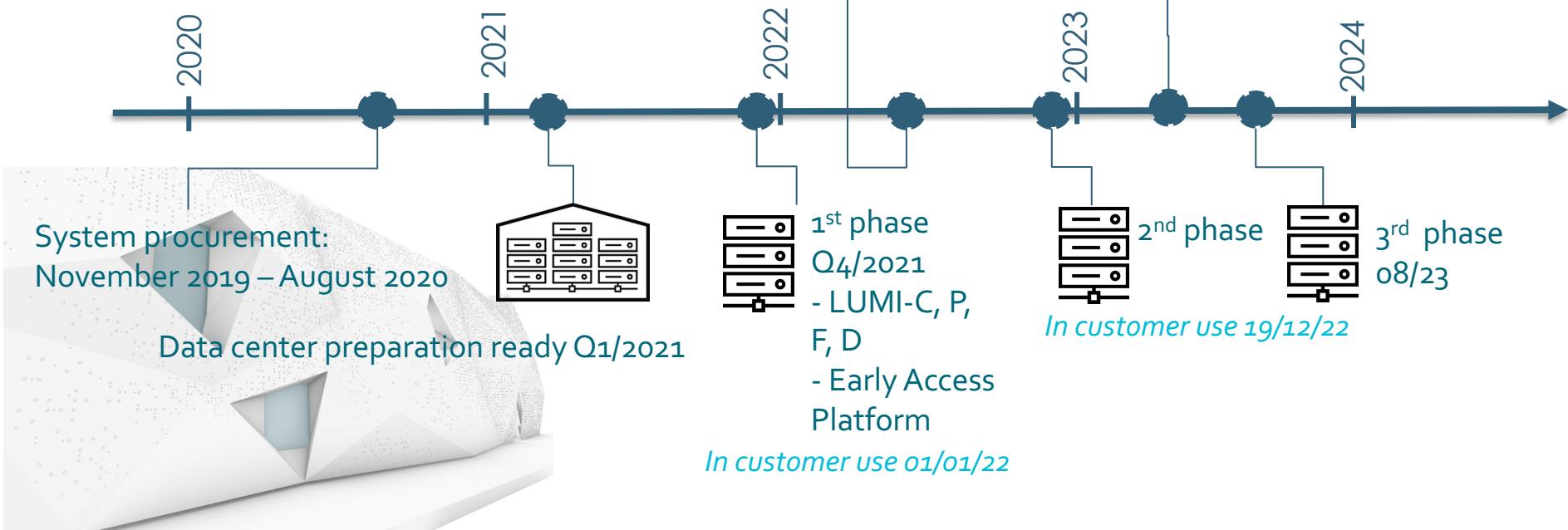
- The **EuroHPC Joint Undertaking** pools EU and national resources in high-performance computing (HPC)
  - **acquiring and providing a world-class supercomputing and data infrastructure** for Europe's scientific, industrial and public users
  - supporting an ambitious **research and innovation agenda**
- The EuroHPC declaration has been signed by **32 European countries**
- The first generation of EuroHPC systems announced in June 2019
  - 3 pre-exascale systems to Finland, Italy and Spain
  - 5 petascale systems to Czech Republic, Bulgaria, Luxembourg, Portugal and Slovenia
- Next generations of systems planned for 2024-2025 and 2027-2029

# 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 timeline



# 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<sub>2</sub> 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



# LUMI: one of the fastest supercomputers in the world

- LUMI is an **HPE Cray EX** supercomputer manufactured by **Hewlett Packard Enterprise**
- HPL performance over **309 petaflop/s** makes the system one of the world's fastest  
#3 in Top500, #2 HPL-MxP, #3 HPCG

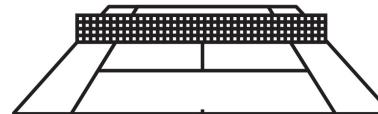


1 system  
**309**  
**Pflop/s**

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

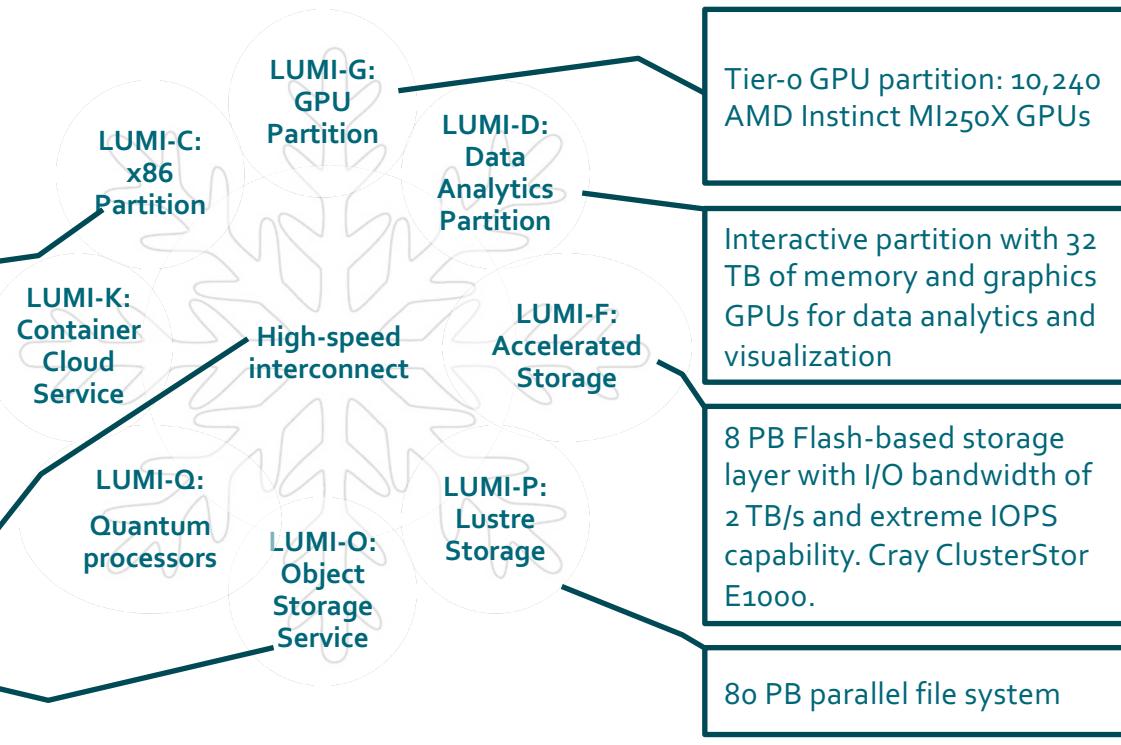
# LUMI, the Queen of the North

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

Supplementary CPU partition, ~200,000 AMD EPYC CPU cores

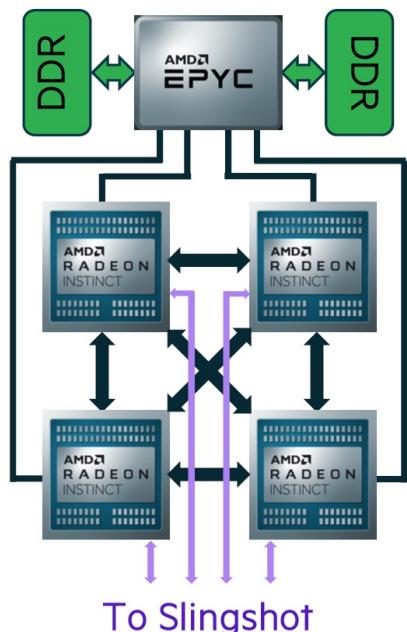
Possibility for combining different resources within a single run. HPE Slingshot technology.

30 PB encrypted object storage (Ceph) for storing, sharing and staging data

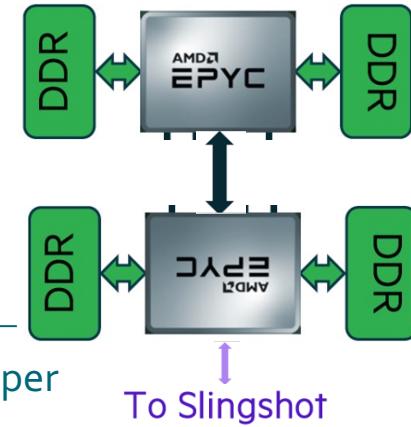


# LUMI compute node configurations

## LUMI-G



2560 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  
 1376 nodes with 256 GB, 128 with 512 GB and 32 with 1TB  
 1 x 200 Gbit/s NIC

**LUMI-C**

# Enhanced user experience

- High-level interfaces on LUMI: Jupyter Notebooks, Rstudio and such to back-end to LUMI compute nodes (07/23)
- 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)

# 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. pandemic.

# Early Science Projects on LUMI

- The projects for the pilot phase of LUMI-G were chosen from the LUMI consortium countries (max 3 per consortium country), presenting various disciplines
  - Astrophysics
  - Natural language processing
  - Materials science
  - Biophysics
  - Deep learning
  - Climate modeling
  - Computational fluid dynamics
- See <https://www.lumi-supercomputer.eu/second-pilot-phase-projects-selected/>
- Several Extreme Scale Access projects started already

# Early Showcases: Large Language Models and Generative AI

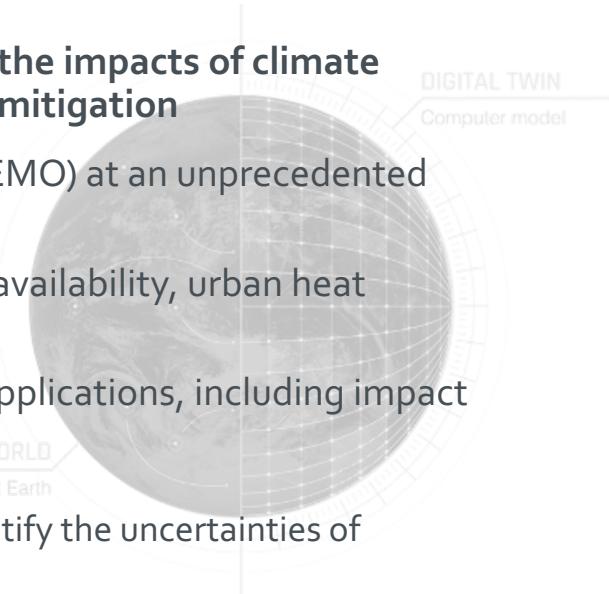
- **Objective: Democratization of generative AI**
- Several ongoing LUMI projects to train large language models of various European languages  
Finnish, Swedish, Norwegian, Estonian, English,...
- One pilot project of LUMI pre-trained a 13B parameter GPT-3 and a 176B parameter Bloom model – by far the 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/>

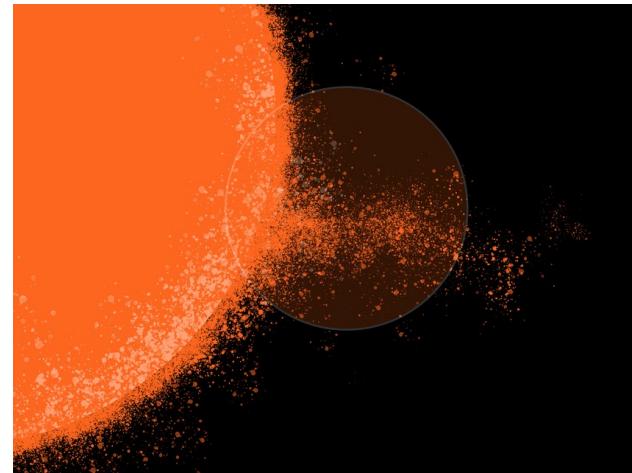
# Early Showcases: Climate Adaptation Digital Twin

- 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 assessments.
- Deployment on LUMI and MareNostrum 5



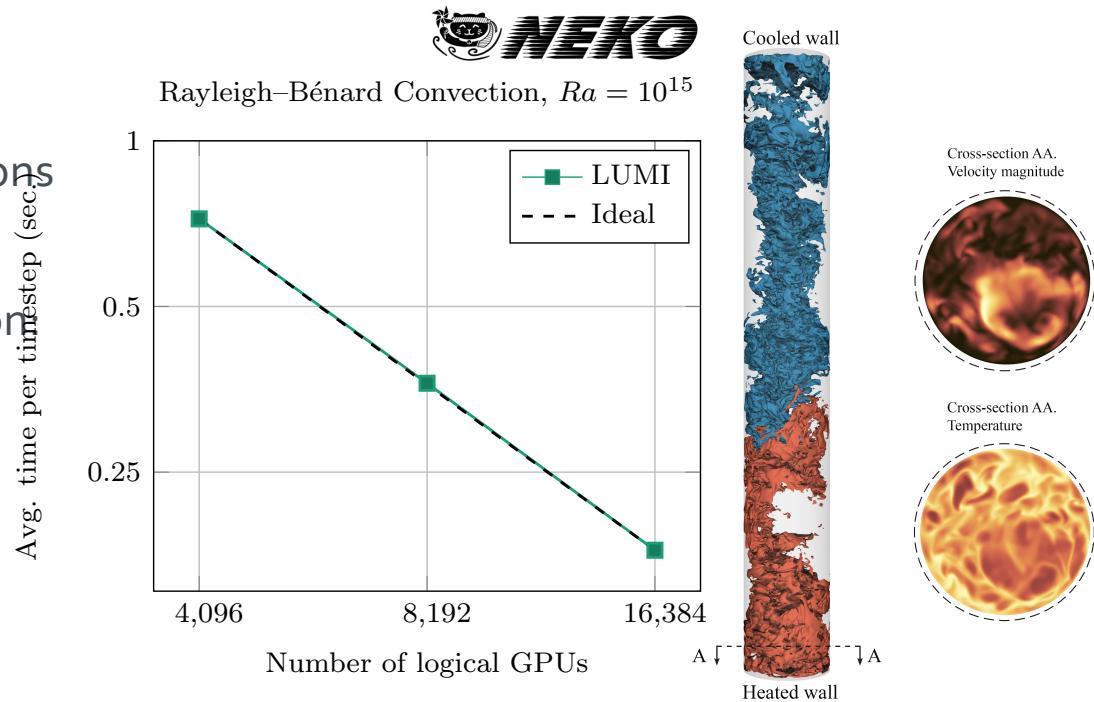
# Early Showcases: Solar Astrophysics

- 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



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

- Objective: High-fidelity Spectral-Element simulations for turbulence
- Rayleigh-Bénard convection: Canonical turbulent convection



## User quotes

*"Overall, I am happy with LUMI. The onboarding was relatively easy for those already familiar with HPC environments. The documentation available online is well-made. In most cases, the code designed for NVIDIA GPUs runs flawlessly on LUMI AMD cards."*

*"From start to finish, I was impressed with how smooth the experience already was for a pilot project. The documentation is nicely organized, with clear instructions and helpful examples, which makes connecting to LUMI and using its vast resources quick and easy. Creating the required environments with the appropriate software was made simple with the pre-made EasyBuild recipes, and the support team was always quick to help and answer questions. The system runs smoothly and quickly and is intuitive to use."*

*"This would never have been possible without a system like LUMI. With smaller systems, we would still calculate this model in 2025."*

*"The work was worthwhile: we can now use LUMI's GPU capacity to do in a day what we used to need a month for when using CPUs ."*

# 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!