



Welcome Back to Kashiwa !!

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The University of Tokyo
Deputy Director, RIKEN R-CCS

ADAC-8, October 30-31, 2019
Kashiwa, Japan

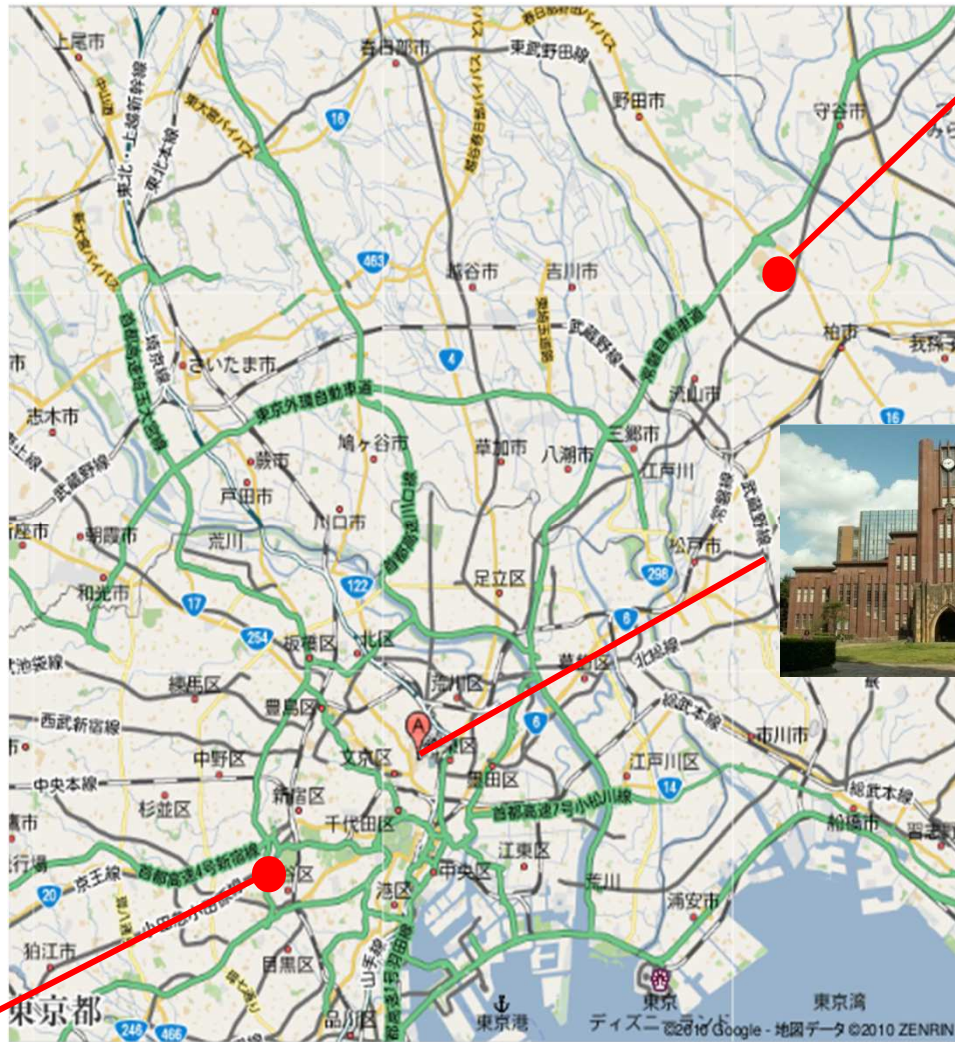
**First of all,
sorry for 2-hour trip from Shinagawa
We have a Big Event in Kashiwa Area**



Three Major Campuses of University of Tokyo



東京大学
THE UNIVERSITY OF TOKYO



Kashiwa



Hongo



Komaba

Kashiwa (栎) : Oak

Kashiwa-no-Ha: Leaf of Oak



“Kashi (櫟)” is
also called “Oak”



“Oak” covers many kinds of trees in Japan

53rd TOP500 (June, 2019)

$R_{\max}$: Performance of Linpack (TFLOPS)
 R_{peak} : Peak Performance (TFLOPS),
 Power: kW

<http://www.top500.org/>

	Site	Computer/Year Vendor	Cores	$R_{\max}$ (TFLOPS)	R_{peak} (TFLOPS)	Power (kW)
1	<u>Summit, 2018, USA</u> DOE/SC/Oak Ridge National Laboratory	IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband	2,414,592	148,600 (= 148.6 PF)	200,795	10,096
2	<u>Sieera, 2018, USA</u> DOE/NNSA/LLNL	IBM Power System S922LC, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband	1,572,480	94,640	125,712	7,438
3	<u>Sunway TaihuLight, 2016, China</u> National Supercomputing Center in Wuxi	Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway	10,649,600	93,015	125,436	15,371
4	<u>Tianhe-2A, 2018, China</u> National Super Computer Center in Guangzhou	TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000	4,981,760	61,445	100,679	18,482
5	<u>Frontera, 2019, USA</u> Texas Advanced Computing Center	Dell C6420, Xeon Platinum 8280 28c 2.7GHz, Mellanox Infiniband HDR	448,448	23,516	38,746	
6	<u>Piz Daint, 2017, Switzerland</u> Swiss National Supercomputing Centre (CSCS)	Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect, NVIDIA Tesla P100	387,872	21,230	27,154	2,384
7	<u>Trinity, 2017, USA</u> DOE/NNSA/LANL/SNL	Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect	979,072	20,159	41,461	7,578
8	<u>ABCI (AI Bridging Cloud Infrastructure), 2018, Japan</u> National Institute of Advanced Industrial Science and Technology (AIST)	PRIMERGY CX2550 M4, Xeon Gold 6148 20C 2.4GHz, NVIDIA Tesla V100 SXM2, Infiniband EDR	391,680	19,880	32,577	1,649
9	<u>SuperMUC-NG, 2018, Germany</u> Leibniz Rechenzentrum	Lenovo, ThinkSystem SD650, Xeon Platinum 8174 24C 3.1GHz, Intel Omni-Path	305,856	19,477	26,874	
10	<u>Lassen, 2019, USA</u> DOE/NNSA/LLNL	IBM Power System S922LC, IBM POWER9 22C 3.1GHz, NVIDIA Volta V100, Dual-rail Mellanox EDR Infiniband	288,288	18,200	23,047	
16	<u>Oakforest-PACS, 2016, Japan</u> Joint Center for Advanced High Performance Computing	PRIMERGY CX1640 M1, Intel Xeon Phi 7250 68C 1.4GHz, Intel Omni-Path	556,104	13,556	24,913	2,719

Current No1. & No2 Systems in Japan

1	<u>Summit, 2018, USA</u> DOE/SC/Oak Ridge National Laboratory	22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband	2,414,592	148,000 (= 148.6 PF)	200,795	10,096
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No.1 in Japan !

No.2 in Japan !

Both are in Kashiwa !!

Kashiwa is the Home of Supercomputers !!

3	<u>Sunway TaihuLight, 2016, China</u> National Supercomputing Center in Wuxi	Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway	10,649,600	93,015	125,436	15,371
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9	<u>SuperMUC-NG, 2018, Germany</u> Leibniz Rechenzentrum	Lenovo System SD650, Xeon 8170 2.4GHz, Intel Omni-Path	1,856	19,477	26,874	
10	<u>Lassen, 2019, USA</u> DOE/NSA/LLNL	IBM Power System S822L 22C 3.1GHz, Mellanox Infiniband	288,288	18,200	23,047	
16	<u>Oakforest-PACS, 2016, Japan</u> Joint Center for Advanced High Performance Computing	PRIMERGY M1, Intel Xeon Phi 7250 68C Intel Omni-Path	556,104	13,556	24,913	2,719

No.1 in Kashiwa/Japan !

No.2 in Kashiwa/Japan !

Oakforest-PACS (OFP): KNL & OPA

- 8,208 Intel Xeon/Phi (KNL), 25 PF Peak Performance
 - Fujitsu
 - Full operation started in December 2016
 - Just before ADAC-3



- TOP 500 #16 (#2 in Japan/柏市),
HPCG #9 (#3) (June 2019)

- JCAHPC: Joint Center for Advanced High Performance Computing

- University of Tsukuba
- University of Tokyo



筑波大学
University of Tsukuba



東京大学
THE UNIVERSITY OF TOKYO

- Kashiwa-no-Ha (Leaf of Oak) Campus/UT Tokyo
which is between Tokyo and Tsukuba



JCAHPC

- <http://jcahpc.jp>

- In spite of KNL & OPA, still an excellent system for
R&D on SW/Algorithms for large-scale computing

Another Important Role of OFP

Alternative National Flagship System

- K computer has been shut down in August 2019.
- OFP is the biggest system in HPCI for shared usage
- Very Important Computational Resource in Japan until the Fugaku (Post K) starts its operation in 2020-2021



- Manycore
- Wide SIMD
- (Small) HBM



Fiscal Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Hokkaido	HTAC-HR 10000 N (1.72TF, 22TB) Cloud System S-2200 (1.47TF, 14TB) 2nd Science Cloud Storage H4000 H40000 (10TF, 1.9PB)			3.96 PF (UCC + CFL/M) 0.9 MW 0.16 PF (Cloud) 0.1MW					35 PF (UCC + CFL-M) 2MW			
Tohoku			SX-ACE(707TF, 160TB, 655TB) LX406e(31TF, Storage(4PB), 3D Vls, 2MW					~30PF, ~30PB/s Mem BW (CFL-D/CFL-M) ~3MW				100-200 PF, 100-200 PB/s (CFL-D/CFL-M) ~4MW
Tsukuba			PPX1 (82TF) PPX2 (82TF) COMA (PACS-X) (1001TF)					Cygnus 3+PF (TPF) 0.4MW				PACS-XI 100PF (TPF)
Tokyo				Oakforest-PACS (OFF) 25 PF (UCC + TPF) 3.2 MW					Post OFP 100+ PF 4.5-6.0MW (UCC + TPF)			
Tokyo Tech.				Readout/CLK 1.8 PF (PACS) 0.71MW Readout/CLK 1.8 PF (PACS) 0.71MW					BDEC 60+ PF (FAC) 3.5-4.5MW			
Nagoya				TSUBAME 3.0 (12.15 PF, 1.66 PB/s)					TSUBAME 4.0 (~100 PF, ~10PB/s, ~2.0MW)			
Kyoto				Fujitsu FX100 (2.9PF, 81TB) Fujitsu CX400 (7.74TF, 71TB) 2MW in total					20+ PF (FAC/UCC + CFL-M) up to 3MW			100+ PF (FAC/UCC+CFL-M) up to 3MW
Osaka				Cray XC40(5.5PF) + CS400(1.0PF) 1.33 MW					20-40+ PF (FAC/TPF + UCC) 1.5 MW			80-150+ PF (FAC/TPF + UCC) 2 MW
Kyushu				NEC SX-ACE NEC Express5800 (423TF) (22.4TF)					3.2PB/s, 15-25Ptop/s, 1.0-1.5MW (CFL-M)			25.6 PB/s, 50-100Ptop/s (TPF) 1.5-2.0MW
JAMSTEC				OCTPUS 1.463PF (UCC)					100+ PF (FAC/TPF + UCC/TPF) ~3MW			
ISM				SX-ACE(1.3PF, 320TB) 3MW					100PF, 3MW			
				UV2000 (98TF, 128TB) 0.3MW					2PF, 0.3MW			

Home of Nobel Prize Scientist

Prof. Takaaki Kajita

Nobel Prize in Physics 2015



- Neutrino experiments at the Kamiokande and the Super-Kamiokande



Kashiwa is Home of All Blacks !!

They stayed in Kashiwa from Sept.10-14 before RWC 2019



Overview of Supercomputers

Information Technology Center

The University of Tokyo

- Current Systems
 - Reedbush-U/H/L
 - Oakforest-PACS (OFP)
 - Oakbridge-CX (OBCX)
- Future Systems towards Society 5.0 (January-April 2021)
 - BDEC (Big Data & Extreme Computing)
 - Data Platform (DP)

Now operating 3 Systems !!

2,000+ users (1,000 from outside of U.Tokyo)

- **Reedbush (HPE, Intel BDW + NVIDIA P100 (Pascal))**
 - Integrated Supercomputer System for Data Analyses & Scientific Simulations
 - Jul.2016-Jun.2020
 - Our first GPU System, DDN IME (Burst Buffer)
 - Reedbush-U: CPU only, 420 nodes, 508 TF (Jul.2016)
 - Reedbush-H: 120 nodes, 2 GPUs/node: 1.42 PF (Mar.2017)
 - Reedbush-L: 64 nodes, 4 GPUs/node: 1.43 PF (Oct.2017)
- **Oakforest-PACS (OFP) (Fujitsu, Intel Xeon Phi (KNL))**
 - JCAHPC (U.Tsukuba & U.Tokyo)
 - 25 PF, #16 in 53rd TOP 500 (June 2019) (#2 in Japan)
 - Omni-Path Architecture, DDN IME (Burst Buffer)
- **Oakbridge-CX (OBCX) (Fujitsu, Intel Xeon Platinum 8280, CLX)**
 - Massively Parallel Supercomputer System
 - 6.61 PF, #45 in 53rd TOP 500, July 2019-June 2023
 - SSD's are installed to 128 nodes (out of 1,368)



Recently Retired Systems

Fujitsu PRIMEHPC FX10 Commercial Version of K

- Oakleaf-FX (Fujitsu PRIMEHPC FX10)
 - 1.135 PF, Apr.2012-Mar.2018
- Oakbridge-FX (Fujitsu PRIMEHPC FX10)
 - 136.2 TF, Apr.2014-Mar.2018
 - for long-time use (up to 168 hr's)



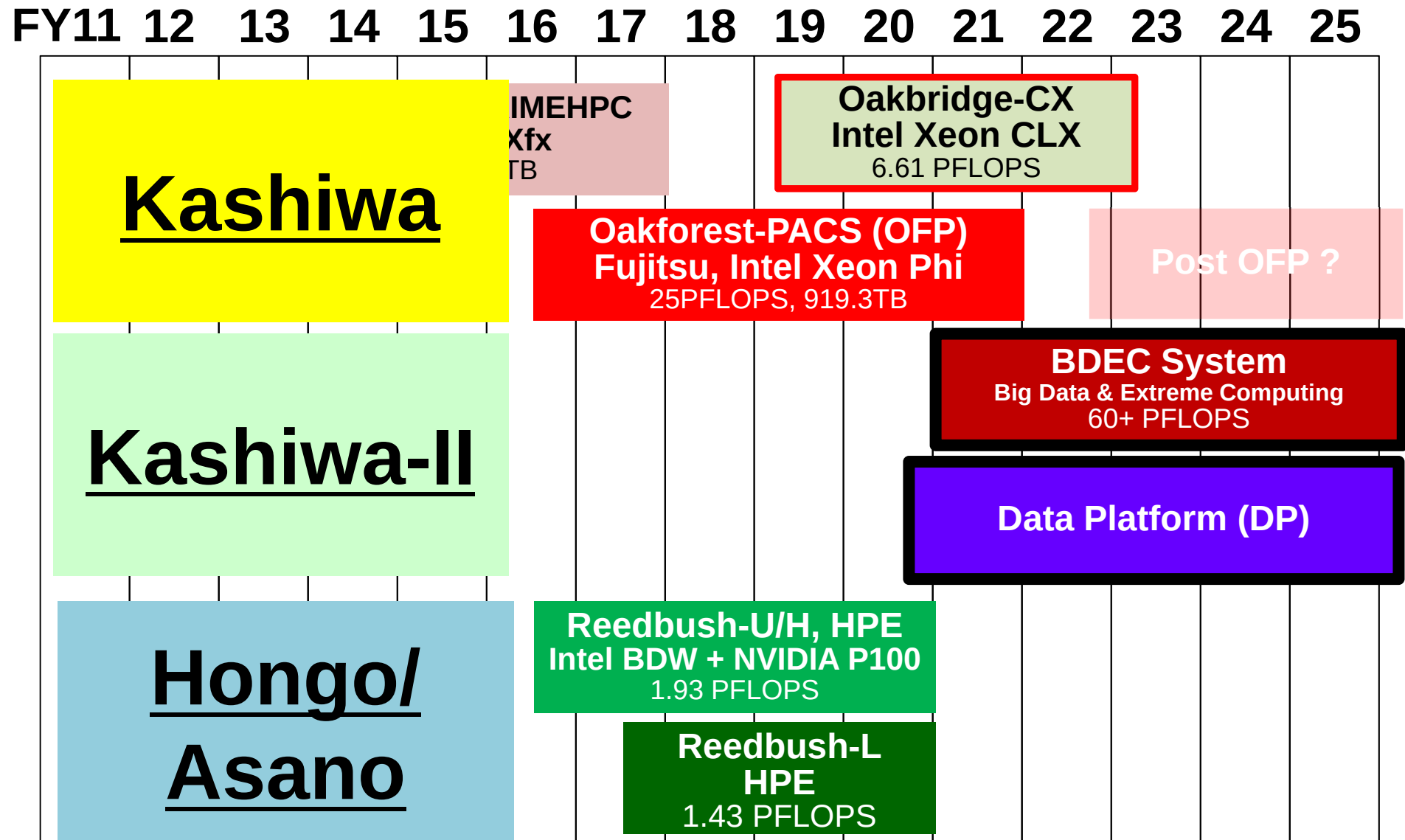
All of Our Systems will be in the Kashiwa Campus in Apr. 2021

- Asano/Hongo Campus
 - Reedbush (will be retired in March 2021)
- Kashiwa Campus: Research Complex Bldg. II
 - 1F: Oakbridge-CX (op. started in July 2019)
 - 2F: Oakforest-PACS
- Kashiwa II Campus (New Campus in Kashiwa)
 - A New Building (New Research Facility for Integration of Large-Scale Network & Supercomputing by U.Tokyo and NII) will be constructed by Fall 2020
 - BDEC (Big Data & Extreme Computing)
 - Data Platform (8-Univ's/NII/AIST Project)
 - Both starts op. in Jan.-Apr. 2021
 - ABCI by AIST (Fastest Linpack system in Ka Japan) is in the same campus

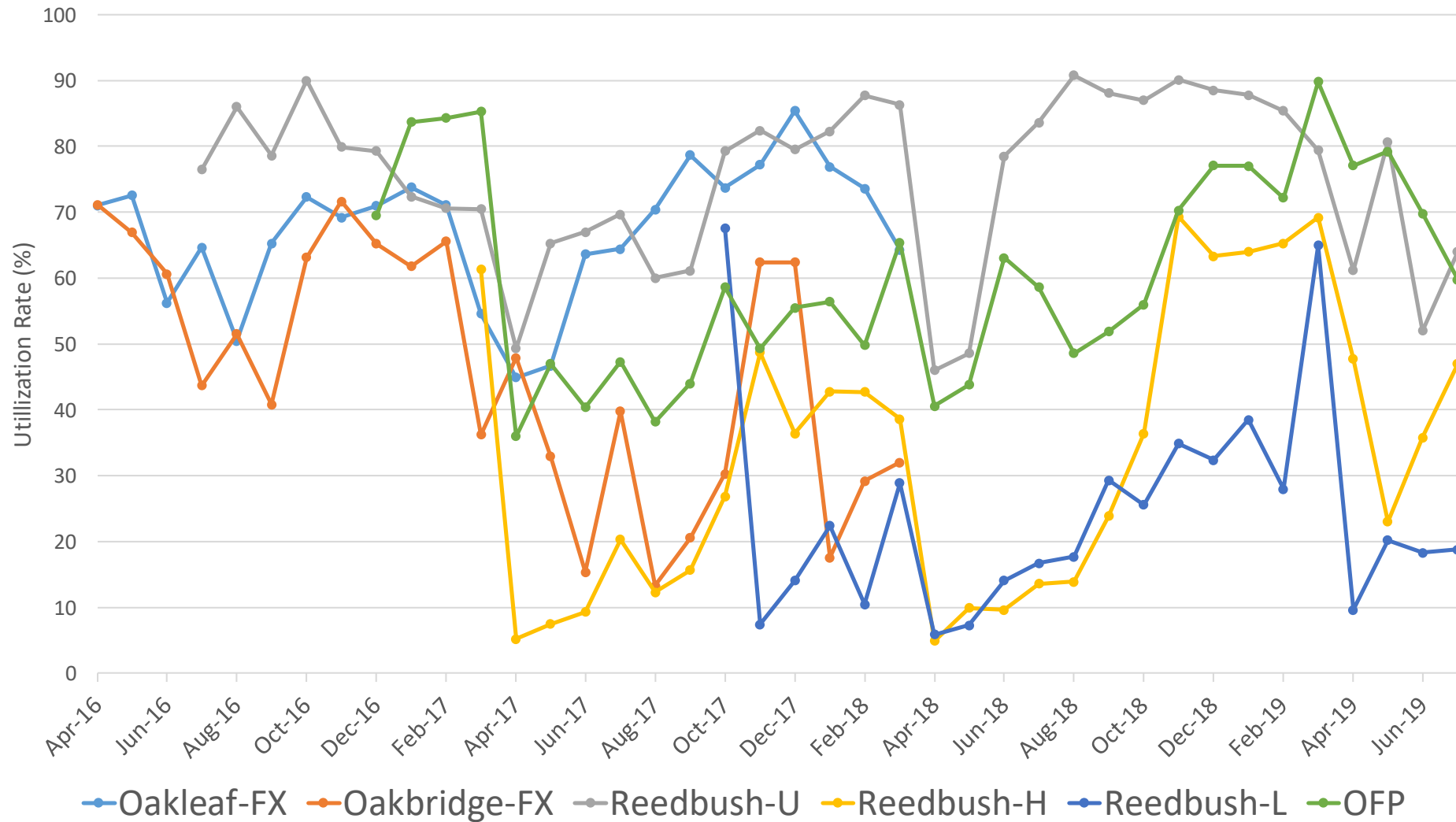


Supercomputers in ITC/U.Tokyo

2 big systems, 6 yr. cycle

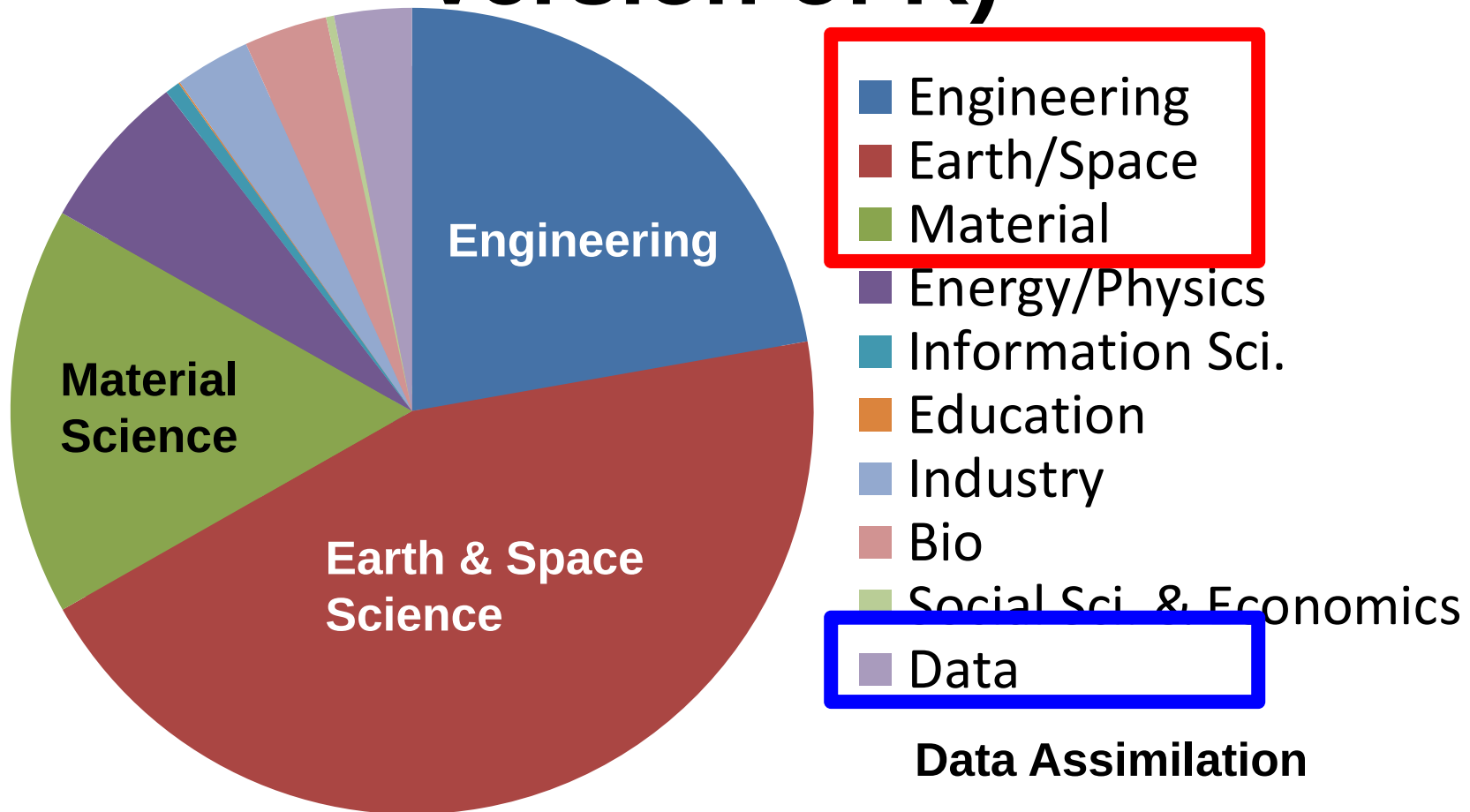


Utilization Rate (Apr. 2016 - Jul. 2019)



[R.Nakahari (ITC/U.Tokyo)]

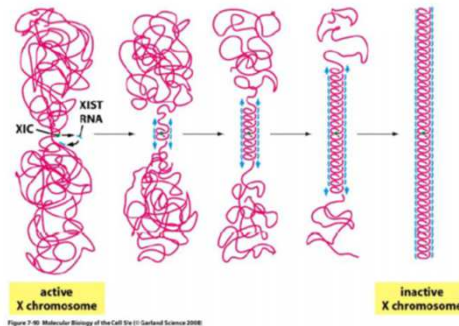
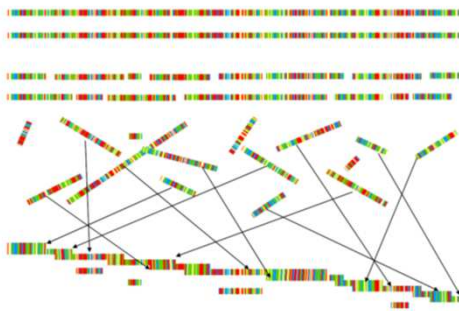
Research Area based on CPU Hours¹⁸ FX10 in FY.2017 (Commercial Version of K)



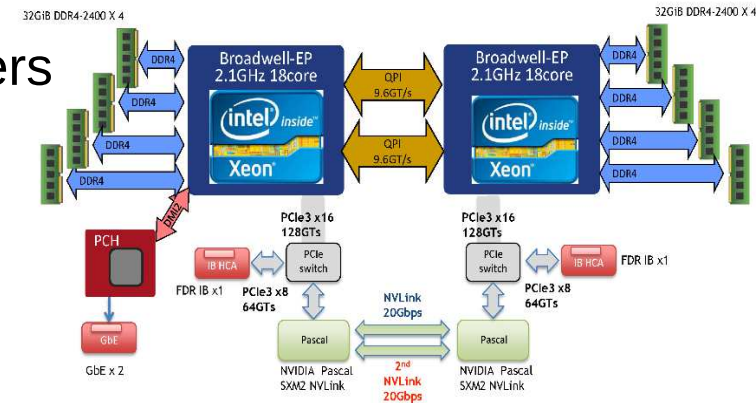
Oakleaf-FX + Oakbridge-FX

Reedbush: Our First GPU System

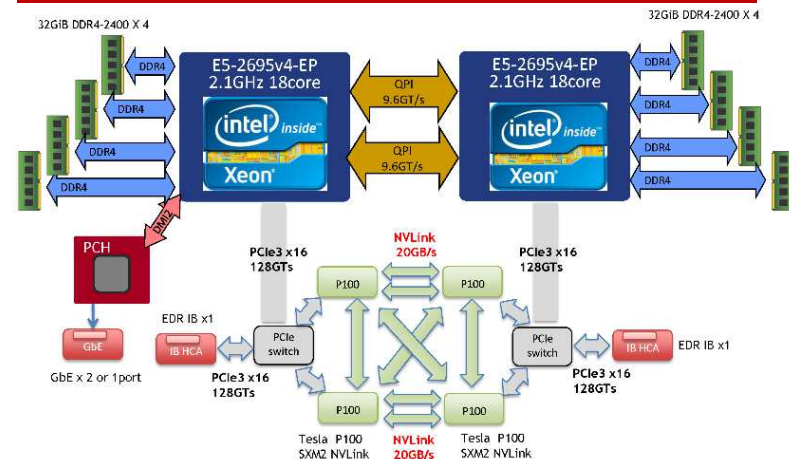
- Before 2015
 - CUDA
 - Not a Choice: We have 2,000+ users
- Reasons of Changing Policy
 - Recent Improvement of OpenACC
 - Similar Interface as OpenMP
 - New Types of Users in Data Science, Deep Learning etc.
- **Reedbush-H (our first GPU cluster) started in March 2017**



Reedbush-H: 2-GPUs /Node



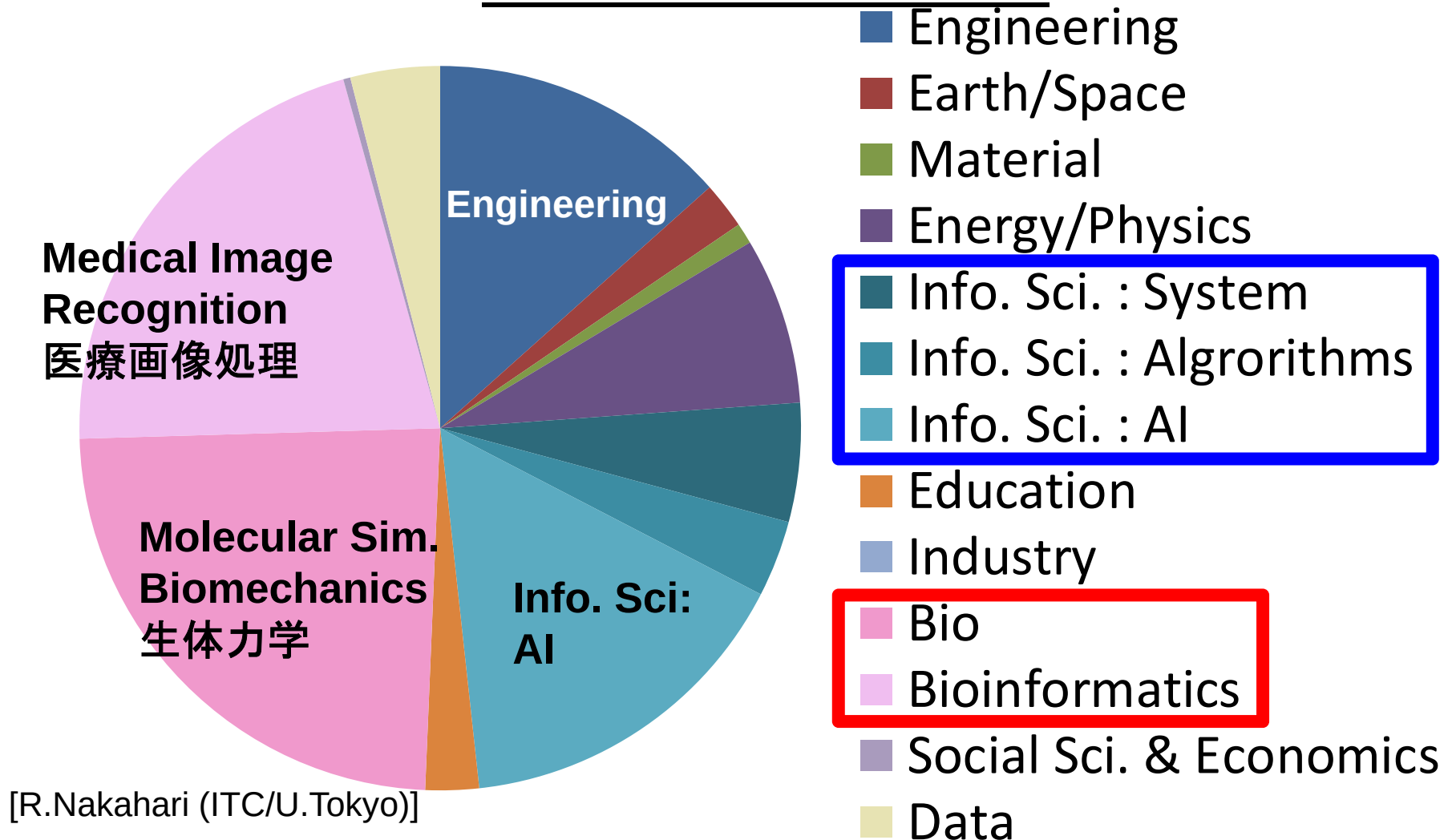
Reedbush-L: 4-GPUs /Node



Research Area based on CPU Hours²⁰

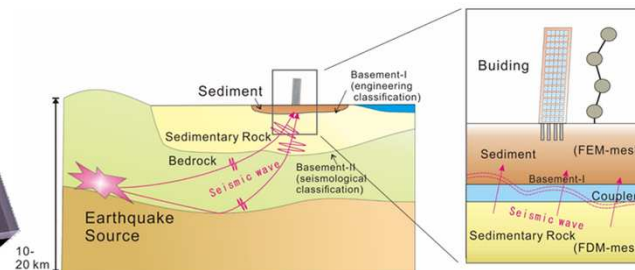
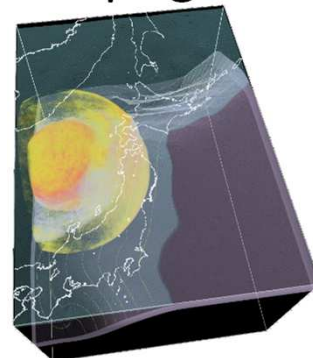
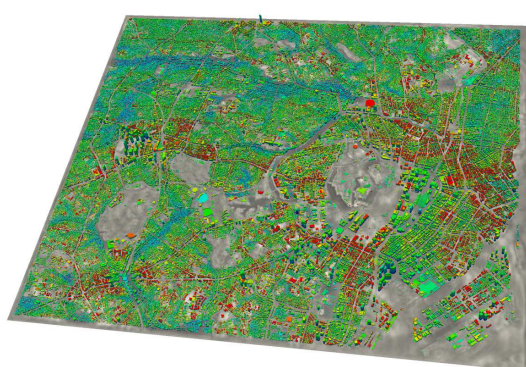
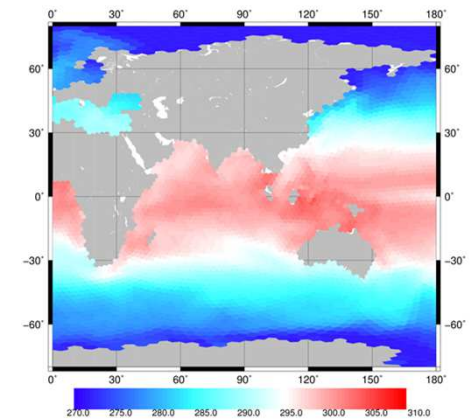
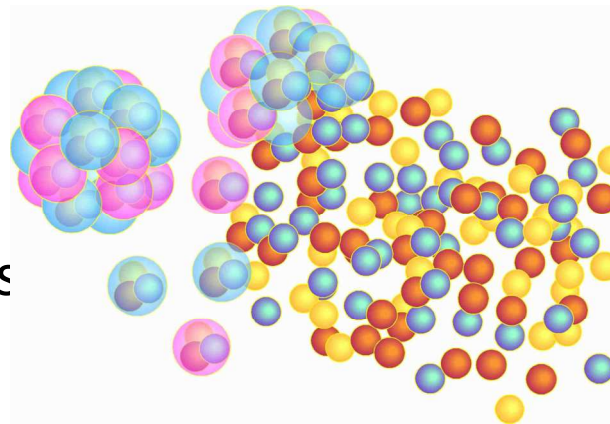
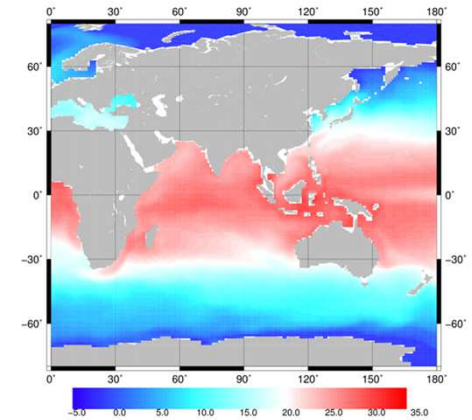
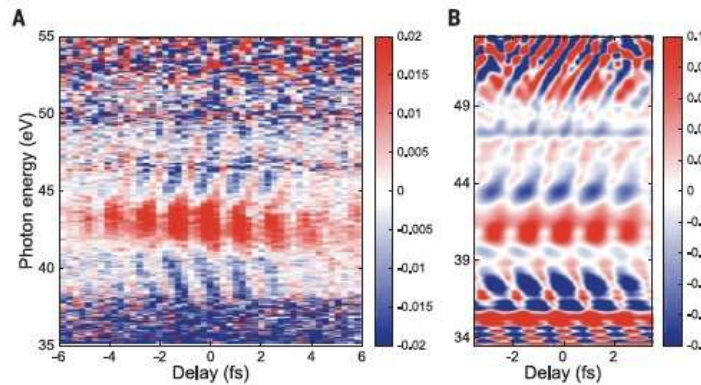
Reedbush-H in FY.2018

2-GPU's/Node

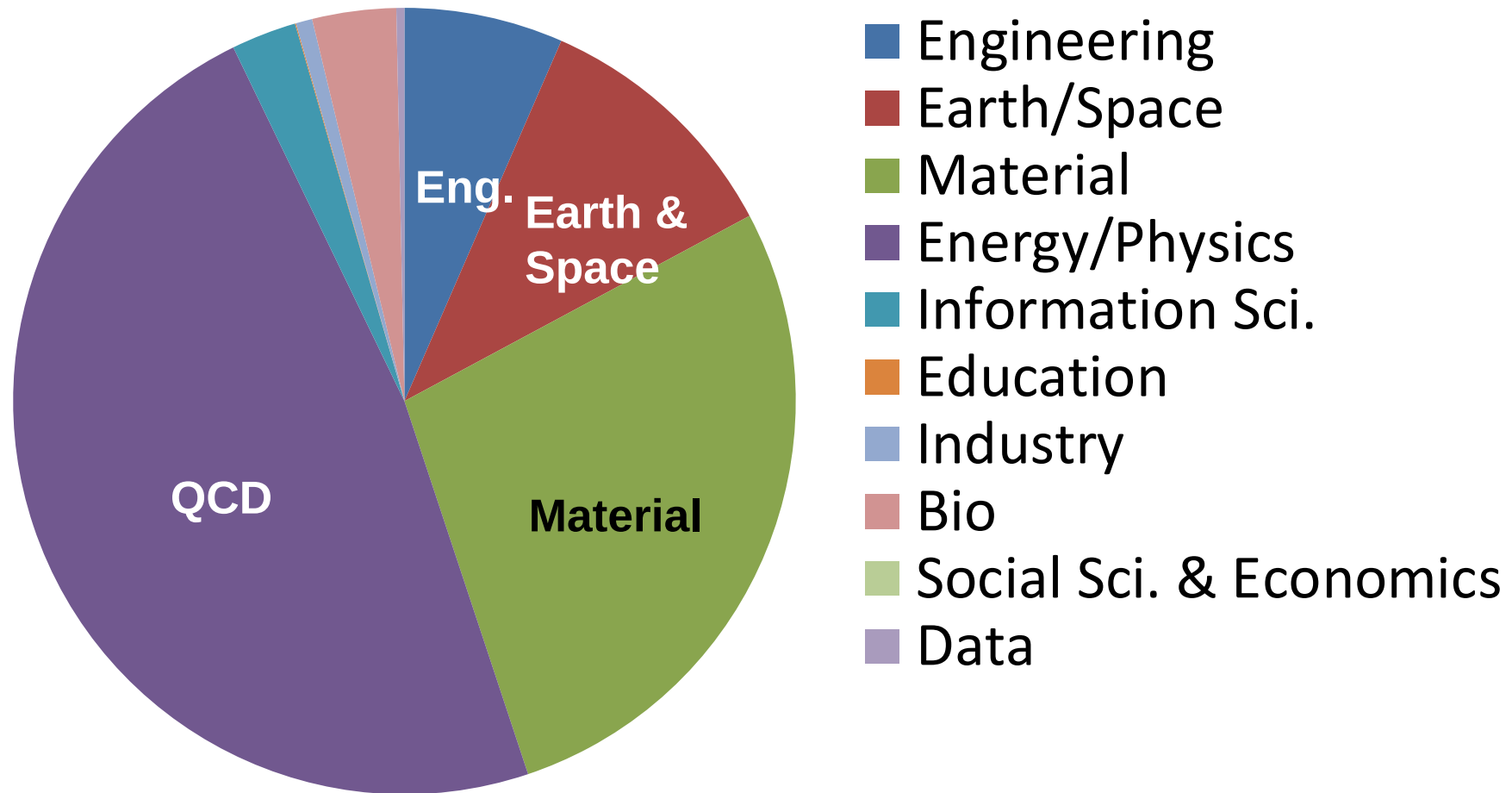


Applications on OFP

- **ARTED**
 - Ab-initio Electron Dynamics
- **Lattice QCD**
 - Quantum Chrono Dynamics
- **NICAM & COCO**
 - Atmosphere & Ocean Coupling
- **GAMERA/GHYDRA**
 - Earthquake Simulations
- **Seism3D**
 - Seismic Wave Propagation

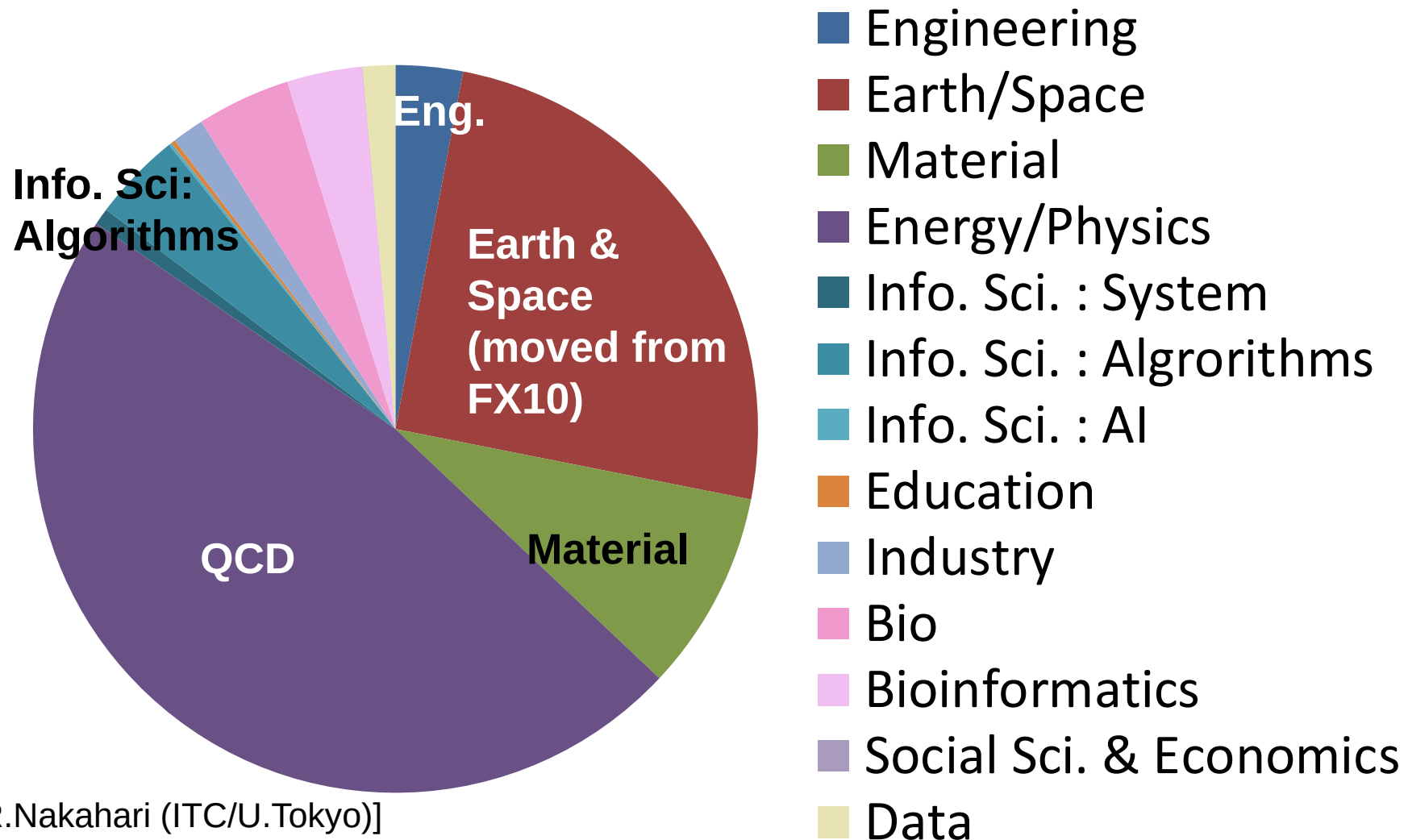


Research Area based on CPU Hours Oakforest-PACS in FY.2017



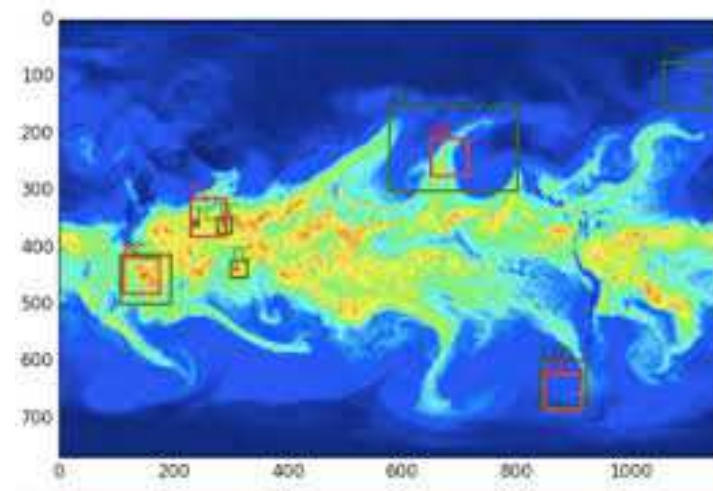
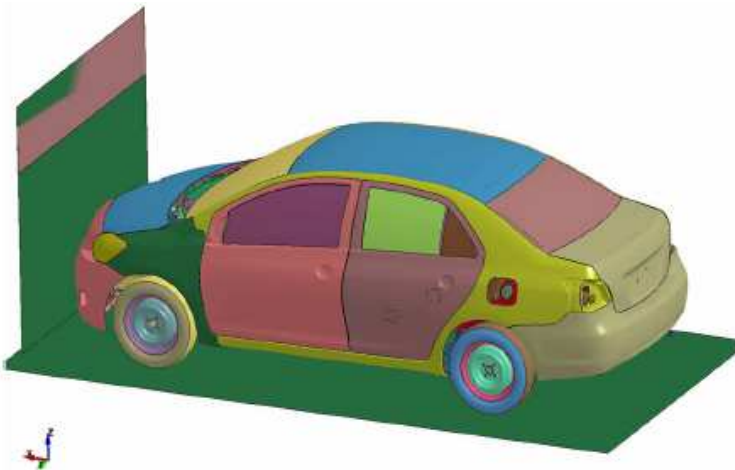
[R.Nakahari (ITC/U.Tokyo)]

Research Area based on CPU Hours Oakforest-PACS in FY.2018



Other Challenges on OFP

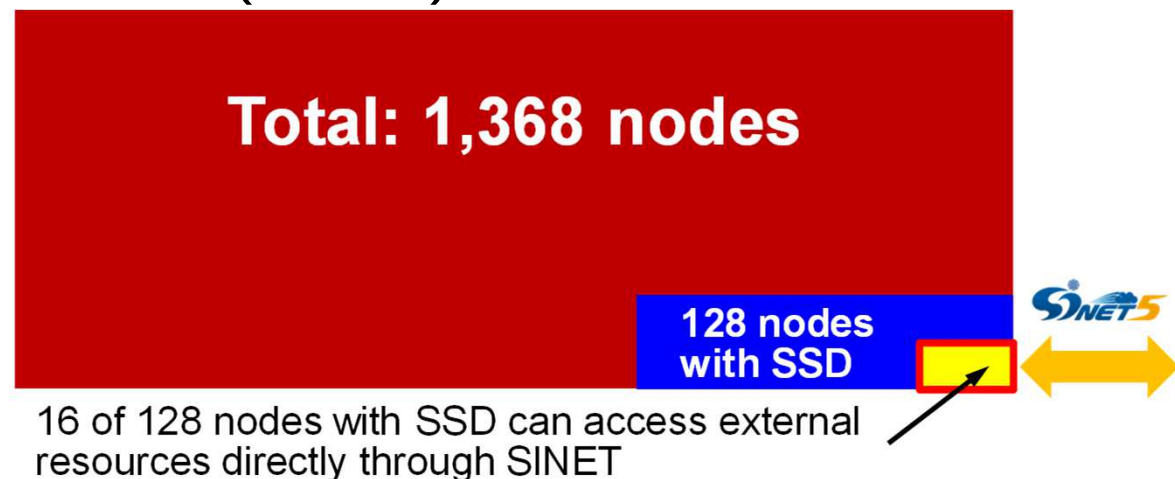
- Collaboration with JAMA
 - Japan Automobile Manufactures Association (日本自動車工業会)
 - Optimization of LS-DYNA on KNL under support by Intel (USA/France) and S/W Vendors
- Massively Parallel Deep Learning
 - TensorFlow, Caffe, and Chainer are available.



[LBNL SC17]

Oakbridge-CX (OBCX)

- Intel Xeon Platinum 8280 (Cascade Lake, CLX), Fujitsu
 - 1,368 nodes, 6.61 PF peak, 385.1 TB/sec, 4.2+ PF for HPL **#45 in 53rd Top500**
 - Fast Cache: SSD's for 128 nodes: Intel SSD, BeeGFS
 - 1.6 TB/node, 3.20/1.32 GB/s/node for R/W
 - Staging, Check-Pointing, Data Intensive Application
 - **16 of these nodes can directly access external resources (server, storage, sensor network etc.) through SINET**
 - Network: Intel Omni-Path, 100 Gbps, Full Bi-Section
 - Storage: DDN EXAScaler (Lustre) 12.4 PB, 193.9 GB/sec
 - Power Consumption: 950.5 kVA
- Operation Start: July 1st, 2019

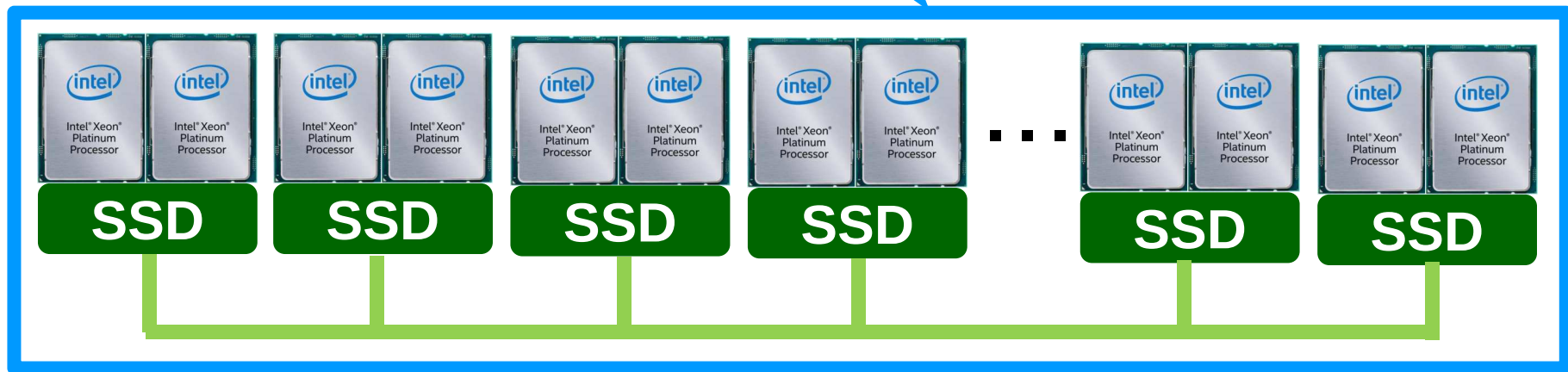


128xSSD's: Single Fast File System

Total: 1,368 nodes

128 nodes
with SSD

16 of 128 nodes with SSD can access external
resources directly through SINET



Single Fast File System with 200+ TB

Overview of Supercomputers

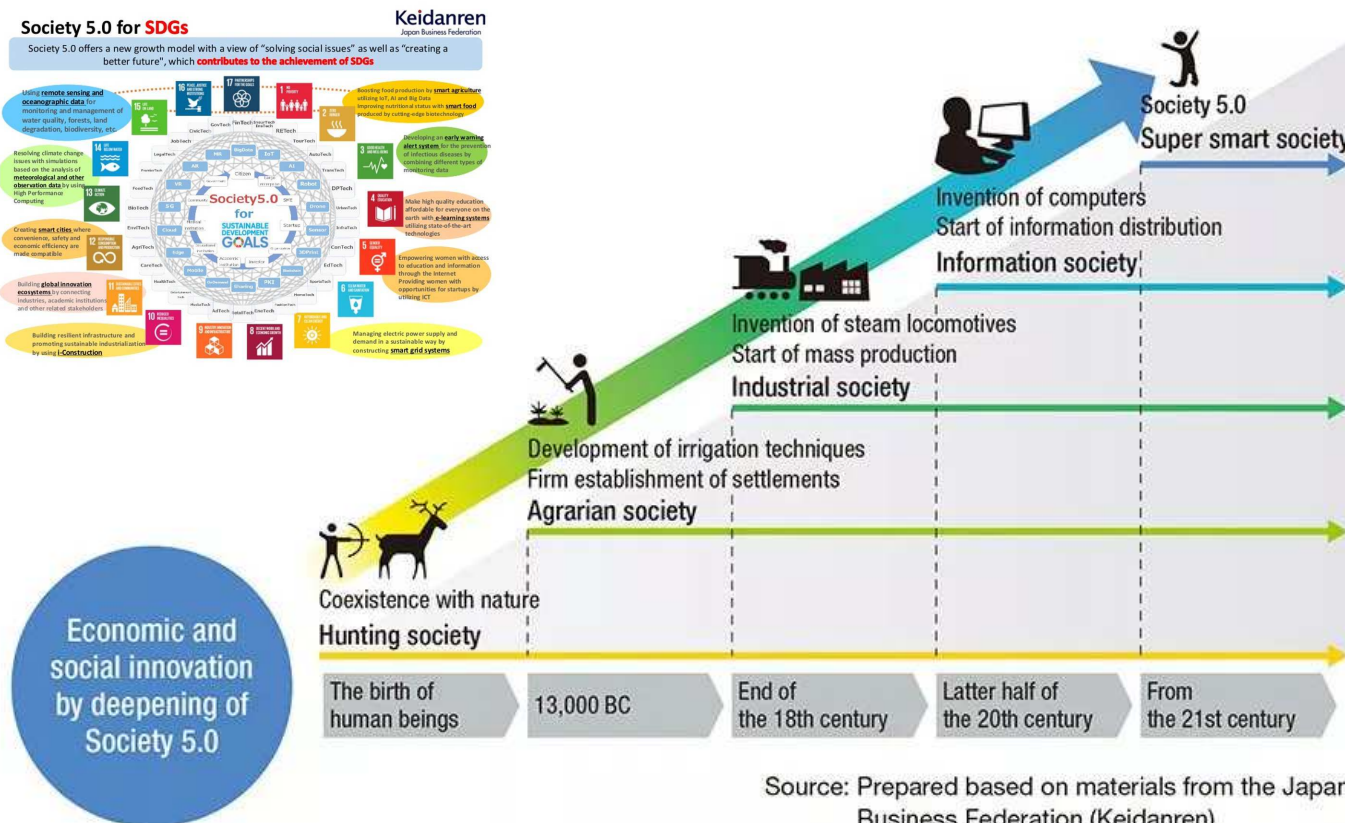
Information Technology Center

The University of Tokyo

- Current Systems
 - Reedbush-U/H/L
 - Oakforest-PACS (OFP)
 - Oakbridge-CX (OBCX)
- **Future Systems towards Society 5.0 (January-April 2021)**
 - **BDEC (Big Data & Extreme Computing)**
 - **Data Platform (DP)**

Society 5.0 (= Super Smart Society) by the Cabinet Office of Japan

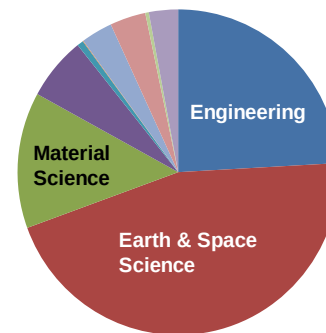
- Paradigm Shift towards Knowledge-Intensive & Super Smart Society by Digital Innovation (IoT, AI, Big Data etc.)



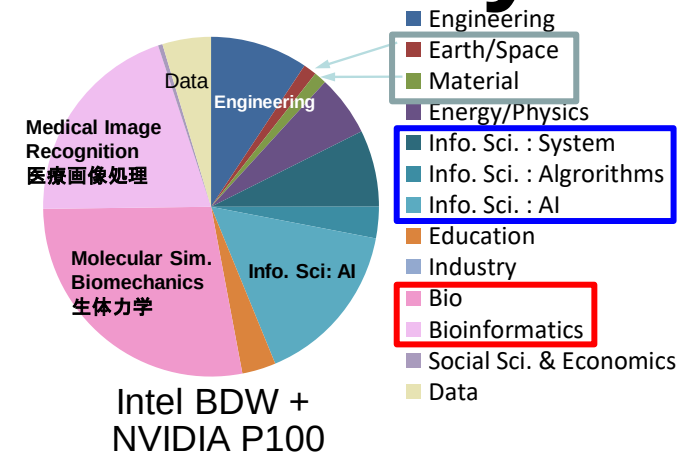
5.0: Super Smart
4.0: Information
3.0: Industry
2.0: Agrarian
1.0: Hunting

Towards Society 5.0 in ITC/UTokyo

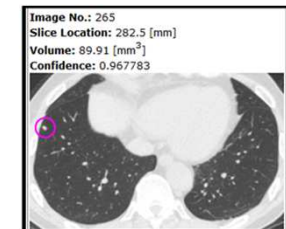
- New Types of Users
 - Mostly CSE, so far
 - Data, ML, AI etc.
 - Genome Analysis
 - Medical Image Recognition
- New Paradigm for Supercomputing
 - Data Driven Approach
 - Utilization & Analyses of Various Types of Data
 - Integration of (Simulations + Data + Learning)
 - S+D+L
- Two Platforms in Kashiwa II Campus
 - BDEC (Big Data & Extreme Computing)
 - Platform for (S+D+L)
 - Reedbush & OBCX are prototypes of BDEC
 - Data Platform (DP)
 - Both are starting in Jan.-Apr. 2021



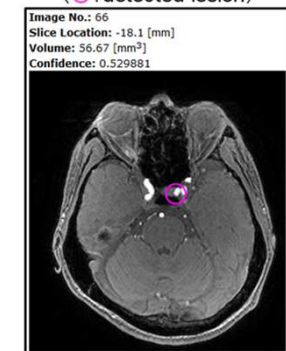
Commercial
Version of K



Intel BDW +
NVIDIA P100



Lung Nodule by Chest CT
(○: detected lesion)

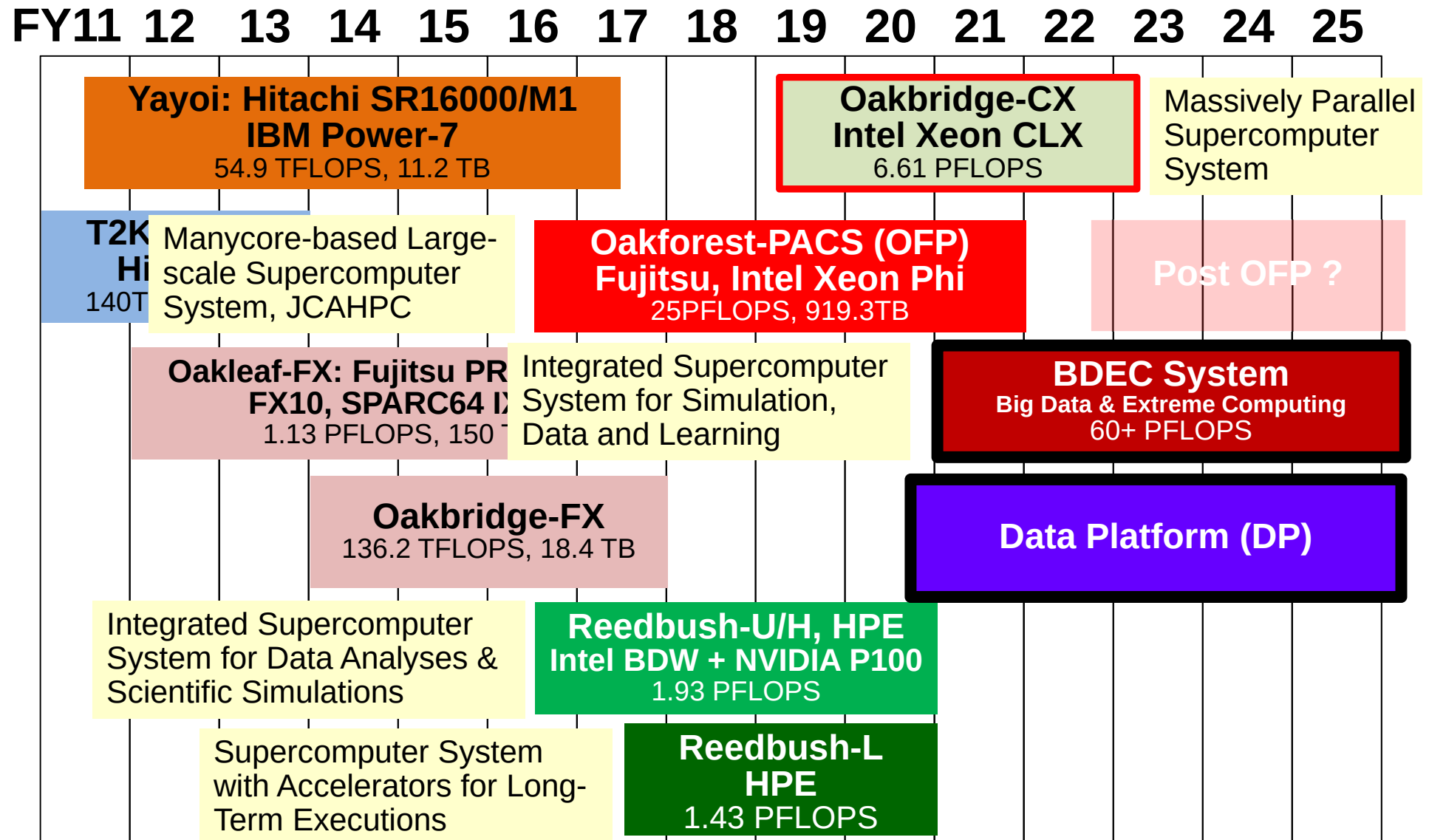


Lung Nodule by Head CT
(○: detected lesion)

[c/o Dr. Y. Nomura
(U.Tokyo Hospital)]

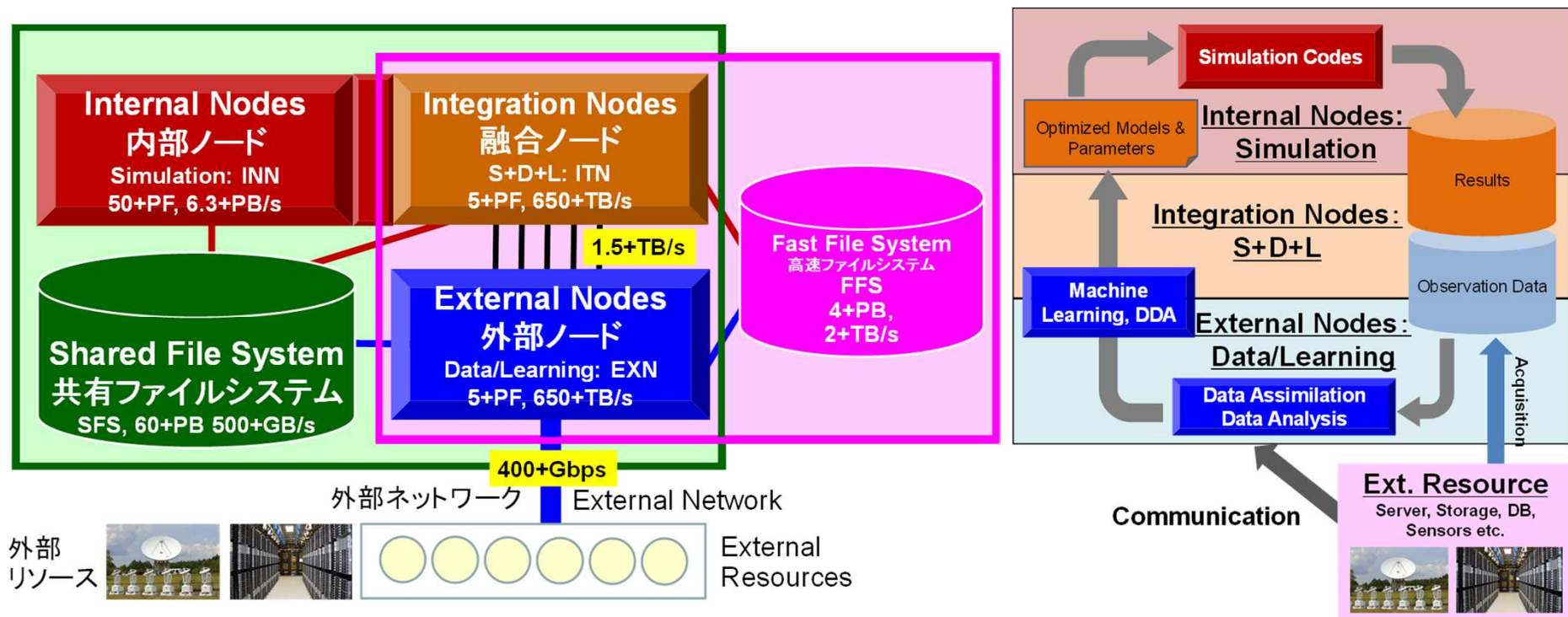
Supercomputers in ITC/U.Tokyo

2 big systems, 6 yr. cycle



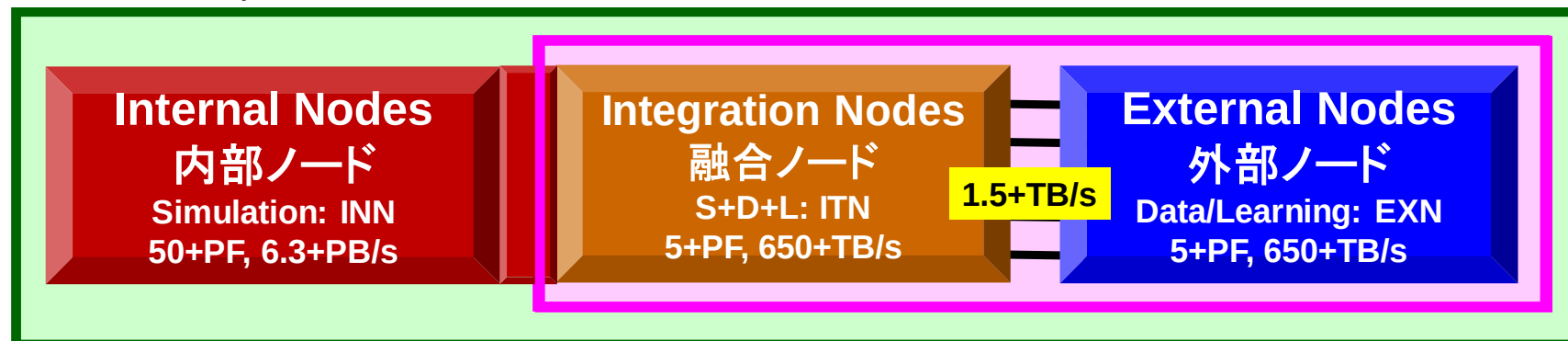
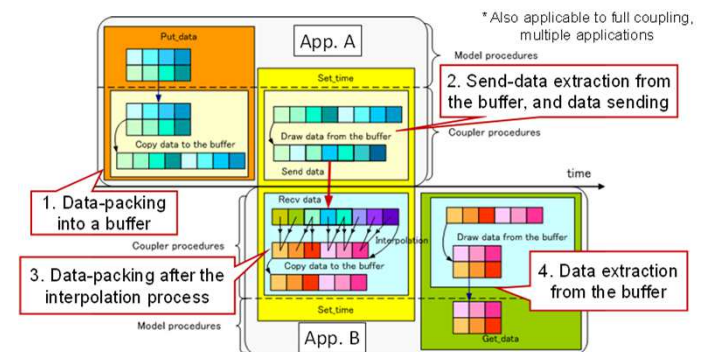
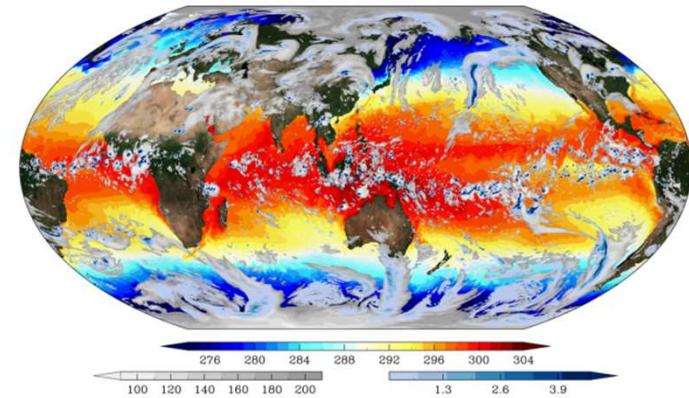
BDEC (1/2): Apr. 2021 (or later)

- 60+ PF, 3.5-4.5 MW including Cooling, $\sim 360 \text{ m}^2$
 - External Nodes for Data Acquisition/Analysis (EXN)
 - Internal Nodes for CSE/Data Analysis (INN) 50+PF, 6.3+PB/s
 - Integration Node for (S+D+L) (ITN)
 - Architecture of EXN could be different from that of (INN+ITN))
 - Shared File System (SFS) + Fast File System (FFS)



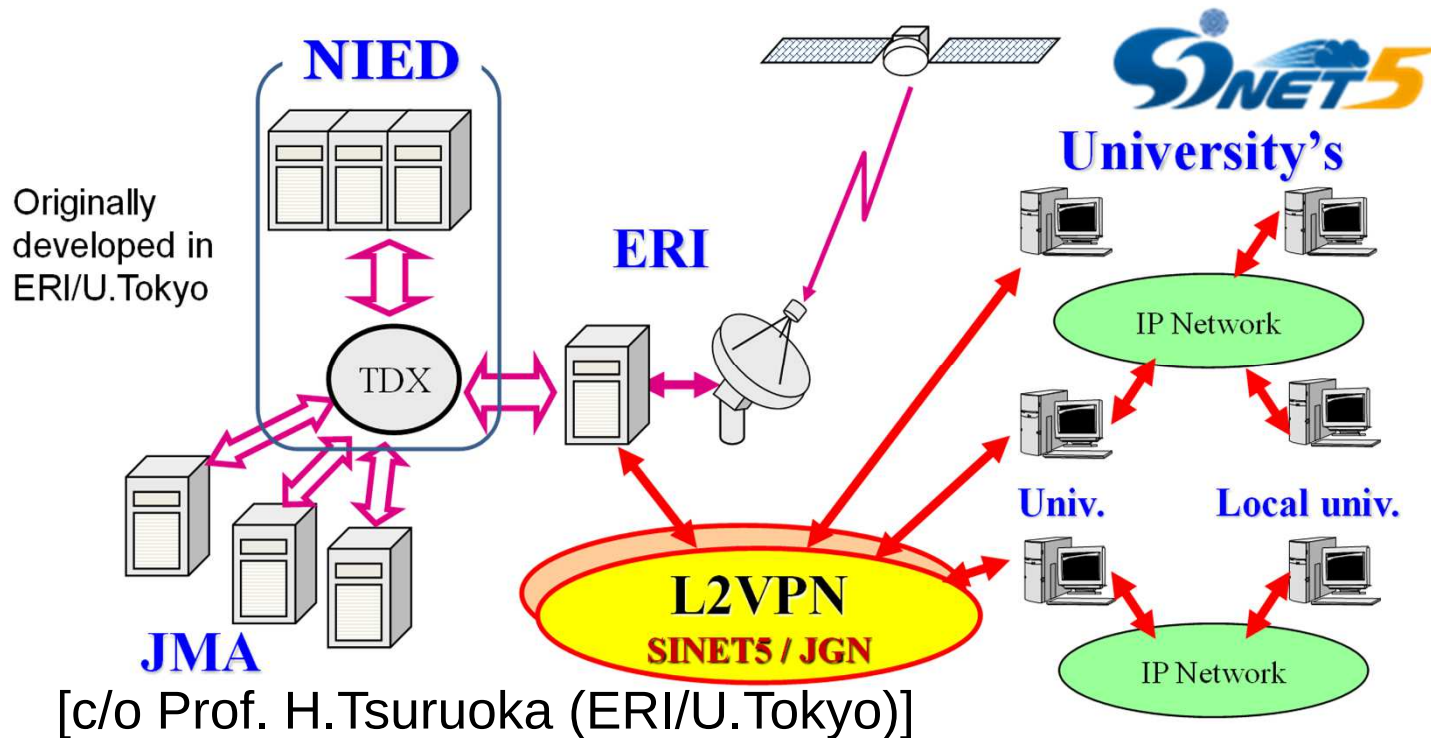
BDEC (2/2): Possible Applications

- Simulations/Data Assimilation
- Atmosphere-Ocean Simulations with Data Assimilation
 - AORI/U.Tokyo
 - RIKEN R-CCS
- Earthquake Simulations with Data Assimilation
 - ERI/U. Tokyo
- Real-Time Disaster Simulations
 - Flood, Tsunami



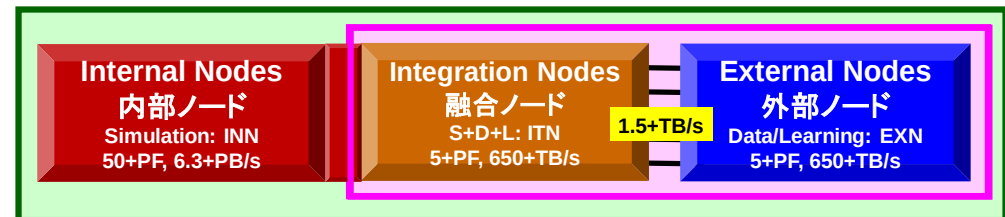
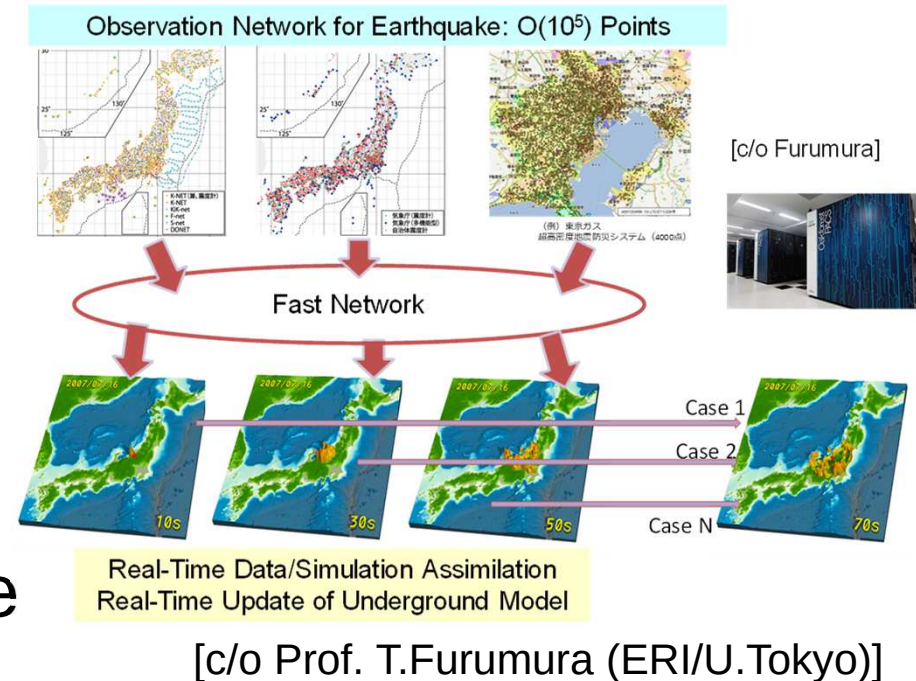
Real-Time Sharing of Seismic Observation is possible in Japan by JDXnet with SINET

- Seismic Observation Data (100Hz/3-dir's/O(10³) pts) by JDXnet is available through SINET in Real Time
 - Peta Server in ERI/U.Tokyo: O(10²) GB/day⇒EXN of BDEC
 - O(10⁵) pts in future including stations operated by industry



Real-Time Earthquake Simulation with Data Assimilation

- **EXN**: Real-Time Data Acquisition through JDXnet
- **ITN**: Real Time Data Analyses/Assimilation using Observed Data on the FFS & Controlling the Entire Program, Parameter Optimization
- **INN**: Large-Scale Seismic Simulations
- Improvement of the UG Model in Normal Operations
 - by Obs. + Simulations + Data Assimilations + ML



h3-Open-BDEC

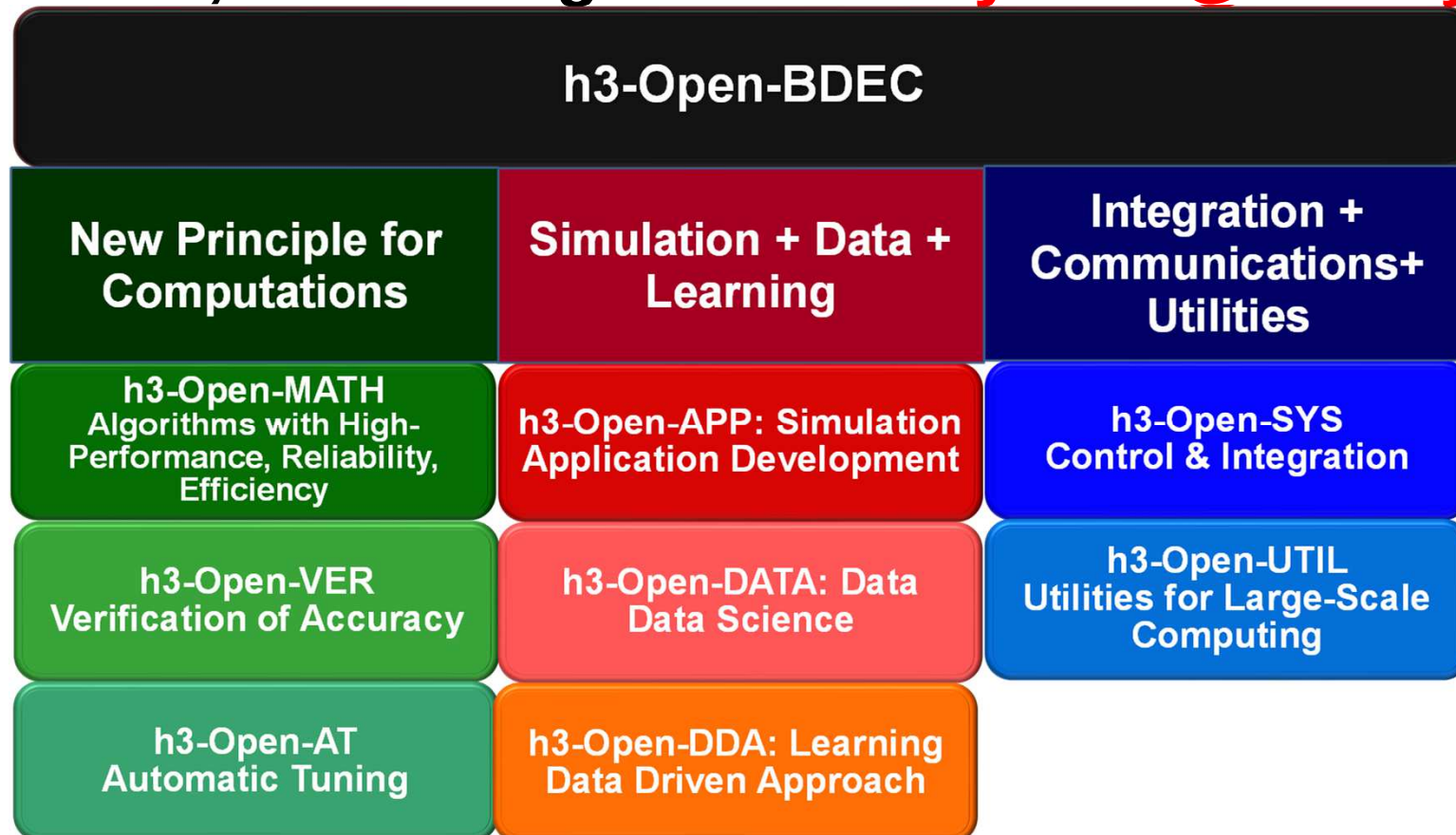
- Towards the end of Moore's law, we need to develop not only new HW, but also new algorithms & appl's.
- Integration of (Simulation + Data + Learning) (S+D+L)
- h3-Open-BDEC
 - Software Infrastructure for (S+D+L)
 - to extract the maximum performance of the supercomputers with minimum energy consumption and minimum computation time
- Target H/W Platform for (S+D+L): BDEC System
- Adopted as “JSPS Grant-in-Aid for Scientific Research (S)” during FY.2019-2023 (PI: Kengo Nakajima)
 - Innovative Method for Computational Science by Integrations of (Simulation + Data + Learning) in the Exascale Era
 - 152.7M JPY= 1.41M USD

h3-Open-BDEC

Hierarchical,
Hybrid,
Heterogeneous

Big Data &
Extreme
Computing

Extension of ppOpen-HPC for Integration of
(Simulation + Data + Learning) in the Exa/Post
Moore Era, Initial Target: **BDEC System@U.Tokyo**



Data Platform (DP)

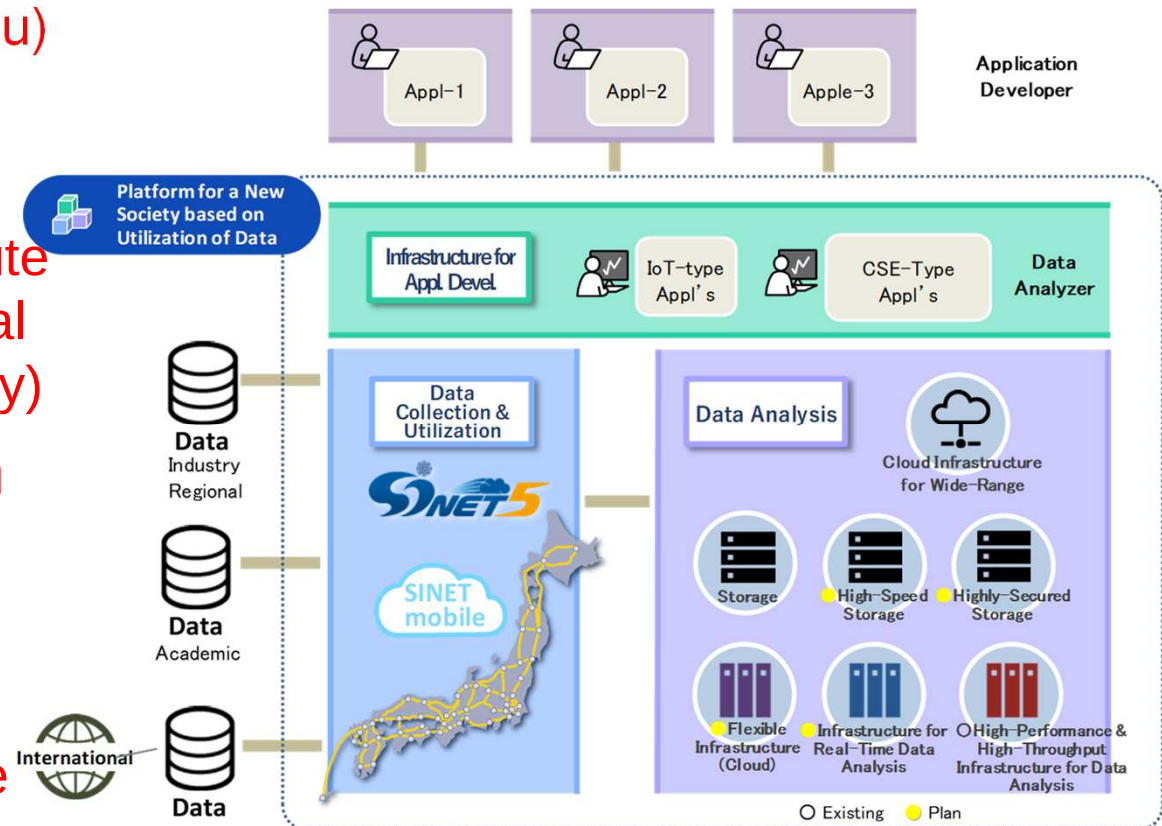
- Platform for Utilization of Data towards Society 5.0
- Project supported by Japanese Government

- Organization: National Univ's and National Lab's

- 8 National Univ's (Tokyo, Hokkaido, Tohoku, Tokyo Tech, Nagoya, Kyoto, Osaka, Kyushu)
- NII (National Institute of Informatics)
- AIST (National Institute of Advanced Industrial Science & Technology)

- Starting Operation in January 2021 (or later)

- In the Same Building/Room where the BDEC locates



BDEC & DP

- BDEC

- HPC System with Capabilities of Data Analyses/Learning

- 60+ PF Total

- DP

- Large-scale Cloud + Storages

- 20-30 PF (DP-base)
 - 30-50% of BDEC

- More focusing on Analyses & Utilization of Data

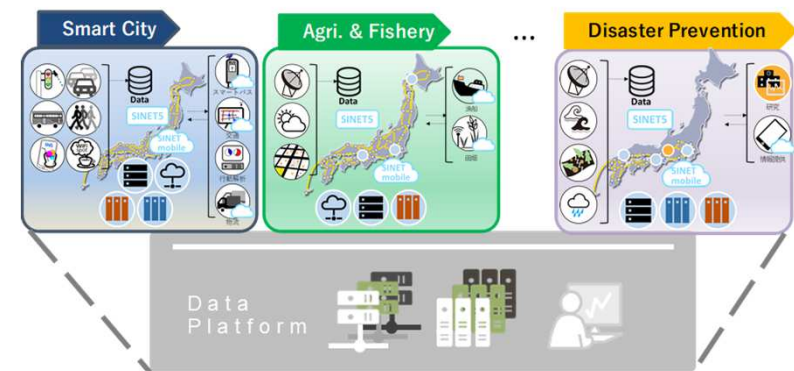
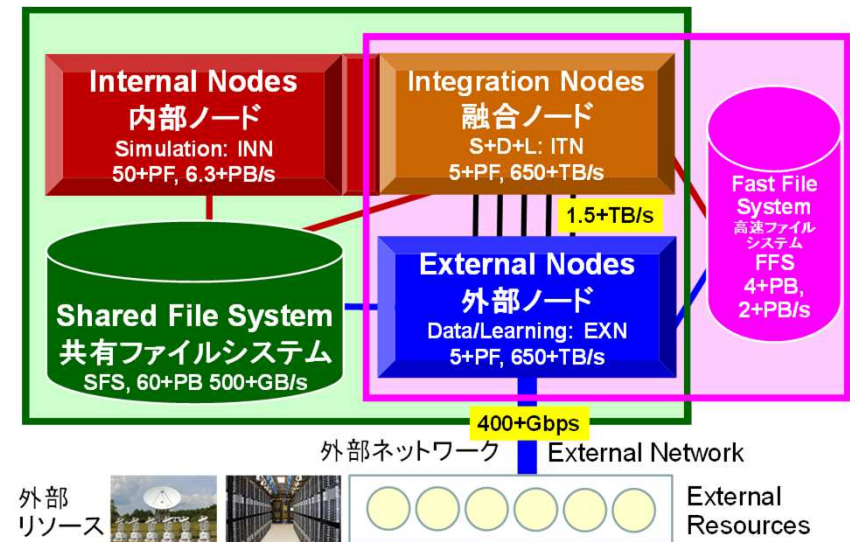
- Computing facility is similar to the EXN of BDEC

- more flexible and more secure

- On-demand Configuration

- Resource Mgmt. & Scheduling

- Kubernetes, OpenStack, ...
 - Slurm, PBS, ...



Current Plan

- Schedule
 - Both of DP and BDEC will start operations in **Jan-Apr. 2021** in the Same Room in the Same Building (Kashiwa II Campus)
 - Individual/Separate Procurement due to Restriction of Budgets
- Development of software (e.g. h3-Open-BDEC) started
 - Research Collaborations are welcome
- BDEC-DP (Next Page)
 - Shared File System (SFS) of BDEC must be available from DP: Baseline
 - Further developments for stronger coupling between DP/BDEC are expected after starting op. in 2021

Shared File System (SFS) of BDEC must be available from DP

