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A Study on the Implementation Method for the Achievement of the Korea High-Performance Computing Innovation Strategy

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ABSTRACT

At the 8th National High-Performance Computing (HPC) Committee convened in 2021, the "National High-Performance Computing Innovation Strategy (draft) for the 4th Industrial Revolution Era" was deliberated and the original draft was approved. In this proposal, the Ministry of Science and ICT in KOREA announced three major plans and nine detailed projects with the vision of "Realizing the 4th industrial revolution quantum jumping by leaping into a high-performance computing powerhouse." Thereby the most important policy about national mid-term and long-term HPC development was established and called the HPC innovation strategy (hereinafter "the innovation strategy"). The three plans of the innovation strategy proposed by the government are: Strategic HPC infrastructure expansion; Secure source technologies; and Activate innovative HPC utilization. Each of the detailed projects has to be executed nationally and strategically. In this paper, we propose a strategy for the implementation of two items ("Strategic HPC infrastructure expansion" and "activate innovative HPC utilization") among these detailed plans.

Keywords: supercomputer, supercomputing strategy, high-performance computing, innovation

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1. INTRODUCTION

The Korean government has tried to build a system that could increase national high-performance computing (HPC) capability through the enactment of the HPC Act (2011) (National Law Information Center, 2013) and the master plan (2013, 2018) (MSIT, 2018). Yet due to the mid-term to the long-term strategy and investment being insufficient, Korean HPC capability was falling in rank (Top 500). Therefore, it was necessary to respond proactively to the technological new trend era that changed petascale to exascale, to close the gap with advanced countries, and create new growth opportunities. Accordingly, the Korean government decided to prepare a consistent mid-term to long-term roadmap to produce meaningful HPC R&D results and came up with strategies and detailed plans in consultation with experts. As a result of experts' diagnosis of the current situation in Korea, the inadequacy could be summarized into the following three categories.

1) HPC resources: The demand for HPC is rapidly increasing, but the lack of resources is getting worse due to stagnant investment in new infrastructure and efficient utilization systems (Table 1). The Korean government's investment in HPC is about 1/10 of that of advanced countries, and the gap is very large.

2) Technology and industry infrastructure: Korean supercomputing technological levels achieved 78.6% (hardware), 70.5% (system software), and 51.5% (application software) of the USA (NRF, 2020). This indicates relatively low compared to other ICT fields (IITP, 2022).

3) HPC resource utilization: HPC resources have been allocated not to strategic fields but mostly to personal research ones. This is causing obstacles to the creation of excellent research results.

To overcome these issues, at the 8th National High-Performance Computing Committee convened in 2021, the "National High-Performance Computing Innovation Strategy (draft) for the 4th Industrial Revolution Era" was deliberated and the original draft was approved. In the draft, called the innovation strategy, the government presented three major plans and nine detailed projects with the vision of "Realizing the 4th industrial revolution quantum jumping by leaping into a high-performance computing powerhouse." (MSIT, 2021). The most fundamental policy, called the innovation strategy to promote national HPC capability, was established.

The three main tasks of the innovation strategy are: Strategic HPC infrastructure expansion; Secure source technologies; and Activate innovative HPC utilization (Table 2). Each of the detailed projects has to be executed nationally and strategically. In this paper, we propose a strategy for the implementation of two items ("Strategic HPC infrastructure expansion" and "activate innovative HPC utilization") among these detailed plans.

Table 1. Trend of Korea's supercomputing ranking in the TOP500

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOP500 ranking	37	90	138	201	373	None	None	13	14	21	38

Source: http://www.top500.org.

Table 2. Three main tasks of the innovation strategy

(Goal) With a focus on the national strategic fields, creating a high-performance computing ecosystem having a virtuous cycle of infrastructure, technology, and utilization		
1. Strategic HPC infrastructure expansion 1.1. Fostering the national HPC center equipped with top-class infrastructure 1.2. Fostering and assigning specialized HPC centers by field 1.3. Constructing HPC resources joint utilization system 2.0	2. Secure source technologies 2.1. Securing core source technologies mentioned in the national HPC strategic technology portfolio[1] 2.2. Development and building of exascale HPC systems based on own processors 2.3. Breaking barriers of technology commercialization and building the foundation of sustainable growing	3. Activate innovative HPC utilization 3.1. Strengthen support of HPC resources for the national strategic fields[2] 3.2. Building an HPC ecosystem utilized openly

[1]Four portfolios: processor, platform technology, data-intensive technology, and core base software.
[2]Ten fields: materials, life sciences, ICT, meteorological environment, auto-driving, space research, fusion accelerators, manufacturing base technology, disaster research, and national security.

2. STRATEGIC HPC INFRASTRUCTURE EXPANSION

2.1. Fostering the National HPC Center Equipped with Top-Class Infrastructure

KISTI's fifth national high-performance computer (NSC, 2022) is the only public-purpose HPC system in Korea. However, the fifth system, which started service in 2018, has already exceeded its service life and is being overloaded. To replace it and meet the rapidly changing demand for science and technology, especially for artificial intelligence, the government is performing a next-generation system procuration project and considering the following firstly.

- Capacity: Estimation of target capacity by the status and role of the national center in consideration of domestic scientific, technological, and industrial demands
- Design/Operation: Design of system architecture and establishment of resource allocation strategies to meet the rapidly growing demand from users in giant science and artificial intelligence
- Utilization support: Enhancement of service support systems to maximize user utilization along with the facility design for efficient system investment and operation

The paper below proposes a solution to the above considerations.

2.1.1. Investment-efficient Construction and Operation

To maximize investment efficiency, recycling of fifth buildings/facilities and designing flexible, low-power green systems should be done. Considering fluctuation in computational demand due to research environmental changes in computational science and artificial intelligence is very important. We should establish a system to enable flexible resource allocation and adjustment.

2.1.2. Strategic HPC Resources Allocation

A system should be developed to manage HPC resources strategically, focusing on national strategic areas

Table 3. Construction cost of major overseas high-performance computers (based on TOP500, November 2021)

Ranking	Machine name	Nationality (Institute)	Rpeak (PFlops)	Cost (unit: billion dollars)	Reference
1	Fugaku	Japan (RIKEN)	537.2	10	https://www.japantimes.co.jp/news/2021/01/07/business/tech/japans-fugaku-supercomputer/ https://qblocks.medium.com/how-much-did-it-cost-to-build-the-fastest-supercomputer-in-the-world-8e9e30a56f60
2	Summit	USA (ORNL)	200.8	0.32	https://www.cnet.com/science/with-ibm-summit-supercomputer-us-reclaims-top-spot-from-china-in-high-powered-computing/
3	Sierra	USA (LLNL)	125.7		
4	Sunway TaihuLight	China (NSCC-Wuxi)	125.4	0.27	http://www.netlib.org/utk/people/JackDongarra/PAPERS/sunway-report-2016.pdf
5	PERLMUTTER	USA (NERSC)	93.8	0.15	https://www.top500.org/news/crays-next-generation-supercomputer-headed-to-berkeley-lab-in-2020/
6	Selene	USA (NVIDIA)	79.2	-	-
7	Tianhe-2A	China (NSCC-GZ)	100.7	0.39	https://en.wikipedia.org/wiki/Tianhe-2#cite_note-2scmp.com/news/china/article/1264529/worlds-fastest-computer-tianhe-2-might-get-very-little-use
8	JUWELS Booster Module	Germany (FZJ)	71.0	-	-
9	HPC5	Italy (Eni S.p.A.)	51.7	-	-
10	Voyager-EUS2	USA (Azure East US 2)	39.5	-	-
	Average cost			0.43	

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and flagship projects.

2.1.3. Expand Custom Support

To improve the utilization of computing resources, we should connect with the KISTI user support system, for instant user education, training, and small and medium-sized enterprises consulting business, and should also provide a user-friendly development interface.

The target capacity estimates the maximum and minimum values in the following four ways based on the strategic goal (Top-Down) and potential demand (Bottom-Up).

- To understand the changing performance trend of high-performance computers, we predict its performance for 2023 through a time-series analysis of performance data (Rmax) for the past 20 years targeting the TOP500 (Top500, 2022) high-performance computers, ranked from first to tenth.
- Choosing countries that have a similar budget for HPC R&D and then using the total HPC capacity of the countries, we predict the total capacity that should be provided at the end of 2023.
- The capacity to be covered by the national supercomputing center there among the total demand for the FGI (Focus Group Interview) representative projects that were surveyed.
- We estimate by applying the capacity ratio to be covered by the national supercomputing center, the selected project ratio there, and the total capacity provided by the government. The data is based on the survey results for researchers.

The system construction budget can be predicted based on the target capacity. Among the systems ranked first to tenth in the TOP500 in November 2021, there were a total of six systems with confirmed construction costs, costing an average of $430 million (511.4 billion won) (Table 3).

2.2. Fostering and Assigning Specialized HPC Centers by Field

The government has designated KISTI as a national HPC center (Article 9 of the Act, 'National Center') by the enactment of the high-performance Computer Act in 2011, and has been trying to maintain a HPC infrastructure to be world-class.

Nevertheless, Korea's total HPC capacity level is getting lower compared to other advanced countries. The ranking in the TOP500 was eighth in 2015 but has been out of the top 10 after 2016 (Table 4). In particular, in the last five years, domestic demand for computation has increased by about 49 times, but the capacity of resources has only been expanded by 3.2 times and in 2020 was only 1/480 of the required capacity (KISTI, 2021).

For this reason, it is difficult to solve this problem with the national flagship HPC infrastructure introduction project alone. Therefore, other projects are also needed to expand various HPC infrastructures and prepare an efficient utilization system. In other word, we propose to establish strategies to develop HPC infrastructure for each national strategic field and promote the creation of an ecosystem for the joint use of domestic HPC infrastructure.

2.2.1. Infrastructure Expansion Plan

An institute that possesses expertise in the special field that requires high-performance computers provides specialized services based on HPC resources, manpower, and technology, and conducts R&D by using HPC in the relevant field has been defined as a specialized HPC center (MSIT, 2022).

For the utilization of HPC in which application fields are widely expanding, we should establish an innovative high-performance infrastructure led by a national center with a specialized center and a joint utilization system. The infrastructure should be specialized for the purpose and field of use. The items to be considered for the establishment of an innovation infrastructure led by a national center and specialized HPC centers are as follows.

- Demands for infrastructure capacity for specialized HPC centers
- A plan to enhance the national infrastructure system, such as fostering local HPC centers which have a high possibility to be specialized HPC centers in the future

Table 4. Trend of Korea's total high-performance computing capacity ranking in the TOP500

Year	2015	2016	2017	2018	2019	2020	2021
TOP500 ranking	8	14	11	9	12	14	9

Source: http://www.top500.org.

- Governance for infrastructure service and operation
- Designing the service model of the national HPC joint utilization system
- Defining national HPC joint utilization resources and planning resource allocation systems
- Establishment of a national and specialized HPC center user support organization
- Supporting resource integration, technical support, education, etc. through supercomputing incubation programs[3]

2.2.2. Designing a Specialized HPC Center

We defined above what a specialized HPC center is. If the supercomputing resources of these specialized centers can be utilized as a national public service through the joint utilization system, the supercomputing services that are concentrated in the national centers can be distributed and the total capacity of the national supercomputing resources can be expanded. These specialized centers should be designated and managed by the government and should have the following functions and roles.

- Must be a leading provider of HPC resources services and operation
- Expansion of research activities related to HPC by field
- Management and operation to support large-scale data related to HPC
- Contribution to the vitalization of HPC such as training and technology development

In addition, the designated specialized centers should be obliged to participate in the joint utilization system, such as securing joint utilization resources and establishing a service environment from the planning stage. This is based on the Act for the joint use of domestic HPC infrastructure (Article 17 of the Act, "joint use of HPC resources") and to strengthen the joint use of resources.

Even if they are not qualified as specialized centers at this stage, there will be institutions with the potential to play a role as specialized centers in the future. An incubator program is needed to help them. There has already been a case where the retired national third and fourth supercomputers were donated and moved to a local supercomputing center. Due to this, the local supercomputing center was able to grow into a specialized center.

According to the HPC act (Article 7 of the Act), the supercomputers of the national HPC center can be donated freely after retirement. The efficiency of national investment can be maximized by recycling high-performance computers, which are introduced and built with the national R&D project budget, as equipment jointly used by specialized centers. Although the donated systems are insufficient as a national flagship high-performance computer due to performance degradation, they are sufficient to be used for research in a specific area at a specialized center. It is important to maintain the cycle of continuously operating the current system while introducing and building a new national flagship high-performance computer and moving it to other centers after service commences for the new system (Table 5).

2.2.3. A System for Joint Use of High-performance Computers

The joint use of high-performance computers is a global trend and advanced countries such as the United States, Japan, and Europe are trying to expand the ecosystem of high-performance computers through joint use. For example, Europe is trying to create an HPC ecosystem through EuroHPC (EuroHPC, 2022) and PRACE (main eight centers) (PRACE, 2022) for joint utilization of HPC and community support. The U.S. has established partnerships with four supercomputing centers through XSEDE (XSEDE, 2022). It provides collaboration to support services, advanced visualization, data analysis services, and training services through partnerships with partners. Germany has also formed HPC Allianz (Gauss-Allianz) to cooperate with all HPC centers in Germany (Gauss-Allianz, 2022).

The purpose of establishing the domestic HPC joint utilization system is to expand, reinforce the utilization of HPC, and promote joint utilization by accumulating data created through HPC utilization research and research equipment. To implement these services effectively, it is necessary to define and design infrastructure that reflects system architecture and resource requirements by field and to verify and integrate available technologies.

2.3. Constructing HPC Resources Joint Utilization System 2.0

The joint utilization system of high-performance computers is based on the concept of "shared resources" that are HPC resources built and provided by public and private centers for joint use at the national level. We suggest

[3]This is a program that helps local HPC centers who are not fulfilled as specialized centers to be specialized HPC centers in the future.

Table 5. Current status of national supercomputers donation

No.	Machine type	Performance (TFlops)	Qty (nodes)	Installed	Retired	Operation (yr/mo)	Recipient	Donation (nodes)	Donation day
1st	Cray 2S	0.002	1	1988.11	1993.10	5/0	None	-	-
2nd	Cray C90	0.016	1	1993.11	2001.05	7/6	None	-	-
3rd	IBM 1st (IBM p690)	4.3	4	2002.01	2008.09	6/9	None	-	-
	IBM 2nd (IBM p690+)		17	2003.07	2008.09	5/3	Tongmyong Univ.	2	2008.10.29
							PaiChai Univ.	2	2008.10.29
							POSTECH	6	2008.10.31
							Sookmyung Women's Univ.	3	2008.11.07
							UNIST	4	2009.04.03
	BIOINFOMATICS ES45	0.128	1	2002.12	2008.08	5/8	None	-	-
	NEC SX-5/8B	0.08	1	2001.06	2008.08	7/3	None	-	-
	NEC SX-6	0.16	1	2003.02	2008.08	5/7	None	-	-
	TeraCluster	2.85	256	2004.01	2008.09	4/9	Pukyong National Univ.	128	2008.10.30
							GIST	128	2008.10.31
4th	IBM 1st (IBM POWER 5+)	5.9	10	2007.09	2015.12.31	8/4	None	-	-
	IBM 2nd (IBM POWER 6)	30.7	24	2009.06	2015.12.31	6/7	Pusan National Univ.	2	2016.12.15
							Pusan National Univ	3	2016.12.06
							KIER	4	2016.12.16
							GIST	2	2016.08.16
							PaiChai Univ	5	2016.07.19
							POMIA	2	2016.08.04
							Jeonbuk National Univ.	4	2017.11.08
	ORACLE 1st (AMD Opteron)	28.2	4 racks	2008.01	2016.04.30	8/5	Pusan National Univ.	4 racks	2016.12.15
	ORACLE 2nd (INTEL Xeon)	300.0	34 racks	2009.09	2018.12.31	9/4	UNIST	20 racks	2019.06.20
							Hanbat National Univ.	2 racks	2019.06.19
							Republic of Korea Army	6 racks	2019.06.19
	IBM login server	-	2	2010.05	2015.12.31	5/8	Chungwoon Univ.	1	2017.08.02
							Chonnam National Univ.	1	2017.08.22

strategies to build this system and use it efficiently.

- Preparing shared-resources allocation and system operating policies for the sharing resources through a special committee—this could be called (Initial name) "National High-Performance Computer Joint Utilization Council"—and starting initial HPC services based on the policies.
- After establishing the initial system, expanding the system to local HPC centers by various supporting measures such as budgets. If the government budget is invested to build the system, some of its resources are obligated to participate in the joint utilization system.
- Linking public-private HPC infrastructure and expanding corporate participation
- To enhance user accessibility for integrated services, providing a cloud-based platform that closely links common resources with different resource characteristics and operating environments
- Building data-sharing storage and establishing a data standard system to save data created through research on the use of HPC, research equipment, etc.
- Expanding data integration and sharing in linking the national research data platforms[4] with large-scale research centers equipped with accelerators or telescopes

3. ACTIVATE INNOVATIVE HPC UTILIZATION

3.1. Strengthen Support of HPC Resources for the National Strategic Fields

The U.S. and Europe directly support their research activities through HPC utilization supporting programs. As a result, they produce visible results in various fields and can discover top-level talented researchers. In Korea, HPC resources are provided to industry, academia, and institute researchers through the R&D innovation support program of the National High-Performance Computing Center (KISTI) as well. However, the resources are provided to be focused on individual needs without strategic targets and they are mainly used as an auxiliary method for research. Therefore, the results are insufficient for creating innovation. On the other hand, in overseas cases, it can be seen that intensive investment contributes to the revitalization of the ecosystem and expansion of the base through the development and education of technologies utilizing HPC.

Accordingly, it is necessary for projects to intensively use national HPC. We propose the following projects should be done.

- Development of core source technologies to discover and solve challenging problems focusing on national strategic areas suggested by the roadmap for developing HPC
- Discovering and supporting research projects with a large ripple effect focused on large-scale computational problems
- Collaboration with scientists and software developers to develop application technologies specialized for each problem and to establish a stable support system
- Developing specialized HPC centers that can lead and expand computational and data-intensive research by field. The role of the centers should include innovative problem solving as well as developing HPC experts, and developing and distributing technologies that can be used in the field.

3.2. Building an HPC Ecosystem Utilized Openly

A professional and open ecosystem is needed to promote innovative utilization. In particular, the development of specialized application software focusing on the national strategic field is a key point. However, this is difficult to expect from the private sector because they cannot guarantee success in their investment. In Korea, the industrial base related to HPC is insufficient, so this development needs to be promoted as a national project. It is necessary to support customized software development and optimization focusing on the promising research fields that need improvement, to systematize and integrate individual software assets owned by universities and research institutes, and to provide shared services through an interworking platform of HPC systems.

It is also necessary to simultaneously pursue catch-up and leading technology development strategies such as petascale → exascale → zetascale system development. We establish a technology roadmap about future development directions for application software and prepare strategies for linking with technology development projects that are already in progress.

A detailed plan is also needed to check the overall level of domestic experts and technology, the demands of

[4]National Bio Data station (https://b.station.re.kr/), Material Research Data Platform (https://kmds.re.kr/), etc.

Table 6. Summary of action planning for the national high-performance computing innovation strategy

High priority tasks to implement the innovation strategy			Progress
Strategic HPC infrastructure expansion	Fostering the national HPC center equipped with top-class infrastructure	Construction and operation of sixth national flagship high-performance computer	In progress as a national project of the government
		Expand small-scale high-performance computers	In progress as a major project of the national center
		Establishment of an integrated operating system of high-performance computing resources	In progress as a major project of the national center
	Fostering and assigning specialized HPC centers by field	Designation of a specialized center	Designation of specialized center scheduled to be announced (as of April 2022)
		High-performance computing center incubator program operation	National high-performance computing infrastructure advancement project planning in progress
	Constructing HPC resources joint utilization system 2.0	Establishment of a joint utilization system for high-performance computers	
		Establishment data hub for high-performance computing	
Secure source technologies	Securing core source technologies mentioned in the national HPC strategic technology portfolio	Development of four strategic technologies; processor, platform technology, data-intensive technology, and utilization	PFlops-scale high-performance computer technology development project in progress (~May 2022) Supercomputer development project in progress (~2023)
	Development and building of exascale HPC systems based on own processors	Development and construction of exascale high-performance computer (complete system) based on its parts, such as processors	Development project of high-performance computer source technology and a full system in preparation
	Breaking barriers of technology commercialization and building the foundation of sustainable growing	Demonstration of introduction and diffusion of domestic products	Planned to be used for the construction of a material research data platform
		Support for the development of new technologies and products	In preparation
		Improving the reliability of domestic parts	In preparation
Activate innovative HPC utilization	Strengthen support of HPC resources for the national strategic fields	Strategically supporting national high-performance computing resources	Plan to be reflected in the operation of flagship high-performance computer and joint utilization systems
		Customized support	Promoting a high-performance computing utilization project and planning for July 2022 (demand survey in progress)
		Establishment of a customized service environment	National high-performance computing infrastructure advancement project in progress
	Building an HPC ecosystem utilized openly	Development of application software and support of sharing services	New project planning in progress for 2023
		Developing high-performance computing R&D service industry	In preparation
		Educating specialists for high-performance computing	In preparation

academic and industrial researchers, and to secure highly useful software within a limited budget. HPC requires interdisciplinary convergence between computer engineering, mathematics, and specialized research fields, and customized software development is possible only when researchers and developers collaborate. Focusing on the national strategic field, it is necessary to materialize the software sharing plan between each specialized center so that researchers can contribute to improving their research performance by using the software. In terms of sharing core research resources, it is desirable to be systematized management of HPC resources by nation so that researchers in various fields can utilize them for science and technology R&D.

4. CONCLUSION

The high-performance computer accelerates innovation in artificial intelligence and data analysis. With the expansion of the intelligent information society, high-performance computers have emerged as core infrastructure. In particular, artificial intelligence and data analysis technologies are integrated and are evolving into tools that provide insight. Convergence between technologies is expanding from the existing computational science (simulation) to artificial intelligence (machine learning) and data analysis (statistical analysis).

The high-performance computer influences national competitiveness as an innovation platform throughout the economy and society. Through R&D based on large-scale data analysis, it is possible to create innovative results by enabling large-scale and cutting-edge research that was previously impossible. Through simulation-based product development, manufacturing productivity can be improved, and new industries such as finance, education, and smart cities can be created by fusion with artificial intelligence and data. It can be also used for solving problems related to national crises, such as protecting people's lives and property and establishing strategies, through advanced prediction and preemptive responses to global environmental problems, disasters, and new infectious diseases.

The high-performance computer is a state-of-the-art technology, creating a new industry through technology diffusion. HPC is state-of-art and contemporary innovative computing technology such as electronic engineering theory, semiconductor manufacturing technology, and software techniques that are mobilized. Related technologies are spread to servers, personal computers, and smartphones, and can be used as the base technologies for the Fourth Industrial Revolution.

The way that enables the Fourth Industrial Revolution based on HPC is the National High-Performance Computing Innovation Strategy, and in this paper a specific method for successful implementation is presented as shown in Table 6. The key contents of the table are summarized as follows.

Fostering the national HPC center equipped with top-class infrastructure. We are starting the procuration project of the sixth national flagship high-performance computer with a budget of 309.9 billion won (fully supported by the Korean government) and the establishment of a 600PF scale computing system infrastructure to respond to various demands for HPC, such as computational science, artificial intelligence, and data analysis.

Fostering and assigning specialized HPC centers by field. We are preparing the "Guideline for Specialized HPC Center Management (Draft)," including the assignment procedure, period, and support for specialized HPC centers. In parallel, the designation will be carried out in stages from 2022 to 2030.

Constructing HPC resources joint utilization system 2.0. We have started planning the national HPC infrastructure advancement project to support the establishment of specialized HPC center infrastructure.

Activating innovative HPC utilization. We have established dedicated projects using HPC highly in national strategic areas. The research topic demand will be surveyed and research topic selection, detailed planning, and project group selection will also be done.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

EuroHPC. (2022). *European High Performance Computing Joint Undertaking*. https://eurohpc-ju.europa.eu/.

Gauss-Allianz. (2022). *HPC in Deutschland Gauβ-Allianz*. https://gauss-allianz.de/en/.

IITP. (2022). *2020 ICT technology level evaluation and competitiveness report*. https://www.iitp.kr/kr/1/knowledge/openReference/view.it.

KISTI. (2021). *Planning report for national flagship high-performance computing infrastructure advancement project preliminary feasibility study*. KISTI.

MSIT. (2018). *Announcement of the 2nd national high-performance computing developing base plan ('18~'22)*. https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=112&pageIndex=1&bbsSeqNo=94&nttSeqNo=1375873&searchOpt=ALL&searchTxt=%EC%B4%88%EA%B3%A0%EC%84%B1%EB%8A%A5.

MSIT. (2021). *Announcement of national high-performance computing innovation strategy*. https://www.msit.go.kr/bbs/view.do?sCode=user&nttSeqNo=3180299&pageIndex&searchTxt&searchOpt=ALL&bbsSeqNo=94&mId=113&mPid=112.

MSIT. (2022). *Announcement of specialized high-performance computing centers assignment*. https://www.msit.go.kr/bbs/view.do?sCode=user&mId=129&mPid=128&bbsSeqNo=100&nttSeqNo=3177763.

National Law Information Center. (2013). *Enforcement decree of the act on utilization and fostering of national supercomputers*. https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=48915&type=part&key=18.

NRF. (2020). *Planning study for supercomputing technology development roadmap and mid-to-long-term business promotion strategy establishment*. NRF.

NSC. (2022). *Nurion*. https://www.ksc.re.kr/ggspcpt/nurion.

PRACE. (2022). *Partnership for Advanced Computing in Europe*. https://prace-ri.eu/.

Top500. (2022). *Top500*. https://www.top500.org/.

XSEDE. (2022). *Organization*. https://www.xsede.org/.