Perspectives on HPC in Meteorology in the Era of Heterogeneous Processor Architecture-Based Supercomputer

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KISTI National Supercomputing Center

Exceeding the limit of technology, securing confident competitiveness for tomorrow

Promoting Korea's future competitiveness through supercomputing technology that supports the nation's growth and the spirit of convergence and collaboration for the greatest value.

Roles defined in the Korean HPC Act.

01 Establishment of resources

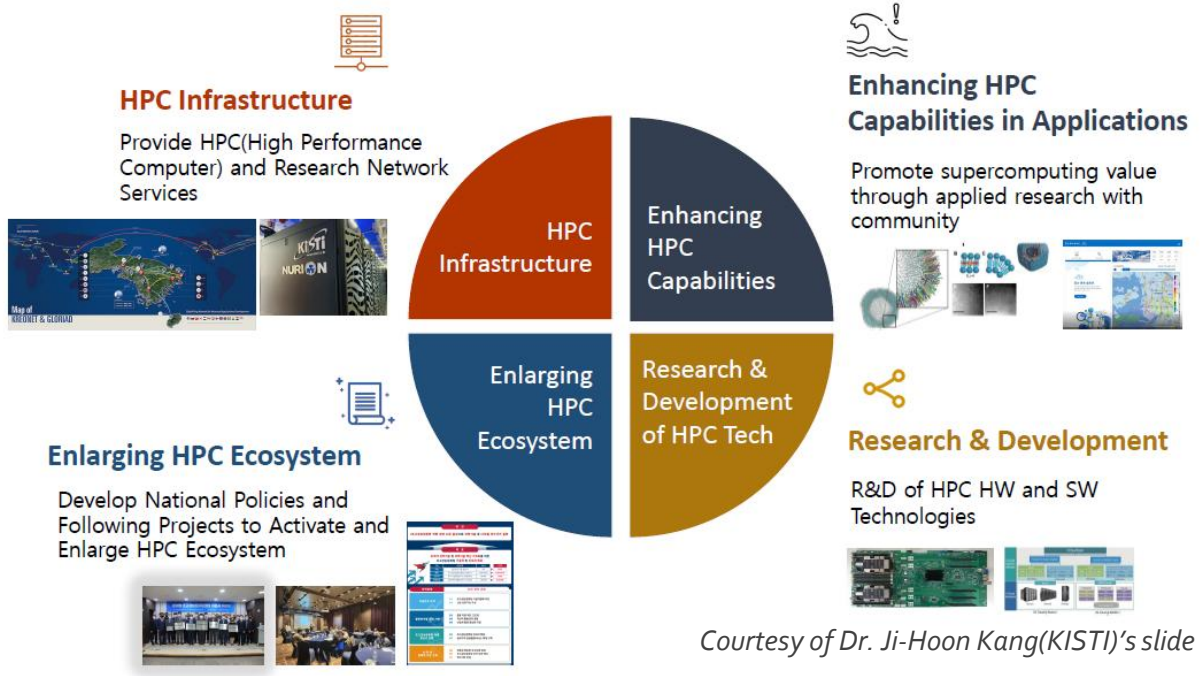
02 Performing R&D projects

03 Technology development

04 Manpower development

05 Vitalization of HPC utilization

06 Political support



Courtesy of Dr. Ji-Hoon Kang(KISTI)'s slide

KISTI Supercomputers

- KISTI has been functioning as the largest supercomputing facilities in Korea for decades. Currently, KISTI operates supercomputing resources (Nurion & Neuron) of **32.08 PF** (Rpeak), supporting the academic & industrial sectors.

Cray-2S
1988.11 ~ 1993.10

1st Supercomputer

Cray C90
1993.11 ~ 2001.5

Cray T3E
1997.6 ~ 2002.12

2nd Supercomputer

PLUTO(128cpus)
2002. ~ 2008

IBM e1350 cluster (512cpus)
2004.1 ~ 2008.9

Sun C48 cluster
(3072 CPU cores)
2008.9 ~ 2016.4

Sun C48 cluster
(25,600 CPU cores)
2010.9 ~

Tachyon

Cray CS500 cluster (570,020 CPU cores)
2018.10 ~

Nurion

KISTI-5

KISTI-6
(2025~)

NEC SX-5
2001.5 ~ 2008.9

NEC SX-6
2003.2 ~ 2009.9

HP SMP
2000.5 ~ 2006.12

IBM p690 (4nodes)
2002.1 ~ 2008.9

IBM p690+ (17nodes)
2003.7 ~ 2008.9

Nobel

KISTI-3

Gaia

IBM p595 (10nodes)
2008.1 ~ 2015.12

IBM p595 (24nodes)
2009.10 ~ 2015.12

KISTI-4

GPU Cluster
(1096 CPU cores, 264 GPUs)
2019.07 ~

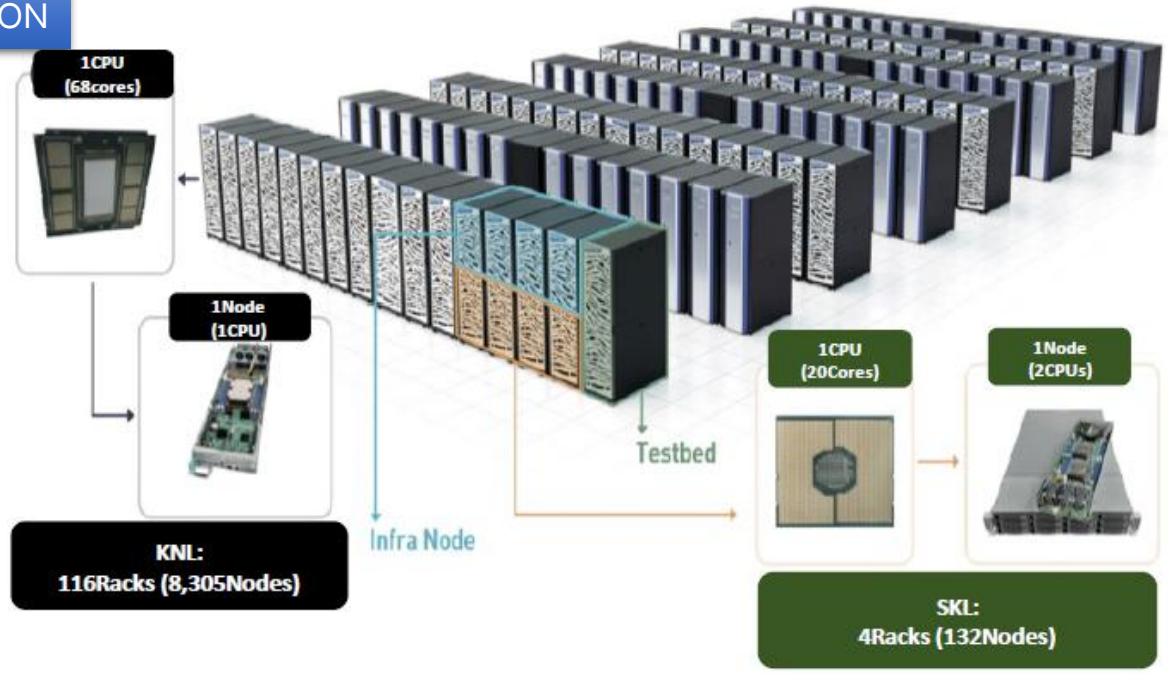
Neuron

√ KMA's 1st supercomputer (1999)

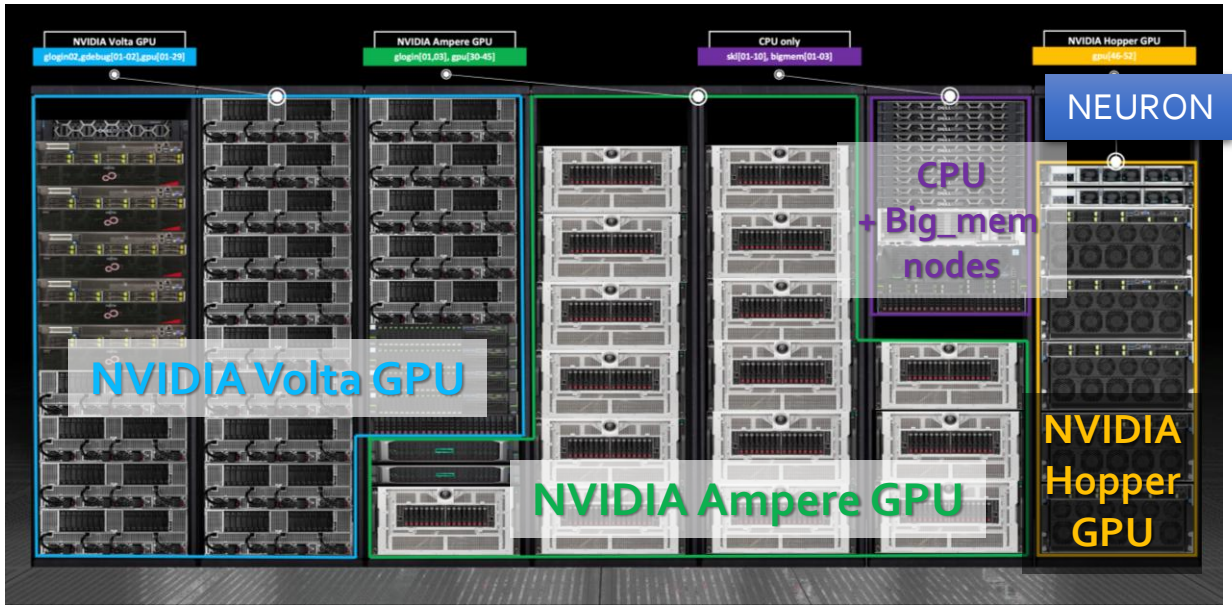
Current Status of KISTI HPC

KISTI-5 NURION & NEURON

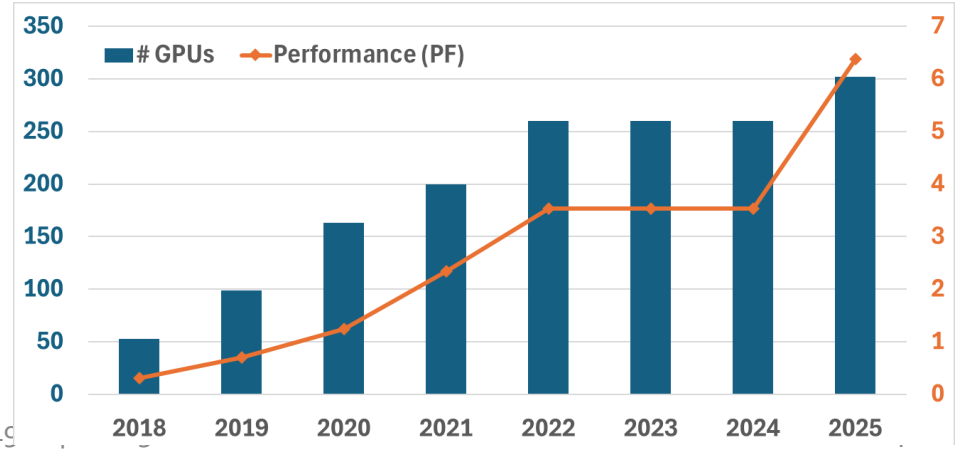
NURION



NEURON



GPU nodes(59ea, 302 GPUs) & CPU nodes(13ea), **6.38 PF** in 2025

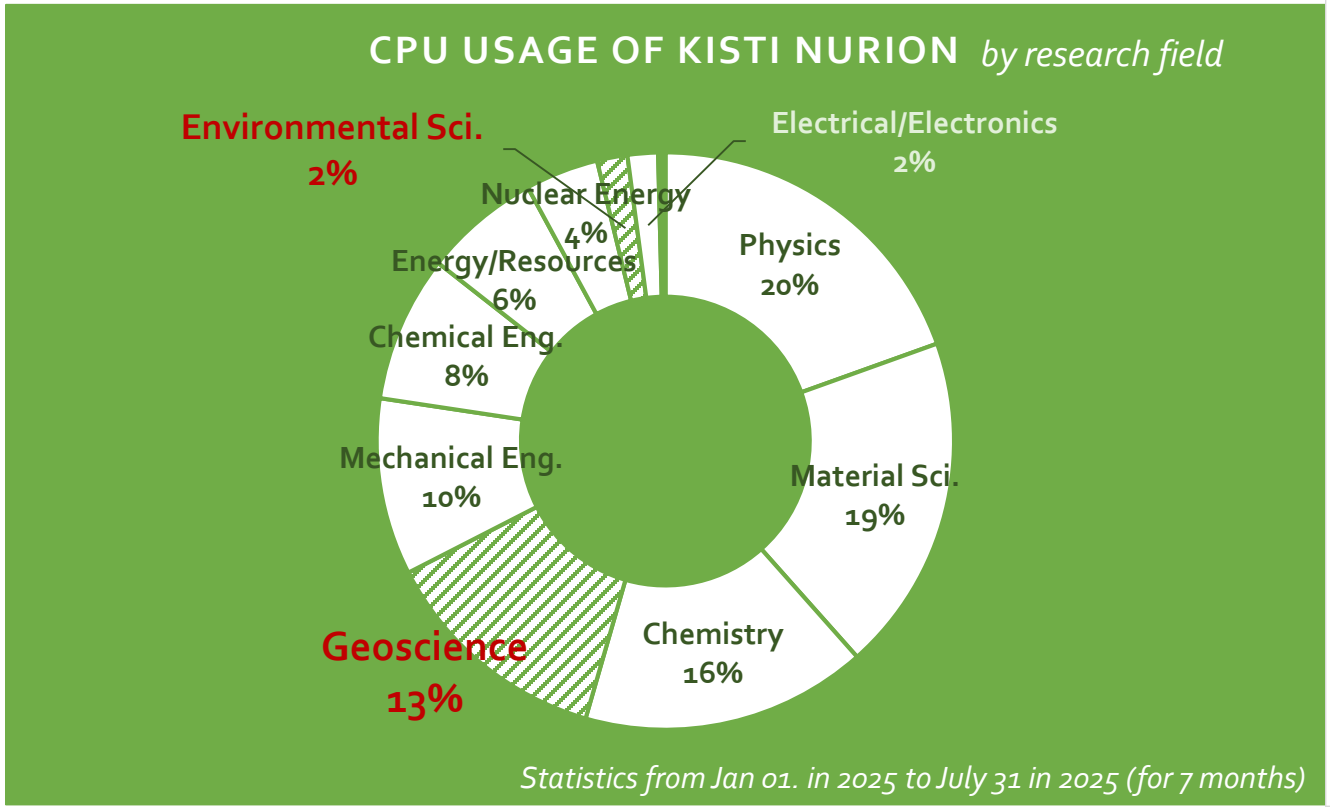


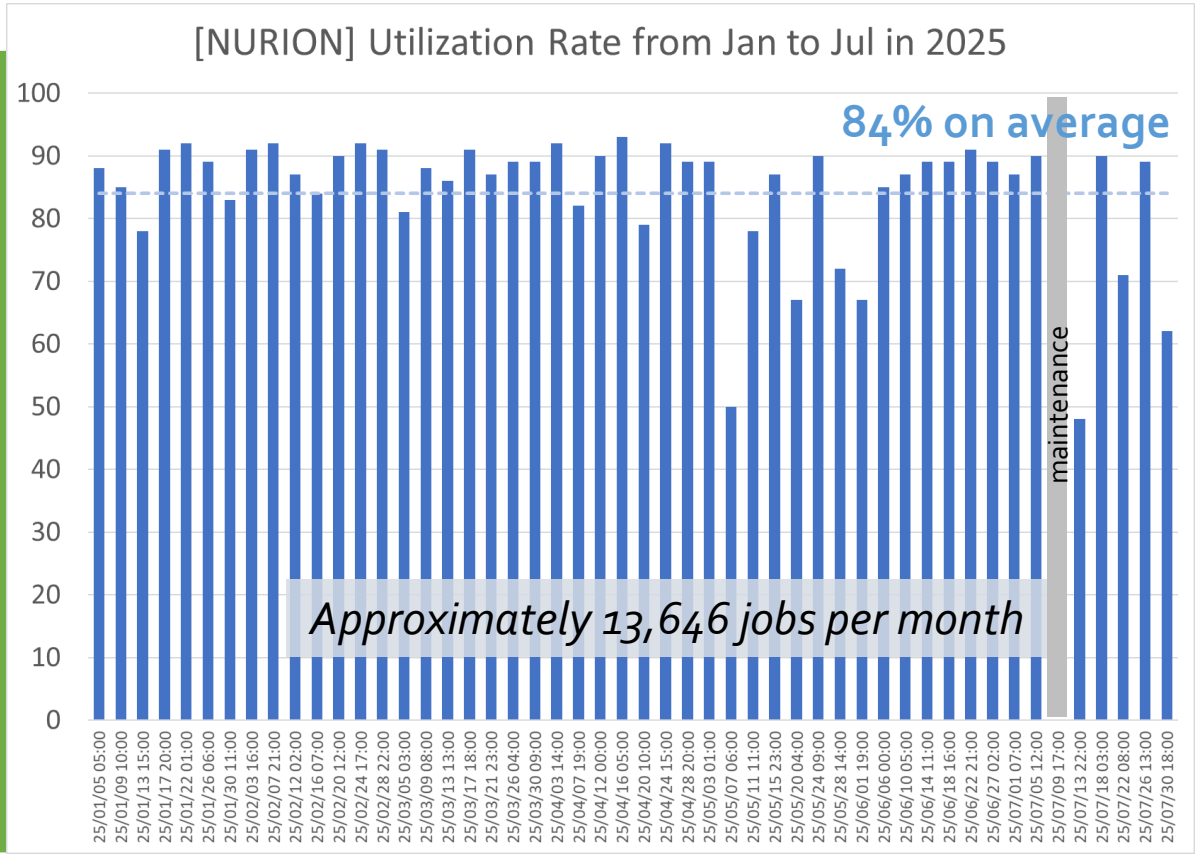
The **25.7 PF** system, which began official service in Dec. 2018

- **Xeon Phi** Cluster (Intel Xeon Phi 7250 1.4GHz) w/ **8,305 nodes** (25.3 PF)
  - 68 cores per node
- **Skylake** cluster (Intel Xeon 6148 2.4GHz) w/ **132 nodes** (0.4 PF)
  - 40 cores per node

Geoscience & Environmental Science w/ KISTI HPC

Utilization of KISTI-5 **NURION**

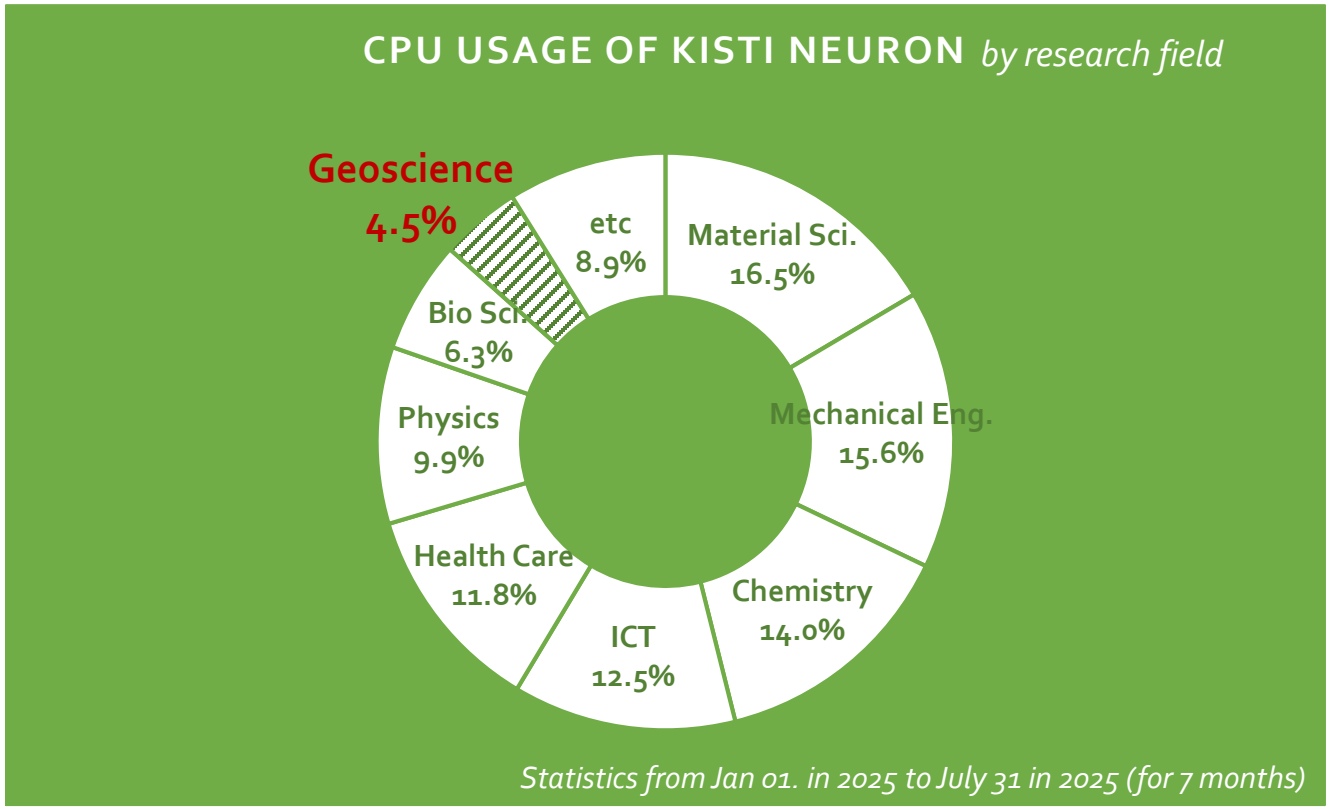




- The field of geoscience & environment science accounts for ~18%, following physics and material science. Users in those fields tend to run their in-house codes and/or the community models including *CESM*, *WRF*, *MPAS*, *ROMS*, ***using many cores of multiple nodes***.

Geoscience & Environmental Science w/ KISTI HPC

Utilization of KISTI-5 **NEURON** (GPU System)



Relatively, GPU utilization of geoscience is low.

Statistics of "Geoscience" Jobs on NEURON

from Jan 01 to July 31 in 2025

No. Jobs	2,462
Avg No. GPU usage per job	**1.8**
Avg. Time of GPU usage (hr) per job	8.7
Avg No. CPU usage per job	19.6
Avg. Time of CPU usage (hr) per job	91.3
Avg No. nodes per job	**1.1**

There are some users taking GPU node to use only CPU to avoid busy NURION.

The average GPU usage per geoscience job appears to be less than two, and multi-node deployments appear to be rare.

For reference, GPU nodes of NEURON are configured w/ 2, 4, or 8 GPUs per node.

KISTI-6 Supercomputer

High-level Overview

Computing Nodes

HPE Cray EX4000 System

GPU Rpeak 588.28 PF (2,084 nodes)
CPU Rpeak 15.7 PF (802 nodes)
SlingShot-400 High Performance Interconnect

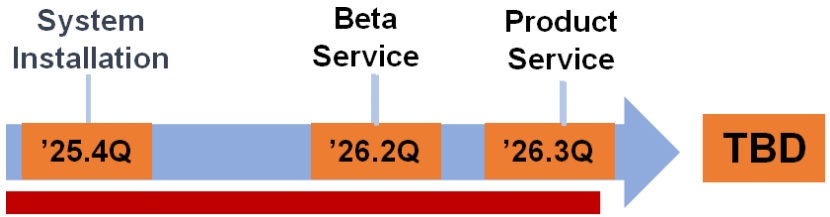
Storage System

HPE Cray Supercomputing Storage System

Over 200 PB Usable Capacity
Flash > 9.0 TB/s (r) > 6.5 TB/s(w)

Total Peak

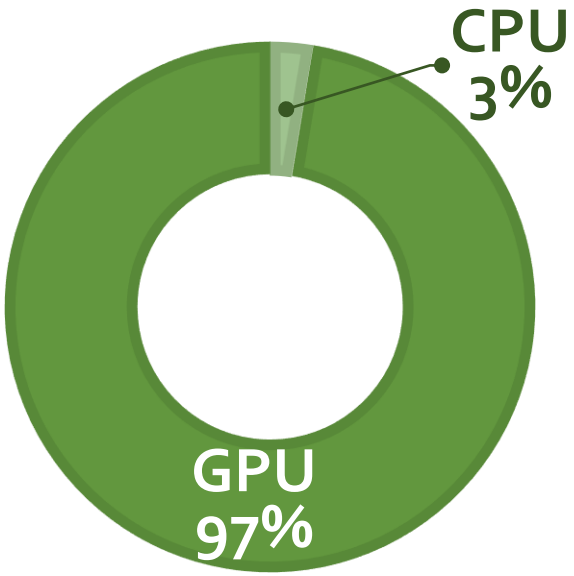
+ 600 PF



We expects to launch the official service of KISTI-6 next year.

Computing Has to Be Done on GPU in KISTI-6!

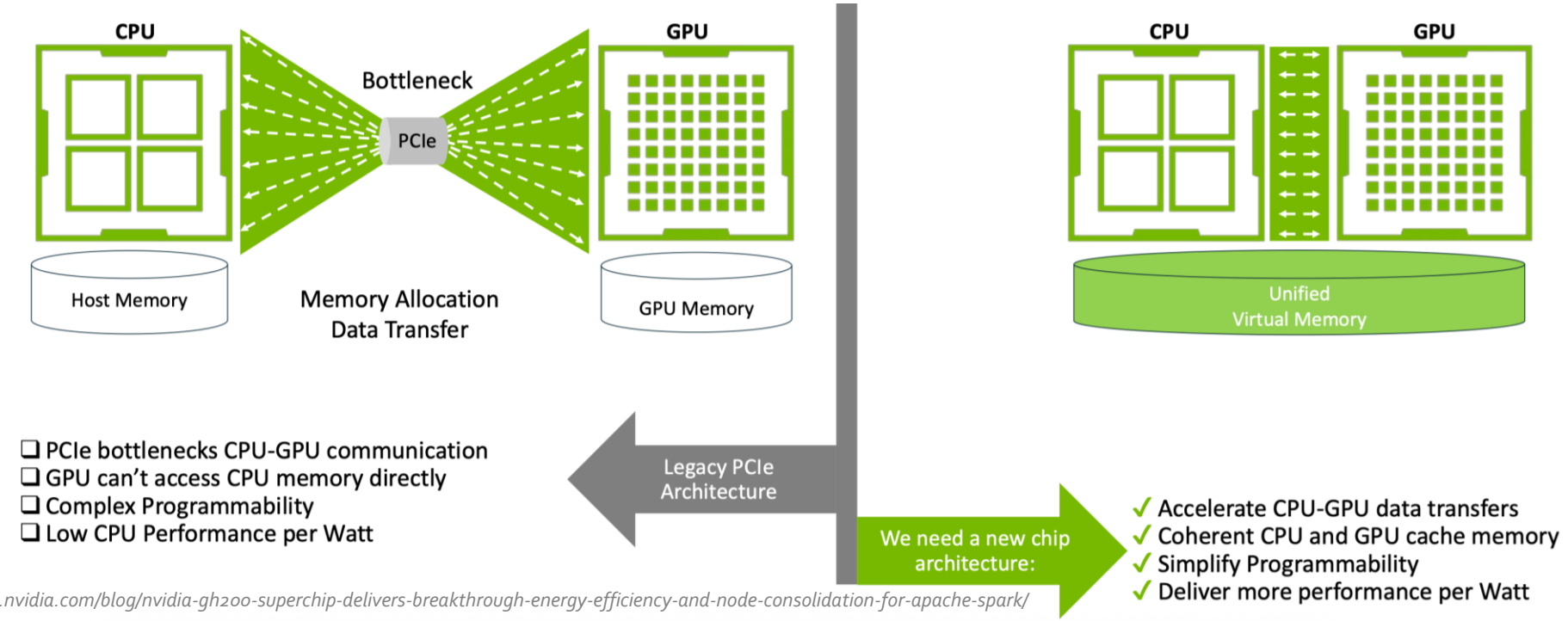
- System info of KISTI-6



CPU partition (15.7 PF)	**HPE Cray EX4000** **EX4252 Gen1 => 802 nodes** • 2xAMD Turin 9745 (128-core 2.4GHz 400W) • 768GB Memory per node • Interconnect: Slingshot 400 Gbps * 1 port • 2x CPU debugging node provided separately
GPU partition (588.28 PF)	**HPE Cray EX4000** **EX254n => 2,804 nodes** • 4x NVIDIA GH200 Grace-Hopper Superchip • Interconnect: Slingshot 400Gbps * 4 ports • 2x GPU debugging node provided separately

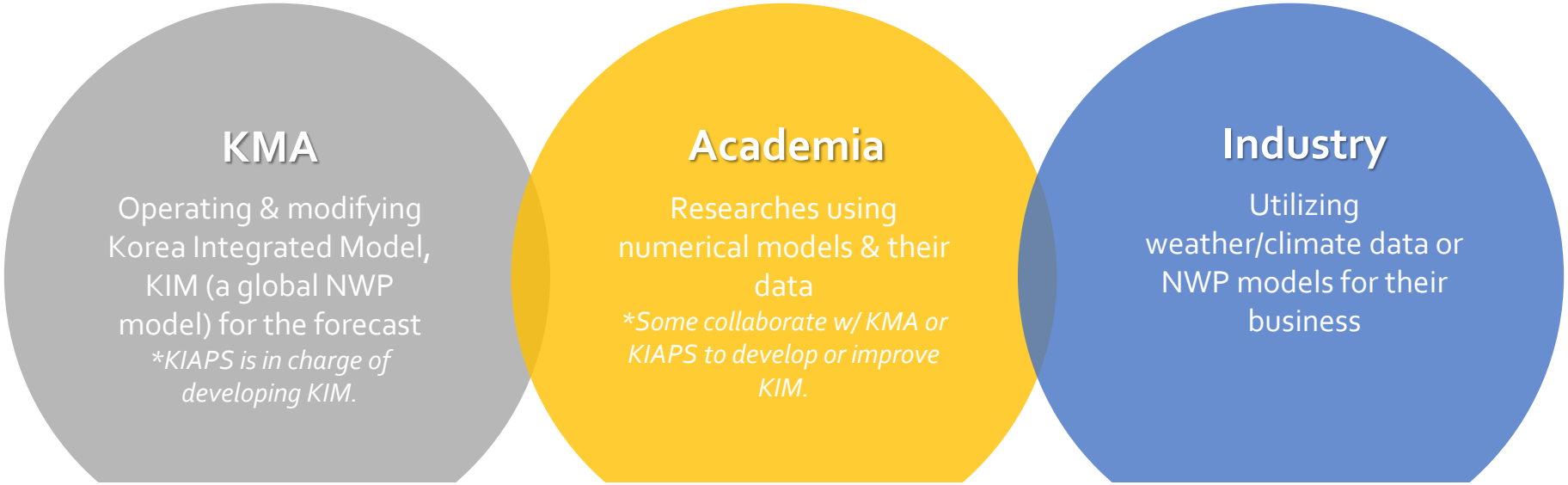
Grace Hopper Superchip

- In heterogeneous computing, memory bottleneck between GPU and CPU is a common issue.
- Grace Hopper (GH) is expected to significantly improve these issues with advanced memory bandwidth.
  - It delivers up to 900 GB/s total bandwidth, which is *7x higher bandwidth than x16 PCIe Gen5 lanes* commonly used in accelerated systems, according to NVIDIA.



https://developer.nvidia.com/blog/nvidia-gh200-superchip-delivers-breakthrough-energy-efficiency-and-node-consolidation-for-apache-spark/

Are We Ready for KISTI-6 in Meteorology?



- How much the Korean community of meteorology is ready to utilize this new machine?
  - Do we have any model(s) to run on GPU efficiently, or are we heading in that direction?
  - Unfortunately, there does not seem to be enough consensus on the need to proactively address evolving computing technologies.

Korean ESM Community

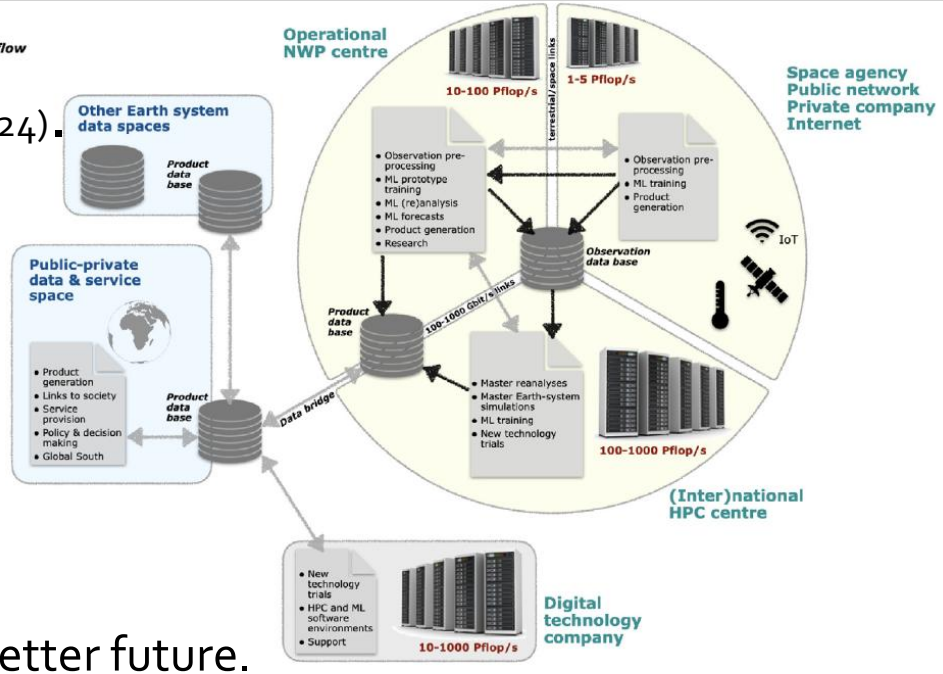
- Research & development of AI models
  - Many data driven models are being developed for specific tasks , including Alpha-Weather(short-term fcst, KMA), Nowcast(KMA-NVIDIA), etc.
    - Development of AI-based model for specific tasks rather than a foundation model.
- Porting KIM (Korean Integrated Model, Hong et al. 2018) to GPU?
  - There seems no explicit plan to have been announced in public (by June 2025).
    - KMA's next supercomputer (2027?) will be a CPU-based one w/ CPU:GPU ratio of 100:5.
- KISTI users in meteorology-related fields have not had enough good experience with GPU version of community models.

We may need more input and stimulation to pay more attention to developing AI-based predictive models or porting physics-based models to GPUs.

International Collaborative Researches

- There are excellent researches addressing challenges in NWP w/ new HWs (e.g. Govett et al. 2024, Bauer 2024).
  - The emergence of other HWs other than GPUs is also possible.
    - KISTI will introduce IONq's next generation quantum computer 'Tempo' in 2026.
  - Efforts and resources necessary to overcome such challenges are too much for a single institute to handle, and hence wider reaching collaboration is important.
    - Institutes like KISTI national supercomputing center also need to participate in these discussions and contribute to a better future.

Conceptual model of future work distribution framework (Bauer,2024)



- Meaningful collaborative research related to enabling heterogenous computing in the meteorological field
  - KISTI actively encourages such international collaborative researches.
  - We would like to find out whether KISTI-6 can contribute to the field of meteorology and what role it can play in reality.

Summary

- KISTI has been providing national supercomputing service for computational science research since the late 1980s.
  - Meteorology has been one of the areas in which we actively utilize our resources.
- With the evolving computer hardware and the new technologies that leverage it, the field of meteorology needs to further develop its supercomputing capabilities to benefit from these technological advancements.
  - We hope to help the meteorological community adapt to the rapid developments.
- We look forward to expanding out knowledge by collaborating with leading research teams, and to sharing meaningful feedback with the community using our upcoming supercomputer KISTI-6 in the future.

Thank you for your attention!

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Any comments or discussions are always welcome!