

RIKEN R-CCS
Annual Report FY2020
R-CCS Research Activities

Appendix
Agreement and Memorandum of Understanding for Collaboration

This appendix material of RIKEN R-CCS Annual Report FY2020 summarizes agreement and memorandum of understanding (MoU) for collaboration related with R-CCS. This is not a full list and some of the agreements and MoUs in effect in FY2020 are not listed, but may be added in future updated versions.

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Part IV

Agreement and Memorandum of Understanding for Collaboration

Appendix A

International Collaboration

A.1 National Center for Supercomputing Applications (NCSA) (#36802)

A.1.1 Scope

This is a MoU between RIKEN Center for Computational Science (R-CCS) and National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign. The first MoU was signed on October 14th, 2015. After twice extensions, this MoU was signed on November 19th, 2019, and shall be effective for a period of five (5) years from this date.

A.1.2 Purpose

This aims furtherance of the mutual interests in education and research in the fields of computer science and computational science, and as a contribution to increased co-operation between R-CCS and NCSA, and agree to implement the following activities;

- Exchange of researchers and staff
- Exchange of scientific and technological information, including delivering lectures and holding joint seminars and symposia,
- Exchange of students
- Exchange of scientific and technological information
- Reciprocal use of facilities, including high-performance computer
- Exchange of information pertinent to industrial applications and collaboration
- Joint research projects by collaborations

A.1.3 Status and Outcome

Before 2019FY, some joint workshops were held and regular meetings were held at every SC in the US. Unfortunately, Due to COVID-19, almost activities were stopped.

Some research collaborations such as “Simplified Sustained System performance benchmark” are carried out through JLESC collaborations.

A.1.4 Publications

[1] Miwako Tsuji, William T. C. Kramer, and Mitsuhsa Sato. “A Performance Projection of Mini-Applications onto Benchmarks Toward the Performance Projection of Real-Applications.” In: 2017 IEEE International Conference on Cluster Computing (CLUSTER), Workshop on Representative Applications (WRAP). IEEE, 2017, On Line. [2] Miwako Tsuji et al. “A new sustained system performance metric for scientific performance evaluation.” In: The Journal of Supercomputing (2021), pp. 1–29.

A.2 University of Reading (#36820)

A.2.1 Scope

This is an MOU between RIKEN R-CCS and University of Reading, UK.

A.2.2 Purpose

The potential collaboration activities promoted under this MOU shall be scientific and technical areas of numerical modelling, data assimilation and the related fields.

The collaboration activities between the parties will be implemented by one or more of the following means.

- Exchange of researchers and staff
- Exchange of scientific and technical information, including delivering
- Lectures and holding joint seminars and symposia
- Exchange of students (in particular doctoral students)
- Exchange of scientific and technological research materials
- Joint research projects

A.2.3 Status and Outcome

During RIKEN International Symposium on Data Assimilation on February 27–March 2, 2017, Prof. Nancy Nichols, Prof. Roland Potthast, and Joanne Waller joined the scientific organizing committee. In the symposium, they contributed as session chairs, and contributed to oral and poster presentations. From University of Reading, Alison Fowler and Flavia Rodrigues Pinheiro also joined the symposium and presented their research results.

In RIKEN International School on Data Assimilation during January 22–26, 2018, Prof. Sebastian Reich (The University of Potsdam / University of Reading) joined the scientific organizing committee and had a lecture.

Under RIKEN President’s Initiative for “DA innovation hub,” three researchers, Alison Fowler, Jemima Tabcart, and Joanne Waller, visited R-CCS in FY2018. We discussed about data assimilation methods that consider observation error correlation, and conducted research and development using real observations.

A.3 The Scuola Internazionale Superiore Di Studi Avanzati (#36825)

A.3.1 Scope

This is an MOU between R-CCS and Scuola Internazionale Superiore di Studi Avanzati, Italy

A.3.2 Purpose

Both parties plan to develop quantum Monte Carlo methods for strongly correlated lattice models and first-principles quantum Monte Carlo methods for real materials. In particular, the focus is on optimizing the simulation codes, which had originally been developed for the K computer based on the previous MOU between the same parties, for Fugaku computer and thereby enabling to perform large-scale and highly accurate calculations.

A.3.3 Status and Outcome

Although the MOU took effect on March 12, 2021, we have been discussing a new algorithm which combines a variational technique with the existing auxiliary-field quantum Monte Carlo method. Preliminary test calculations were performed for the doped Hubbard model on a square lattice, resulting in a consistent phase diagram with the state-of-the-art density matrix renormalization group calculations.

A.4 Centre National de la Recherche Scientifique (CNRS) / Maison de la Simulation(MDLS) (#37008)

A.4.1 Scope

This is a MoU between RIKEN Center for Computational Science (R-CCS) and Maison de la Simulation(MDLS) operated by Centre National de la Recherche Scientifique (CNRS). The first MoU was signed on November 21, 2002, and renewed by the director of R-CCS and President and COE of CNRS on April 14th, 2019, and shall be effective until April 13th 2024.

A.4.2 Purpose

This aims furtherance of the mutual interests in education and research in the fields of advanced computer science and computational science, and as a contribution to increased co-operation between R-CCS and MDLS, and agree to implement the following activities;

- Exchange of scientific and technological information
- Joint research projects by collaborations
- Exchange of researchers and staff for human resources
- Other activity agreed with both organizations

A.4.3 Status and Outcome

Upto 2018, the joint project in SPPEXA, “MYX-MUST Correctness Checking for YML and XMP Programs” was carried out with R-CCS, University of Tsukuba, MDLS and RWTH Aachen, and several publications were produced as outcomes of this project in 2019 and 2020. And, we invited Prof. Thomas Dufaud as a visiting researcher, and carried out collaboration on the parallel numerical algorithms.

We had a discussion on the collaboration on Fugaku for “Sparse matrix computation and graph algorithm” with the Programming environment research team of R-CCS and Prof. Petiton’s group of MDLS, and The MoU for collaboration on Fugaku will be submitted in 2021.

A.4.4 Publications

- [1] Thomas Dufaud, Miwako Tsuji and Mitsuhsa Sato, ”Design of Data Management for Multi-SPMD Workflow Programming Model”, Fourth International IEEE Workshop on Extreme Scale Programming Models and Middleware, On Line, 2018.11.10-11. Hutchison Convention Center Dallas TX USA, IEEE, 2018,
- [2] Joachim Protze, Miwako Tsuji, Christian Terboven, Thomas Dufaud, Hitoshi Murai, Serge Petiton, Nahid Emad, Matthias S. Müller and Taisuke Boku, ”MYX: Runtime Correctness Analysis for Multi-Level Parallel Programming Paradigms”, Software for Exascale Computing SPPEXA 2016-2019, (T.J. Barth et.al., editors), LNCS 136, 545–569, Springer, 2020,
- [3] Jerome Gurhem, Miwako Tsuji, Serge Petiton and Mitsuhsa Sato, ”Distributed and Parallel Programming Paradigms on the K computer and a Cluster”, HPCAsia2019,–, 2019.01.14-11. Guangzhou China, ACM, 2019,
- [4] Miwako Tsuji, Hitoshi Murai, Taisuke Boku, Mitsuhsa Sato, Serge G Petiton, Nahid Emad, Thomas Dufaud, Joachim Protze, Christian Terboven and Matthias S Müller, ”Multi-SPMD Programming Model with YML and XcalableMP”, XcalableMP PGAS Programming Language, (Mitsuhsa Sato, editors), LNCS 136, 219–243, Springer, 2021,

A.5 JLESC (Joint Laboratory for Extreme-Scale Computing) (#37050)

A.5.1 Scope

The Joint Laboratory for Extreme Scale Computing (JLESC) is an international, virtual organization whose goal is to enhance the ability of member organizations and investigators to make the bridge between Petascale and Extreme computing. The founding partners of the JLESC are INRIA and UIUC. Further members are ANL, BSC, JSC and R-CCS. UTK is an associate member.

R-CCS was approved to join to JLESC on 15th March, 2015.

A.5.2 Purpose

The purposes of JLESC are as follows:

- Joint research projects by collaborations
- Exchange of scientific and technological information through workshops
- Exchange of researchers and staff

The research areas include:

- Scientific applications (big compute and big data) that are the drivers of the research in the other topics of the joint-laboratory.
- Modeling and optimizing numerical libraries, which are at the heart of many scientific applications.
- Novel programming models and runtime systems, which allow scientific applications to be updated or reimaged to take full advantage of extreme-scale supercomputers.
- Resilience and Fault-tolerance research, which reduces the negative impact when processors, disk drives, or memory fail in supercomputers that have tens or hundreds of thousands of those components.
- I/O and visualization, which are important part of parallel execution for numerical simulations and data analytics
- HPC Clouds, that may execute a portion of the HPC workload in the near future.

A.5.3 Status and Outcome

In 2020FY, due to COVID-19 pandemic, the 11th JLESC Workshop, the first virtual one in the history of the JLESC, was held online from September 8 to 10, 2020, and the 12th JLESC Workshop will be held online from February 24 to 26, 2021. As well as project reports and short lighting talks by individual researchers, the following break-out-sessions (BOSS) were organized by R-CCS researchers:

- Heterogeneous and reconfigurable architectures for the future of computing (JLESC 11, JLESC 12)
- Multiprecision Numerics for HPC (JLESC 11)
- Challenges and opportunities with running AI workloads on HPC systems (JLESC 11)
- Arm for HPC (JLESC 12)

The following joint projects (in running state) by R-CCS members and collaborators are carried out:

- Simplified Sustained System performance benchmark (Miwako Tsuji (R-CCS), Bill Kramer (UIUC, NCSA), Mitsuhsa Sato (R-CCS))
- Deep Neural Networks for CFD Simulations (Andreas Lintermann (JSC), Makoto Tsubokura (R-CCS), Keiji Onishi (R-CCS), Mario Rüttgers (JSC))
- Machine Learning-driven Predictive Analysis of Protein Diffraction Data (Michela Taufer (UTK), Florence Tama (R-CCS), Piotr Luszczek (UTK), Osamu Miyashita(R-CCS), Paula Olaya Garcia (UTK), Silvina Caino-Lores (UTK), Michael Wyatt(UTK))
- Evaluating high-level programming models for FPGA platforms (Kazutomo Yoshii (ANL), Carlos Alvarez (BSC), Daniel Jimenez-Gonzalez (BSC), Xavier Martorell (BSC), Osman Unsal (BSC), Eric Rutten (INRIA), Kentaro Sano (R-CCS), Zheming Jin (ANL), Hal Finkel (ANL), Franck Cappello (ANL))
- HPC libraries for solving dense symmetric eigenvalue problems (Toshiyuki Imamura (R-CCS), Inge Gutheil (JSC))
- Developer tools for porting and tuning parallel applications on extreme-scale parallel systems (Brian J.N. Wylie (JSC), Miwako Tsuji (R-CCS), Hitoshi Murai (R-CCS), Christian Feld(JSC), Judit Gimenez (BSC), German Llort (BSC))

- International Survey (on MPI) (Atsushi Hori (R-CCS), George Bosilca (UTK), Emmanuel Jeannot (INRIA), Takahiro Ogura (R-CCS))
- Deep Memory Hierarchies (Leonardo Bautista Gomez (BSC), erofi Balasz (R-CCS), Swann Perarnau (ANL), Yukata Ishikawa (R-CCS))
- Compression for instruments (Franck Cappello (ANL), Sheng Di (ANL), Ali Murat Gok (ANL), Kento Sato (R-CCS), Kentaro Sano (R-CCS), Tomohiro Ueno (R-CCS), Jon Calhoun (EXT), Robert Underwood(EXT))

A.6 Pacific Earthquake Engineering Research Center(PEER) (#42977)

A.6.1 Scope

- RIKEN, RIKEN Center for Computational Science (R-CCS)
- Pacific Earthquake Engineering Research Center (PEER)

PEER is a multi-institutional research and education consortium headquartered at the University of California, Berkeley, with the following core institutions as members.

PEER's mission is to develop, validate, and disseminate proven seismic design techniques for buildings and infrastructure that are compatible with society's and people's need for safety and a diverse economy.

– member universities:

University of California, Berkeley, California Institute of Technology, Oregon State University, Stanford University, University of California, Davis, University of California, Los Angeles, University of California, San Diego, University of Nevada, Reno, University of Southern California. University of Washington

- Kobe University, School of Engineering and Research Center for Urban Safety and Security
- National Research Institute for Earth Science and Disaster Resilience (NIED), Center for Advanced Research Facility (E-Defense)
- Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Center for Mathematical Science and Advanced Technology (MAT)

A.6.2 Purpose

The purpose of this project is to contribute to the development of science and technology in Japan and the U.S. by enhancing joint research in the field of computational science and promoting the development of human resources such as future researchers in order to further deepen research cooperation in disaster research.

A.6.3 Status and Outcome

By using the following advanced programs such as DPP (Data Processing System) developed by RIKEN Center for Computational Science, IES (Integrated Engineering System) developed by JAMSTEC researchers, and DACSAR (Ground Simulation) developed by Kobe University, we will conduct simulations of natural hazards such as structural failure and ground liquefaction caused by earthquakes. In addition, we will conduct a coupled analysis of urban structures through preliminary and detailed studies of actual structure scale experiments using a hybrid model of computation and experimentation at the E-Defense.

We will step forward to have a workshop in Kobe using a hybrid system after the difficult time to initiate the collaborative research in person because of COVID, which overwhelmed the world just after the MOU started.

A.7 National Chiao Tung University (#42978)

A.7.1 Scope

This is an MOU between Field Theory Research Team, R-CCS and Lattice Gauge Theory Research Team, College of Science, National Chiao Tung University, Taiwan. From February 1st 2021, the name of the university is changed as National Yang Ming Chiao Tung University due to the merger with National Yang Min University.

A.7.2 Purpose

This aims furtherance of the mutual interests in the field of new methods of numerical computations in quantum field theories and the related research, to implement various levels of exchange programs including human exchange, delivering lectures each other, exchange of scientific and technological information, and to seeking possibility of joint research projects.

A.7.3 Status and Outcome

Although the human exchange programs originally planned were canceled due to the world-wide pandemic situation, the online seminars and discussion meetings were held. Frequent participation, with students at some occasions, to the team seminar at R-CCS enhanced physics ideas for future large scale field theory computations. The discussion meetings lead to a research result in conference proceedings [1].

A.7.4 Publications

[1] W. Detmold, A. V. Grebe, I. Kanamori, C.-J. D. Lin, S. Mondal, R. J. Perry, Y. Zhao, “A Preliminary Determination of the Second Mellin Moment of the Pion’s Distribution Amplitude Using the Heavy Quark Operator Product Expansion”, (APLAT 2020) arXiv:2009.09473.

A.8 Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB) (#42980)

A.8.1 Scope

This is a MoU between RIKEN Center for Computational Science (R-CCS) and Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB). The MoU was signed by the director of R-CCS and Vice President of ZIB on Feb. 25th 2020.

A.8.2 Purpose

This aims furtherance of the mutual interests in education and research in the fields of computer science, parallel and high performance computing, graph optimization algorithm, integer optimization, numerical algorithm, and as a contribution to increased co-operation between R-CCS and ZIB, and agree to implement the following activities;

- Exchange of researchers and staff
- Exchange of scientific and technological information, including delivering lectures and holding joint seminars and symposia,
- Exchange of students
- Exchange of scientific and technological information
- Joint research projects by collaborations
- Any other programs and activities incidental to the forgoing

A.8.3 Status and Outcome

During 2020FY, the meeting and the join workshop were planned, but unfortunately these were canceled due to COVID-19.

The collaboration on graph algorithm was started between Dr. Shinano's group of ZIB and the programing environment research team of R-CCS. It focused on the SSSP (Single-Source-Shortest-Path) problem as well as BFS (Breadth-First Search) problem in Graph 500.

A.9 DAEGU University (#42982)

A.9.1 Scope

RIKEN Centre for Computational Science / Computational Molecular Science Research Team, RIKEN (Japan) and Quantum Chemistry Laboratory Team, DAEGU University (Korea)

Quantum Chemistry Laboratory Team is affiliated in the Department of Chemistry Education of DAEGU University and Prof. Jong-Won Song manages it as a Principal Investigator

A.9.2 Purpose

To attain the mutual interests in education and research by international co-operation we hope to perform research collaboration projects with mutual agreement.

(i) Exchange of researchers and staff (ii) Exchange of scientific and technological information including delivering lectures and holding joint seminars and symposia (iii) Exchange of students (in particular doctoral students) (iv) Exchange of scientific and technological research materials (v) Collaboration research project (vi) Application of research fund for international collaboration

A.9.3 Status and Outcome

Presently, due to COVID19 pandemic, most of the international mutual activities are restricted. Only some collaboration work is ongoing. In 2020, specifically, we studied the core electron binding energies (CEBEs) and core-level excitation energies of thymine, adenine, cytosine, and uracil using the Kohn-Sham (KS) method with long-range corrected functionals. The CEBEs are estimated according to the Koopmans-type theorem for density functional theory. The excitation energies from the core to the valence and Rydberg states are calculated as the orbital energy differences between core-level orbitals of a neutral parent/cation and valence or Rydberg orbitals of its cation. The model is intuitive, and the spectra can easily be assigned. Core excitation energies from oxygen 1s, nitrogen 1s, and carbon 1s to valence and Rydberg states, and the chemical shifts, agree well with previously reported theoretical and experimental data. The straightforward use of KS orbitals in this scheme carries the advantage that it can be applied efficiently to large systems such as biomolecules and nanomaterials.

A.9.4 Publications

[1] Kimihiko Hirao, Takahito Nakajima, Bun Chan, Jong-Won Song, and Han-Seok Bae, Core Level Excitation Energies of Nucleic Acid Bases Expressed as Orbital Energies of Kohn-Sham Density Functional Theory with Long-Range Corrected Functionals, *Journal of Physical Chemistry A*, vol. 124, 10482 (2020).

[2] Kimihiko Hirao, Bun Chan, Jong-Won Song, and Han-Seok Bae, Charge-Transfer Excitation Energies Expressed as Orbital Energies of Kohn-Sham Density Functional Theory with Long-Range Corrected Functionals, *Journal of Physical Chemistry A*, vol. 124, 8079 (2020).

[3] Kenji Mishima, Masanori Kaneko, Jong-Won Song, Hiroki Kawai, Koichi Yamashita, and Kimihiko Hirao, Application of Accelerated Long-range Corrected Exchange Functional to Periodic Boundary Condition Systems: CO Adsorption on Cu(111) Surface, *Journal of Chemical Physics*, vol. 152, 104105 (2020).

[4] Kimihiko Hirao, Bun Chan, Jong-Won Song, Kamala Bhattarai, and Subrata Tewary, Excitation energies expressed as orbital energies of KS-DFT with LC functionals, *Journal of Computational Chemistry*, vol. 41, 1368-1383 (2020).

A.10 European Centre for Medium-Range Weather Forecasts (#44269)

A.10.1 Scope

This is an MOU between R-CCS and European Centre for Medium-Range Weather Forecasts.

A.10.2 Purpose

This aims to accelerate the use of FP16 (half precision) in meteorological model simulations on Fugaku.

A.10.3 Status and Outcome

This activity was from December in 2020. At the first meeting, we agreed to focus on the dynamic process (fluid dynamics part). In order to evaluate different methods in dynamics, we decided that ECMWF conducted a feasibility study for the spectral method using spherical harmonics, while RIKEN conducted that using the finite volume method. We have started the discussion by bringing each other's results once every few months.

A.11 The DL4Fugaku Project (#44356)

A.11.1 Scope

The scope of the MOU is porting, optimization, performance measurement and usability enhancement of AI frameworks on Fugaku. The MOU is entered into on **RIKEN Center for Computational Science**, a research center of RIKEN, a National Research and Development Institute duly organized and existing under the laws of Japan, having its head office at 2-1, Hirosawa, Wako, Saitama, 351-0198, Japan (hereinafter referred to as “R-CCS”); and **Arm Limited**, a company incorporated in England and Wales with company number 2557590 whose registered office is at 110 Fulbourn Road, Cambridge, CB1 9NJ, UK (“Arm”); and **FUJITSU LIMITED**, a company incorporated in Japan with company number FC024070 whose registered office is at Shiodome City Center 1-5-2 Higashi-Shimbashi Minato-ku, Tokyo 105-7123, Japan (“FUJITSU”); and **LINARO LIMITED**, a company incorporated in England and Wales with company number 07180318 whose registered office is at Harston Mill, Harston, Cambridge, CB22 7GG, UK (“LINARO”),

A.11.2 Purpose

The purpose of this MOU is to record the mutual interest of the parties in discussing and furthering an ongoing strategic relationship relating to enabling, optimizing and benchmarking open-source deep learning frameworks (specifically Tensorflow, Pytorch, and Chainer) for Arm Scalable Vector Extensions (SVE) and more specifically the A64FX microarchitecture implementation of it developed by Fujitsu.

A.11.3 Status and Outcome

Large-scale deep learning has emerged as an essential machine learning approach for many research challenges such as image classification, speech recognition and many others. Fast and large-scale deep learning enables us to train neural networks with more training data in shorter time. Supercomputer Fugaku is expected to enable high performance computing for deep learning. However, to make use of Fugaku/A64FX hardware performance, tuning software stacks from deep learning frameworks to low-level numerical libraries is indispensable. In 2020, we worked on: (1) performance analysis and tuning of deep learning frameworks and low-level numerical libraries used by the frameworks; (2) Reliable deployment of large-scale deep learning environments; (3) Enhancement of the usability for production use in Fugaku. We organized a project team for DL4Fugaku from PIs and researchers in the application development unit, the high-performance AI system research team, the high-performance big data research team and the large-scale parallel numerical computing technology research team under collaboration with industry, academia and government; AIST, ARM, Cybozu, Fujitsu laboratories, Fujitsu limited, Linaro and Toky Tech. We evaluated our tuned AI frameworks with MLPerf HPC benchmarks (DeepCam and CosmoFlow) on Fugaku and ABCI. We submitted the CosmoFlow results to the MLPerf HPC ranking and ABCI was ranked at No. 2 and Fugaku was ranked at No. 1 in the world. All the research and development results are incorporated into AI frameworks (PyTorch and TensorFlow) installed in Fugaku.

A.11.4 Publications

- [1] Fujitsu, AIST, and RIKEN Achieve Unparalleled Speed on the MLPerf HPC Machine Learning Processing Benchmark Leveraging Leading Japanese Supercomputer Systems, <https://www.fujitsu.com/global/about/resources/news/press-releases/2020/1119-02.html>, November 19, 2020
- [2] 機械学習処理ベンチマークMLPerf HPCにて最高レベルの速度を達成 <https://pr.fujitsu.com/jp/news/2020/11/19-1.html>, November 19, 2020
- [3] 富岳CPU A64FX用ディープラーニングライブラリの深層-研究者が語る開発の軌跡- <https://blog.fltech.dev/entry/2020/11/18/fugaku-onednn-deep-dive-ja> November 18, 2020
- [4] 富岳のディープラーニング処理を支えるJITコンパイラ「Xbyak_aarch64」誕生秘話 <https://gihyo.jp/news/interview/2020/11/1801>, November 18, 2020
- [5] 富岳版XbyakがIntelの深層学習ライブラリoneDNNにmergeされる https://blog.cybozu.io/entry/xbyak_for_fugaku, November 18, 2020
- [6] HPC and AI Initiatives for Supercomputer Fugaku and Future Prospects <https://www.fujitsu.com/global/about/resources/publications/technicalreview/2020-03/article09.html>, November 11, 2020
- [7] 「スーパーコンピュータ「富岳」におけるHPC/AIへの取り組みと将来への展望」 <https://www.fujitsu.com/jp/about/resources/publications/technicalreview/2020-03/article09.html>, October 13, 2020

A.12 Agency for Science, Technology and Research (A*STAR) (#44361)

A.12.1 Scope

This MOU for Research Collaboration is entered into by and between RIKEN Center for Computational Science, a research center of RIKEN, a National Research and Development Institute duly organized and existing under the laws of Japan, and Agency for Science, Technology and Research, A*STAR Computational Resource Center, Singapore.

A.12.2 Purpose

The collaborative activities promoted under this MOU shall be the computational science and the related fields which would contribute to overcome existing societal issues in South –East Asian countries.

A.12.3 Status and Outcome

A.12.3.1 Interoperation of SC@FT and WHEEL

A*CRC and R-CCS are collaborating on making interoperable tools SC@FT and WHEEL developed by each institute. SC@FT is an intelligent resource manager developed by A*CRC and WHEEL is a workflow engine developed by R-CCS. Combining these two tools is believed to enable job submissions that can automatically select appropriate computing resources in wide-area settings. As the first step to this collaboration, we have prepared the user accounts on both sites and are currently learning each other's tools in an experimental setting. We semi-regularly have meetings on modifying and extending the capabilities of both tools to interface the tools together. An apparent obstacle that is already revealed is the mismatch in the interface between the tools. That is, SC@FT uses a Web-interface that is intended for interaction with human users, while WHEEL only supports traditional job scheduler interfaces.

A.12.3.2 Data-sharing environment between ACRC and R-CCS

Gfarm is a distributed parallel file system developed by the University of Tsukuba, and the HPCI shared storage system also uses Gfarm. We installed a Gfarm file server in both ACRC and R-CCS, and built a data-sharing environment. The data replication function of Gfarm enables high-speed data-sharing even between two geographically separated points such as ACRC and R-CCS. We will verify the operation of tools such as WHEEL and SC@FT on our data-sharing environment. We will use actual HPC workloads to confirm that the system is at a production level. In addition, we aim to realize a data-sharing environment between ACRC and Fugaku using HPCI shared storage. The HPCI shared storage is the data-sharing infrastructure of HPCI and is used for more than 50 HPCI projects every year, and is also accessible from Fugaku. The use of tools such as WHEEL and SC@FT on the HPCI shared storage is expected to promote the use of Fugaku. We are actually considering how accounts should be managed in a data sharing environment. R-CCS proposes to manage accounts tied to HPCI IDs in consideration of consistency between the data sharing environment, HPCI shared storage, and HPCI projects. By using the HPCI ID, the same user can be easily identified in the data sharing environment with ACRC and HPCI projects. Next, the data sharing environment is currently built on the Internet, but we are making it possible to build a secure client environment within the intranet of the ACRC and other research organizations. To this end, we are exchanging information on the port numbers and other information required by the Gfarm system. Secure data sharing from within a research organization is expected to promote the use of Fugaku.

A.13 University of Regensburg (#44362)

A.13.1 Scope

This is an MOU between R-CCS and Universität Regensburg, Institute for Theoretical Physics, Germany.

A.13.2 Purpose

Both parties have been promoting research and development on LQCD software to take advantage of the power of CPUs with the arm-based architecture, especially Fujitsu A64FX, seeking good and expanding use of the

supercomputers “Fugaku” at R-CCS and “QPACE-4” at Universität Regensburg. The field theory research team in R-CCS aimed to develop, with a collaboration of Flagship2020 project, QWS (QCD Wide SIMD), highly optimized LQCD library for Fugaku. Universität Regensburg, in collaboration with the Programming Environment Research Team in R-CCS, implemented the arm-specific functionality for A64FX in the LQCD package Grid, which is one of the most popular LQCD package in the world and has also been used by the field theory research team for large scale simulations before Fugaku. Both activities for these different programs are conducted in parallel so far with much accumulated knowledges in each R&D. This MOU is aiming to encourage exchanging knowledges and to accelerate the R&D in each, and then to seek collaborations beneficial to both parties to further expanding the use of Fugaku and QPACE-4 and eventually to a breakthrough for large scale Lattice QCD simulations in the exa-scale computing era.

A.13.3 Status and Outcome

Although the MOU took effect on March 23, 2021, we have been in contact with each other having on-line discussions on Grid and QWS, which was useful to understand the status of both activities and the standing problems for the tuning for A64FX. Each party further continue investigating tuning and the results has been used for benchmarks and test runs of LQCD applications.

A.14 OPEN ACC-STANDARD.ORG (#44713)

A.14.1 Scope

OpenACC.org is a nonprofit organization founded to help scientists and researchers do more science and less programming by providing a high-level directives-based programming model for high performance computing. The charter of OpenACC.org is to develop and deliver the OpenACC specification, and to help educate and support scientists and researchers using or considering using OpenACC directives.

R-CCS joined to OpenACC.org as a Auxiliary Member from 3rd, August, 2019.

A.14.2 Purpose

The purposes of joining OpenACC.org are as follows:

- Drive the OpenACC specification by setting directions and development priorities, as well as brainstorming new features with the technical team, and explore the programming models related to OpenACC for Fugaku and the next of Fugaku.
- Opportunity to collaborate with fellow members and build relationships with OpenACC experts and technical developers that shape the specification.
- Gathering information about the latest specification and activities of OpenACC.

A.14.3 Status and Outcome

We participated the regular on-line meeting of OpenACC.org. and gathered several information about the latest specification and activities from OpenACC.org. As for 2020FY, due to the COVID-19, the activities were unfortunately low.

The programming environment research team was interested in using OpenACC to program for SIMDs of Fugaku, and started to explore the way to use OpenACC for the SIMD.

A.15 OpenHPC (#44716)

A.15.1 Scope

OpenHPC is a Linux Foundation Collaborative Project whose mission is to provide a reference collection of open-source HPC software components and best practices, lowering barriers to deployment, advancement, and use of modern HPC methods and tools. RIKEN Advanced Institute for Computational Science (AICS) (renamed R-CCS) joined to OpenHPC as a “Lab Member” on 31th March 2016.

A.15.2 Purpose

The purposes of joining OpenHPC are as follows:

- Dissemination of software developed by FLAGSHIP 2020 project through the community of OpenHPC.
- Gathering information about the latest Open HPC software.

A.15.3 Status and Outcome

We participated the regular on-line meeting of OpenHPC, and gather several information about the latest distribution released from OpenHPC project. The activity on OpenHPC in R-CCS was finished at the end of FLAGSHIP2020 project, March 2021.

Appendix B

International Collaboration with R-CCS and Other RIKEN Institutions

B.1 University of Maryland (#36804)

B.1.1 Scope

This is an MOU between RIKEN and the University of Maryland (UMD), USA.

B.1.2 Purpose

The purpose of this MOU is to engage in cooperation and develop joint projects in fields of common interest including but not limited to numerical modelling, data assimilation and related research fields.

RIKEN and UMD agreed to implement the following activities:

- Exchange of faculty and students for research, teaching and study
- Joint research activities
- Exchange of scholars for seminars, conferences and other academic meetings
- Exchange of scholarly publications and other information, including collections and services, in areas of interest to both parties

B.1.3 Status and Outcome

We have been actively collaborating in a wide range of research topics related to data assimilation, from fundamental research to real-world application. TL Takemasa Miyoshi is a visiting professor at UMD. Prof. Eugenia Kalnay of UMD is a member of the research project “Enhancing Precipitation Prediction Algorithm by Data Assimilation of GPM Observations” led by TL Takemasa Miyoshi, funded by the Japan Aerospace Exploration Agency (JAXA). A summary of this project was published in 2020 as a book chapter, as shown below. Cheng Da was a student at UMD and visited R-CCS in 2017 for internship.

B.1.4 Publications

- [1] Miyoshi, T., S. Kotsuki, K. Terasaki, S. Otsuka, G.-Y. Lien, H. Yashiro, H. Tomita, M. Satoh, and E. Kalnay, 2020: Precipitation Ensemble Data Assimilation in NWP Models. In: Levizzani V., Kidd C., Kirschbaum D., Kummerow C., Nakamura K., Turk F. (eds) Satellite Precipitation Measurement. Advances in Global Change Research, 69, Springer, 983–991. doi:10.1007/978-3-030-35798-6_25

B.2 Commissariat A L’Energie Atomique Et Aux Energies Alternatives (CEA) (#37011)

B.2.1 Scope

The Cooperation Program between RIKEN and CEA under the implementing arrangement between MEXT of Japan and MENSERSR of France in the field of computational science and computer science concerning high performance computing and computational science was signed by the President of RIKEN and the Chairman of CEA on January 11th 2017. The collaboration of this Cooperation Program continues for a period of five (5) years to 2022.

B.2.2 Purpose

The R-CCS and The CEA will collaborate on developing software libraries and simulations software, and the management issues such as human resource management. The details of the works, work plans and technical details are to be described on Statement of Work (SOW) as annexed to this Cooperation Program. On SOW, the following topics are described:

- Programming Language Environment
- Runtime Environment
- Energy-aware batch job scheduler
- Large DFT calculations and QM/MM
- Application of High Performance Computing to Earthquake Related Issues of Nuclear Power Plant Facilities
- Key Performance Indicators
- Human Resource and Training
- Arm Performance Evaluation
- Artificial Intelligence and BigData

B.2.3 Status and Outcome

Usually, two meetings were used to be held on each side, Japan and France. As for 2020FY, two on-line workshops were held on 7-9th October 2020 and 29-31 March, 2021. As well as the discussion on the recent progress of each SOW, we started the discussion on the renewal of The Cooperation Program from 2022. We agreed to renew the fields for the next Cooperation Program by adding new emerging fields such as AI/DL and Quantum Computing.

Since the Fugaku was ready for the service since March 2020, we agreed to add a new SOW about Fugaku and Arm technologies, and exchange other the MoU about the usage of Fugaku.

B.3 Pennsylvania State University (#39769)

B.3.1 Scope

This is an MOU between RIKEN and the Department of Meteorology and Atmospheric Science (MAS), Pennsylvania State University, USA.

B.3.2 Purpose

The purpose of this MOU is to strengthen and expand the collaborative relations in all the aspects of research and development being undertaken at the two institutions including theoretical and mathematical sciences as well as numerical modelling, data assimilation and related research fields, and to promote exchanges of researchers, staff and students.

RIKEN and MAS agreed to implement the following programs and activities.

- Exchange of researchers and staff
- Exchange of scientific and technological information, including delivering lectures and holding joint seminars and symposia
- Exchange of students (in particular doctoral students)
- Exchange of scientific and technological research materials
- Joint research projects

B.3.3 Status and Outcome

Under this MOU, Atsushi Okazaki was a visiting scientist at R-CCS when he was a postdoc at MAS. A research on data assimilation for paleoclimate reconstruction was conducted. Unfortunately, Prof. Fuqing Zhang, who was the main counterpart at MAS, has passed away in July 2019. Nevertheless, under this MOU, the paper below was published in FY2021.

B.3.4 Publications

- [1] Okazaki, A., T. Miyoshi, K. Yoshimura, S. J. Greybush, and F. Zhang, 2021: Revisiting online and offline data assimilation comparison for paleoclimate reconstruction: an idealized OSSE study. *J. Geophys. Res. Atmos.*, 126.

B.4 National Central University (#39793)

B.4.1 Scope

This is an MOU between RIKEN and National Central University (NCU) in Taiwan (R.O.C.).

B.4.2 Purpose

The purpose of this MOU is to promote education and research in the fields of theoretical and mathematical sciences as well as numerical modelling, data assimilation and related research fields.

RIKEN and NCU agreed to implement the following programs and activities.

- Exchange of researchers and staff
- Exchange of scientific and technological information, including delivering lectures and holding joint seminars and symposia
- Exchange of students (in particular doctoral students)
- Exchange of scientific and technological research materials
- Exchange of information pertinent to industrial application and collaborations
- Joint research projects
- Any other programs and activities incidental to the foregoing

B.4.3 Status and Outcome

RIKEN and NCU are actively collaborating in the field of data assimilation, particularly about data assimilation of weather radar observations for predicting tropical cyclones. In February 2020, RIKEN and NCU planned to hold a joint workshop in Taiwan, which was postponed unfortunately due to the pandemic of COVID-19. In 2020, our proposal titled “Advancing the convective-scale ensemble data assimilation to assimilate large-volume radar data and its impact on heavy rainfall prediction” was accepted by Ministry of Science and Technology, R.O.C. Prof. Shu-Chih Yang of NCU is a visiting scientist at R-CCS under this MOU. In FY2020, three papers in the next subsection were published.

B.4.4 Publications

- [1] Chang, C., S. G. Penny, and S. Yang, 2020: Hybrid Gain Data Assimilation Using Variational Corrections in the Subspace Orthogonal to the Ensemble. *Mon. Wea. Rev.*, 148, 2331–2350.
- [2] Hsiang-Wen Cheng, Shu-Chih Yang, Yu-Chieng Liou, Ching-Sen Chen, An Investigation of the Sensitivity of Predicting a Severe Rainfall Event in Northern Taiwan to the Upstream Condition with a WRF-based Radar Data Assimilation System, SOLA, 2020, Volume 16, Pages 97–103.
- [3] Wu, P., S. Yang, C. Tsai, and H. Cheng, 2020: Convective-Scale Sampling Error and Its Impact on the Ensemble Radar Data Assimilation System: A Case Study of a Heavy Rainfall Event on 16 June 2008 in Taiwan. *Mon. Wea. Rev.*, 148, 3631–3652.

B.5 Ecole nationale supérieure Mines-Télécom Atlantique Bretagne Pays de la Loire (#43367)

B.5.1 Scope

This is an MOU between RIKEN (RIKEN Center for Computational Science, RIKEN Cluster for Pioneering Research, RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program) and Ecole nationale supérieure Mines-Télécom Atlantique Bretagne Pays de la Loire (IMT Atlantique), France.

B.5.2 Purpose

The purpose is to promote education and research activities, including but not limited to data assimilation, statistical data analysis and data-driven prediction.

RIKEN and IMT Atlantique agreed to implement the following programs and activities.

- Exchange of researchers and staff
- Exchange of scientific and technological information, including delivering lectures and holding joint seminars and symposia
- Exchange of students (in particular doctoral students)
- Exchange of scientific and technological research materials
- Joint research projects

B.5.3 Status and Outcome

Currently, Prof. Pierre Tandeo is a visiting scientist at R-CCS, and we are collaborating in research topics on data-driven approaches in data assimilation and prediction. Prof. Tandeo stayed at R-CCS during February–July 2018 and attended the RIKEN International Workshop on Uncertainty Quantification. Maha Mdini was a former student of IMT Atlantique, and currently working at R-CCS as a postdoc researcher. TL Miyoshi visited IMT Atlantique in 2017. Under this MOU, we hosted the following events:

- February 22, 2019: IMT Atlantique & RIKEN workshop
5 scientists from R-CCS visited IMT Atlantique and discussed data assimilation and data-driven approaches.

- February 10–13, 2020: The Second IMT-Atlantique & RIKEN Joint Workshop
8 scientists from RIKEN visited IMT Atlantique and discussed fusion of AI and data assimilation, including AI-based precipitation nowcasting and fusion of numerical weather prediction and AI.
- February 17–April 14, 2021: IMT-Atlantique & RIKEN Online Joint Seminar Series
5 online seminars were held and fusion of AI and data assimilation was discussed.

B.5.4 Publications

Under this MOU, the following paper was published in FY2020:

- [1] Tandeo, P., P. Ailliot, M. Bocquet, A. Carrassi, T. Miyoshi, M. Pulido, and Y. Zhen, 2020: A review of innovation-based methods to jointly estimate model and observation error covariance matrices in ensemble data assimilation. *Mon. Wea. Rev.*, 148, 3973–3994.

Appendix C

Japanese Domestic Collaboration

C.1 Intel Corp., The University of Tokyo and University of Tsukuba (#36811)

This is a MoU between RIKEN AICS (renamed R-CCS), Intel Corporation, The University of Tokyo and University of Tsukuba for Machine Testing of software (mOS by Intel and McKernel by R-CCS) and Joint Publications. The MoU was signed by the director of FLAGSHIP2020 project Planning and Coordination Office, the Corp. VP, Enterprise and Government Group, the director of Information Technology Center, and the director of Center for Computational Sciences, University of Tsukuba, on 3rd October, 2017.

C.1.1 Purpose

Through this MoU, the Parties cooperate in the Collaboration as follow:

Phase 1: Machine Testing The Parties run mOS and McKernel on the machines operated by the University of Tokyo and University of Tsukuba.

Phase 2: Joint Publications Upon completion of Phase 1, the Parties intend to jointly author a publication that discusses the Collaboration and the results of Phase 1.

Several evaluations were done using the Oakforest-PACS operated by the JCAHPC of The University of Tokyo and University of Tsukuba, and several publications were produced. The activities of this MoU was finished at the end of the FLAGSHIP 2020 project, March 2021.

C.1.2 Publications

[1] B. Gerofi et al., "Performance and Scalability of Lightweight Multi-kernel Based Operating Systems," 2018 IEEE International Parallel and Distributed Processing Symposium (IPDPS), 2018, pp. 116-125, [doi:10.1109/IPDPS.2018.00022](https://doi.org/10.1109/IPDPS.2018.00022).

[2] Weisbach H., Gerofi B., Kocoloski B., Härtig H., Ishikawa Y., "Hardware Performance Variation: A Comparative Study Using Lightweight Kernels." In: Yokota R., Weiland M., Keyes D., Trinitis C. (eds) High Performance Computing. ISC High Performance 2018. Lecture Notes in Computer Science, vol 10876. Springer, Cham. https://doi.org/10.1007/978-3-319-92040-5_13

[3] Gerofi B., Takagi M., Ishikawa Y. (2019) "IHK/McKernel." In: Gerofi B., Ishikawa Y., Riesen R., Wisniewski R.W. (eds) Operating Systems for Supercomputers and High Performance Computing. High-Performance Computing Series, vol 1. Springer, Singapore. https://doi.org/10.1007/978-981-13-6624-6_17

[4] K. Nakajima, B. Gerofi, Y. Ishikawa and M. Horikoshi, "Parallel Multigrid Methods on Manycore Clusters with IHK/McKernel," 2019 IEEE/ACM 10th Workshop on Latest Advances in Scalable Algorithms for Large-Scale Systems (Scala), 2019, pp. 52-61, [doi:10.1109/Scala49573.2019.00012](https://doi.org/10.1109/Scala49573.2019.00012).

[5] Kengo Nakajima, Balazs Gerofi, Yutaka Ishikawa, and Masashi Horikoshi. "Efficient Parallel Multigrid Method on Intel Xeon Phi Clusters." In The International Conference on High Performance Computing in Asia-Pacific Region Companion (HPC Asia 2021). Association for Computing Machinery, New York, NY, USA, 46-49. DOI:<https://doi.org/10.1145/3440722.3440882>

[6] Kengo Nakajima, Balazs Gerofi, Masashi Horikoshi, and Yutaka Ishikawa. “Communication-Computation Overlapping for Preconditioned Parallel Iterative Solvers with Dynamic Loop Scheduling.” In International Conference on High Performance Computing in Asia-Pacific Region Workshops (HPCAsia 2022 Workshop). Association for Computing Machinery, New York, NY, USA, 60–71. DOI:<https://doi.org/10.1145/3503470.3503477>

[7] Masashi Horikoshi, Balazs Gerofi, Yutaka Ishikawa, and Kengo Nakajima. “Exploring Communication-Computation Overlap in Parallel Iterative Solvers on Manycore CPUs using Asynchronous Progress Control.” In International Conference on High Performance Computing in Asia-Pacific Region Workshops (HPCAsia 2022 Workshop). Association for Computing Machinery, New York, NY, USA, 29–39. DOI:<https://doi.org/10.1145/3503470.3503474>

C.2 University of Tsukuba (#38661)

C.2.1 Scope

This is a MoU between RIKEN and University of Tsukuba for the collaboration on the promotion of advanced computational science. The MoU was signed by the director of Advanced Institute for Computational Science (AICS), RIKEN and the director of Center for Computational Sciences, University of Tsukuba, on 1st February, 2017. This MoU was extended on 31st March, 2020, and shall be effective for a period of five (5) years from this date.

C.2.2 Purpose

This aims furtherance of the mutual interests in education and research in the fields of advanced computer science and computational science, and as a contribution to increased co-operation between R-CCS and CCS U Tsukuba, and agree to implement the following activities;

- Exchange of scientific and technological information
- Joint research projects by collaborations
- Exchange of researchers and staff for human resources
- Exchange of information pertinent to industrial applications and collaboration
- Other activity agreed with both organizations

C.2.3 Status and Outcome

The collaboration is carried out mainly between CCS of U Tsukuba and Programming Environment Research Team, Processor as follows:

- Prof. Sato is appointed to a Professor of the Cooperative Graduate School Program of Degree Programs in Systems and Information Engineering. A student, Yutaka Watanabe, is supervised by Prof. Sato. He is accepted as a Student Trainee of the programming environment research team.
- Prof. Boku is invited as a Senior Visiting Scientist of the programming environment research team.
- The collaboration on FLAGSHIP2020 was carried out on the topics “researches on programming environment and network for Post-K”.
- The members of the programming environment research team applied to Multidisciplinary Cooperative Research Program in Center for Computational Sciences, University of Tsukuba to share the computation resources in CCS, U Tsukuba.
- The research collaborations on FPGA for high performance computing were carried out by the research fundings of Kaken-hi led by Prof. Boku, CCS of U Tsukuba and Dr. Sano, R-CCS, respectively.

C.3 Nagasaki University (#44247), University of Aizu (#42244), Hiroshima City University (#44246), Kyoto University (#42245), Tokyo Institute of Technology (#42250), Kumamoto University (#42246), Japan Advanced Institute of Science and Technology (#42253), National Institute of Informatics (#42254)

C.3.1 Scope

These are MoUs between R-CCS and each of the following organizations:

1. Graduate School of Engineering, Nagasaki University
2. University of Aizu
3. Graduate School of Information Sciences, Hiroshima City University
4. Graduate School of Informatics, Kyoto University
5. School of Engineering, Tokyo Institute of Technology
6. Faculty of Advanced Science and Technology, Kumamoto University
7. Research Center for Advanced Computing Infrastructure, Japan Advanced Institute of Science and Technology,
and a MoU between Architecture Research Team, FS2020 and
8. Koibuchi Lab., Information Systems Architecture Science Research Division, National Institute of Informatics.

C.3.2 Purpose

The signed parties have been promoting research and development on additional values of the supercomputer “Fugaku” with an experimental FPGA cluster, ESSPER (Elastic and Scalable System for high-PERformance Reconfigurable computing), which was developed in FS2020. They considered and/or designed specialized hardware modules for applications on FPGAs and evaluated use cases of the ESSPER’s system stack developed in Architecture Research Team.

C.3.3 Status and Outcome

Due to the COVID-19 pandemic, we had online meetings on each MoU to discuss and progress its research. We experienced the ESSPER’s system stack with hardware and software, evaluated their usage with problem reports. Some of the parties developed preliminary hardware of the following applications with FPGAs of ESSPER: an FDTD for sound rendering, Inference in ML, BFS of a graph, convex hull processing, and Bayesian network analysis.

C.3.4 Publications

[1] 多田 大希, 上野 知洋, 小柴 篤史, 佐野 健太郎, 河野 隆太, 井口 寧, ”FDTD法による音響シミュレーションのためのストリーム計算ハードウェアの設計と評価”, 電子情報通信学会リコンフィギャラブルシステム研究会 信学技法, Vol.120, No.339, RECONF2020-60, pp.13-18, Jan 25-26, 2021.

C.4 National Institute for Environmental Studies (#42248)

C.4.1 Scope

This is an MOU between Application Development Team in R-CCS and National Institute for Environmental Studies.

C.4.2 Purpose

This aims to improve the performance of NICAM + LETKF, which is one of the target applications in Fugaku development.

C.4.3 Status and Outcome

In FY2020, Fugaku went into full-scale operation and measured the performance on target problem using NICAM + LETKF, which is to assimilate 1000 ensemble simulations of the global model with 3.5km mesh to observational data. We confirmed that the performance was 100 times higher than that of the K computer, and we were able to reach the target performance. This achievement was selected as a finalist of the Gordon Bell Award at SC20.

C.4.4 Publications

[1] Yashiro, H., K. Terasaki, Y. Kawai, S. Kudo, T. Miyoshi, T. Imamura, K. Minami, H. Inoue, T. Nishiki, T. Saji, M. Satoh, and H. Tomita (2020): "A 1024-Member Ensemble Data Assimilation with 3.5-Km Mesh Global Weather Simulations" in SC20: International Conference for High Performance Computing, Networking, Storage and Analysis (SC), Atlanta, GA, US, 2020 pp. 1-10. (Gordon Bell Finalist)

Appendix D

Japanese Domestic Collaboration with R-CCS and Other RIKEN Institutions

D.1 JICFuS (Joint Institute for Computational Fundamental Science) (#43442)

D.1.1 Scope

This joint institute consists of 13 institutions in Japan, including High Energy Accelerator Research Organization (KEK), Center for Planetary Science at Kobe University, Center for Computational Sciences at University of Tsukuba, RIKEN Nishina Center for Accelerator-Based Science, RIKEN Center for Computational Science and 8 other institutions.

D.1.2 Purpose

Signed parties operate the joint institute in mutual cooperation by making use of its own ability of research and development, human resource and infrastructure, to make it a strategic institute for the research and education in the fields of particle physics, nuclear physics and planetary science and then to contribute to an advancement in the computational science in Japan.

D.1.3 Status and Outcome

With MEXT Program for Promoting Researches on the Supercomputer Fugaku, the following two projects in the Area 1 “Challenges for Solving Universal Problems of Mankind or Pioneering the Future” are conducted under JICFuS starting from this fiscal year:

- “Simulation for basic science: from fundamental laws of particles to creation of nuclei” and
- “Toward a unified view of the universe: from large scale structures to planets”.

JICFuS makes commitment on improving the research environment by 1) supporting researchers in computational fundamental science, 2) providing fields of collaborations involving researchers in computational fundamental science and computer science, 3) creating new research field. JICFuS and R-CCS together held a series of HPC-Phys workshops (from 7th to 10th) online in FY2020 to exchange various ideas in computational fundamental science. Further information about JICFuS can be found at:

URL <https://www.jicfus.jp/>.