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Supercomputer Fugaku and new achievement using Fugaku and AI technologies for high-resolution, real-time tsunami inundation prediction

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FUJITSU LIMITED

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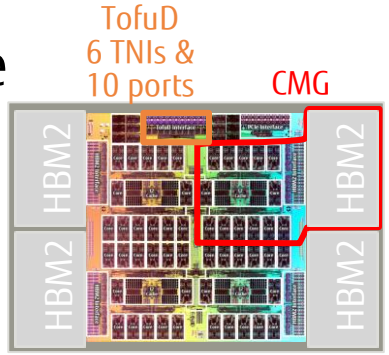
Outline

- Supercomputer Fugaku
  - Fugaku features
  - Benchmark results
- HPC x AI
  - High-resolution, real-time tsunami inundation prediction
- Summary

Fugaku Features

Node architecture

Single socket 3.3 TF
Arm CPU “A64FX”



Spec.		Note
Node	A64FX CPU x 1	Armv8-A, SVE
Cores	48	for user computation
Freq.	2.2 / 2.0 GHz	via API to change
SIMD	512 bits, 2x FMA	per core
L1D	64KiB, 4way	per core, 256 / 282GB/s
LL(L2)	8MiB,16way	per CMG, 1.0 / 1.1TB/s
Memory	32GiB (HBM2 x4)	per node, 1024GB/s

System architecture

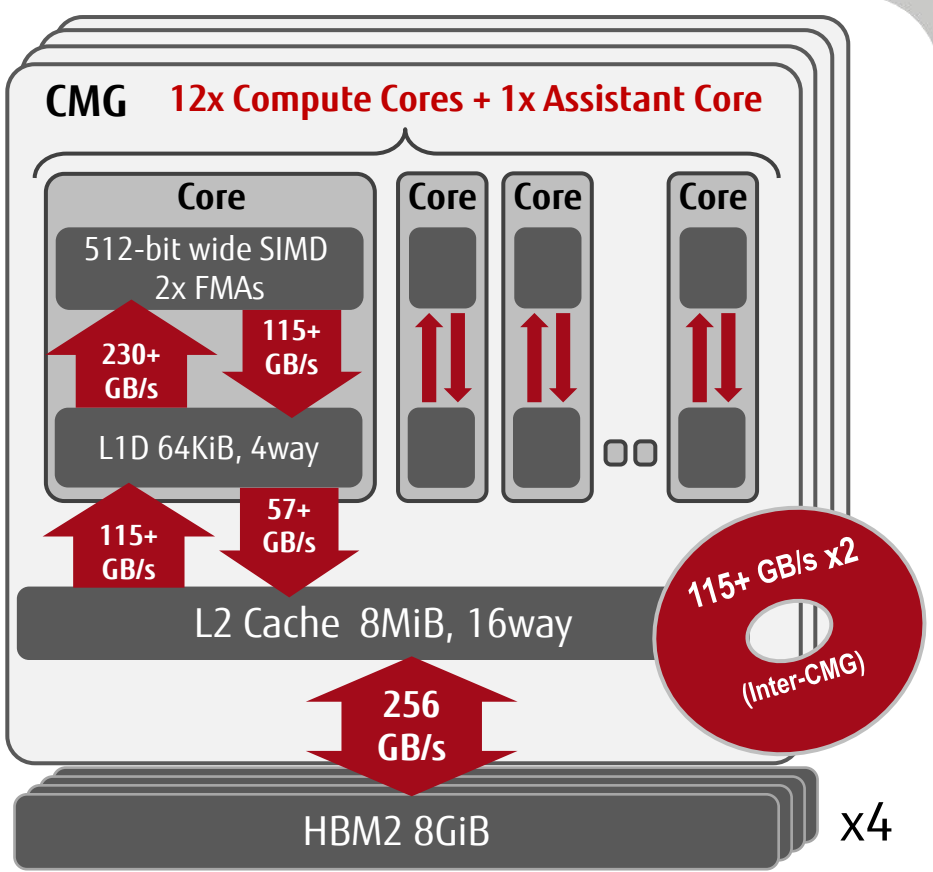
432 racks

Spec.		Note
Number of nodes	158,976	1 CPU / node
Interconnect	TofuD	24 x 23 x 24 x 2 x 3 x 2
		HW barrier & reduction
Peak flops	537.2 PF	Boost mode (2.2GHz)
	488.4 PF	Normal mode (2.0GHz)
Theoretical mem BW	162.8 PB/s	

Fujitsu-designed CPU Core w/ High Memory Bandwidth

- A64FX out-of-order controls in cores, caches, and memories achieve superior throughput
  - DP performance:
    - 2.7+ TFLOPS, >90%@DGEMM
  - Memory BW:
    - 1024 GB/s, >80%@STREAM Triad

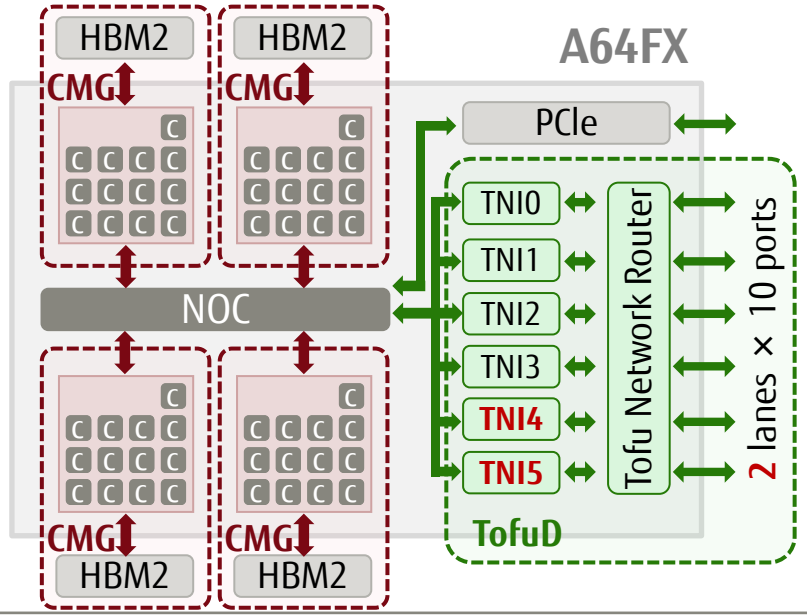
BW and calc. perf.	A64FX	B/F
DP floating perf. (TFlops)	2.7+	-
L1 data cache (TB/s)	11+	4
L2 cache (TB/s)	3.6+	1.3
Memory BW (GB/s)	1024	0.37



A64FX Tofu Interconnect D

- Integrated w/ rich resources
  - Increased TNIs achieves higher injection BW & flexible comm. patterns
  - Increased barrier resources allow flexible collective comm. algorithms
- Memory bypassing achieves low latency
  - Direct descriptor & cache injection

	TofuD spec.
Port bandwidth	6.8 GB/s
Injection bandwidth	40.8 GB/s
	Measured
Put throughput	6.35 GB/s
Ping-pong latency	0.49~0.54 μs
One hop latency	Approx. 80 ns



TOP500 & HPCG @ ISC21

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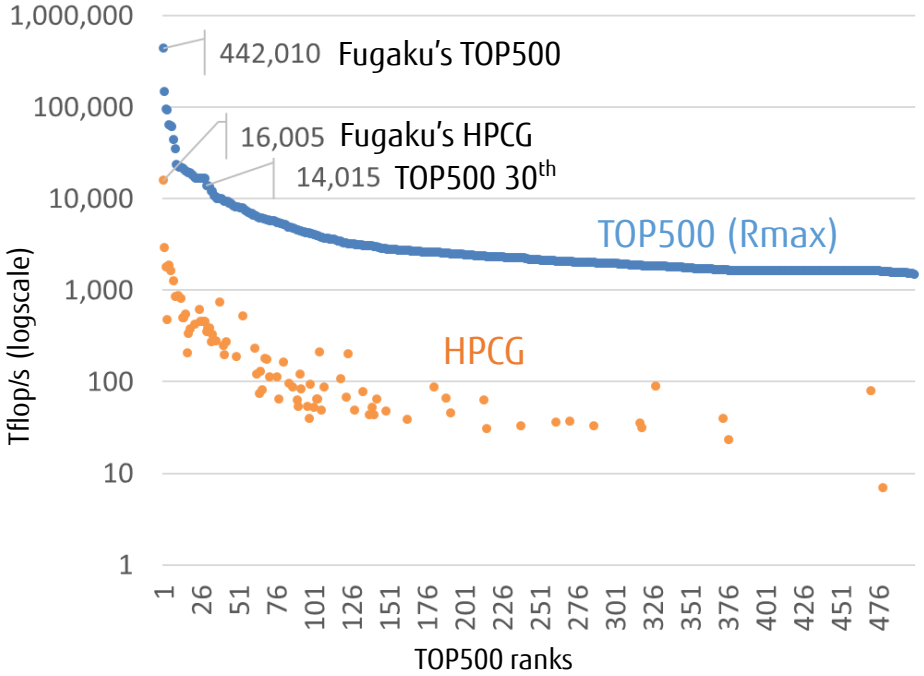
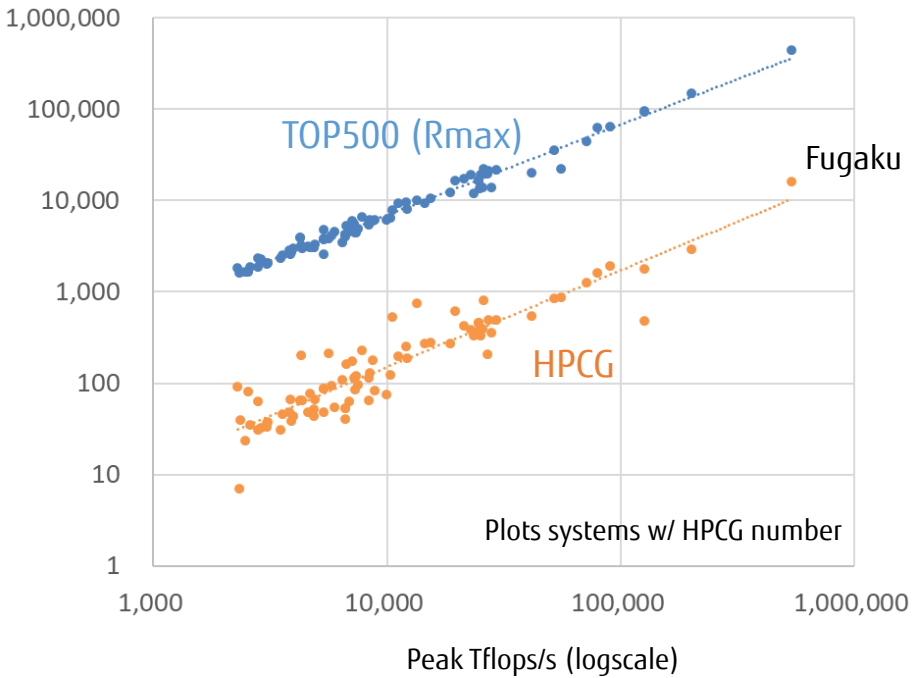
TOP500 and HPCG as Bookends

- Fugaku's HPCG > TOP500 30th Rmax



Fugaku's HPCG performance is beyond the trend curve



An AI technology for high-resolution, real-time tsunami inundation prediction

Background

- The 2011 Great East Japan Earthquake caused enormous damage due to the huge tsunami, and many issues remained from the perspective of acquiring and utilizing information for efficient evacuation.
- In tsunami prediction technology, there is an urgent need to develop technology to quickly obtain more accurate and detailed prediction information in order to reduce damage caused by inappropriate evacuation behavior.
- Conventional tsunami forecasts have mainly been related to coastal tsunami heights, but for safe evacuation, tsunami inundation forecast is also required.

Acknowledgment: This research is being conducted on “Fugaku" (hp200201, hp210220). We use the data of the Cabinet Office Nankai Trough Megathrust Earthquake Model Study Group.

Expansion of tsunami observations after the earthquake

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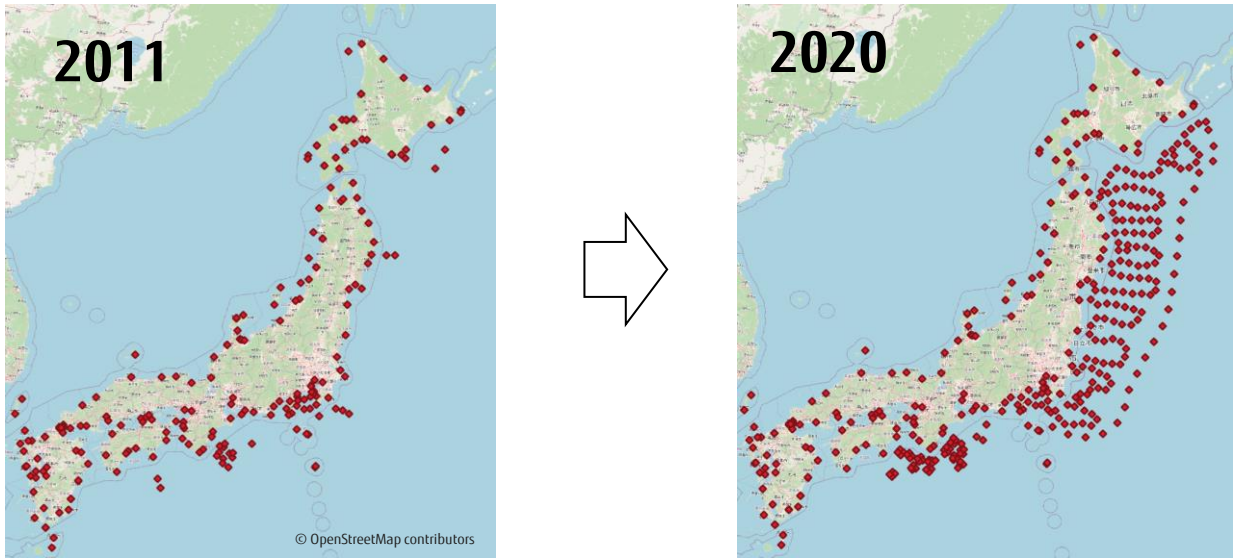
- Since the Great East Japan Earthquake, the tsunami observation network in Japan has been widely deployed, and technological development of highly accurate tsunami prediction in coastal areas using real-time offshore tsunami observation data is being actively promoted.



From Headquarters for Earthquake Research Promotion Homepage

This research

富岳

Supercomputer “Fugaku”

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Supercomputer that has become tens of times faster in 10 years after the earthquake

Artificial intelligence that has progressed significantly 10 years after the earthquake

New technology for high-resolution tsunami inundation prediction that runs on a PC

Tsunami prediction AI

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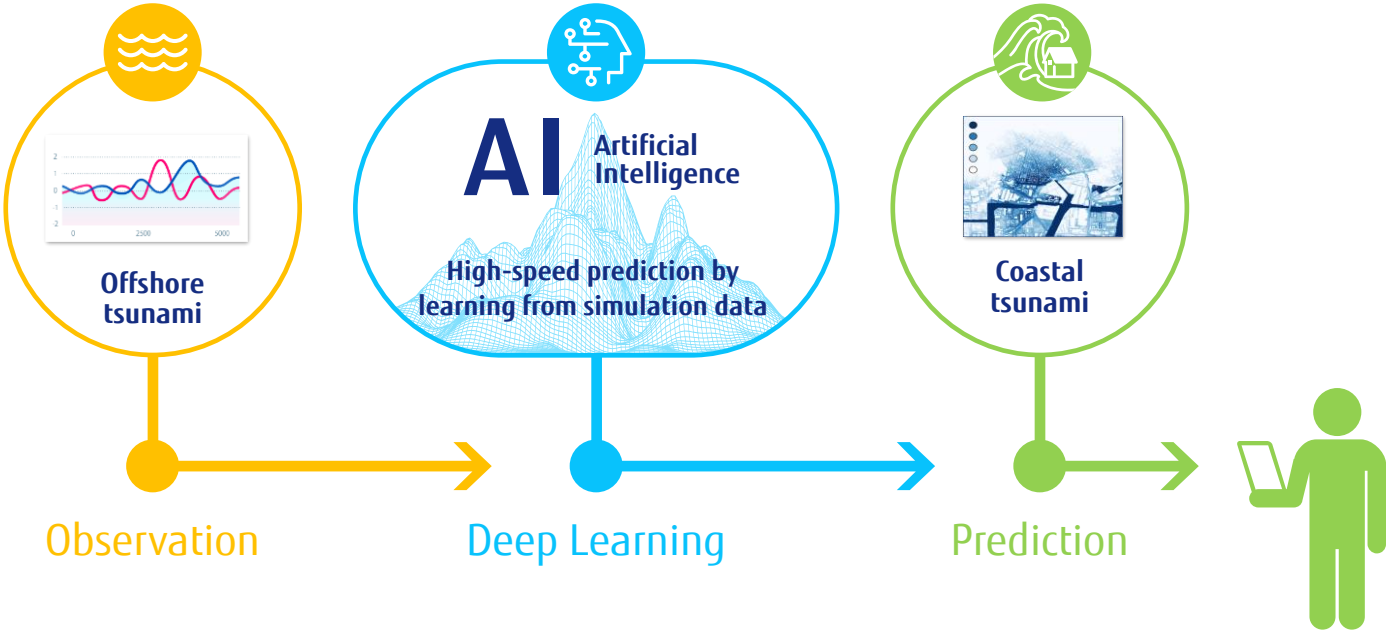
- By inputting the tsunami waveform observed offshore into the AI model, it will be possible to predict the inundation situation in the coastal area with a high spatial resolution of 3 m before the arrival of the tsunami.



Generation of tsunami forecast AI on Fugaku

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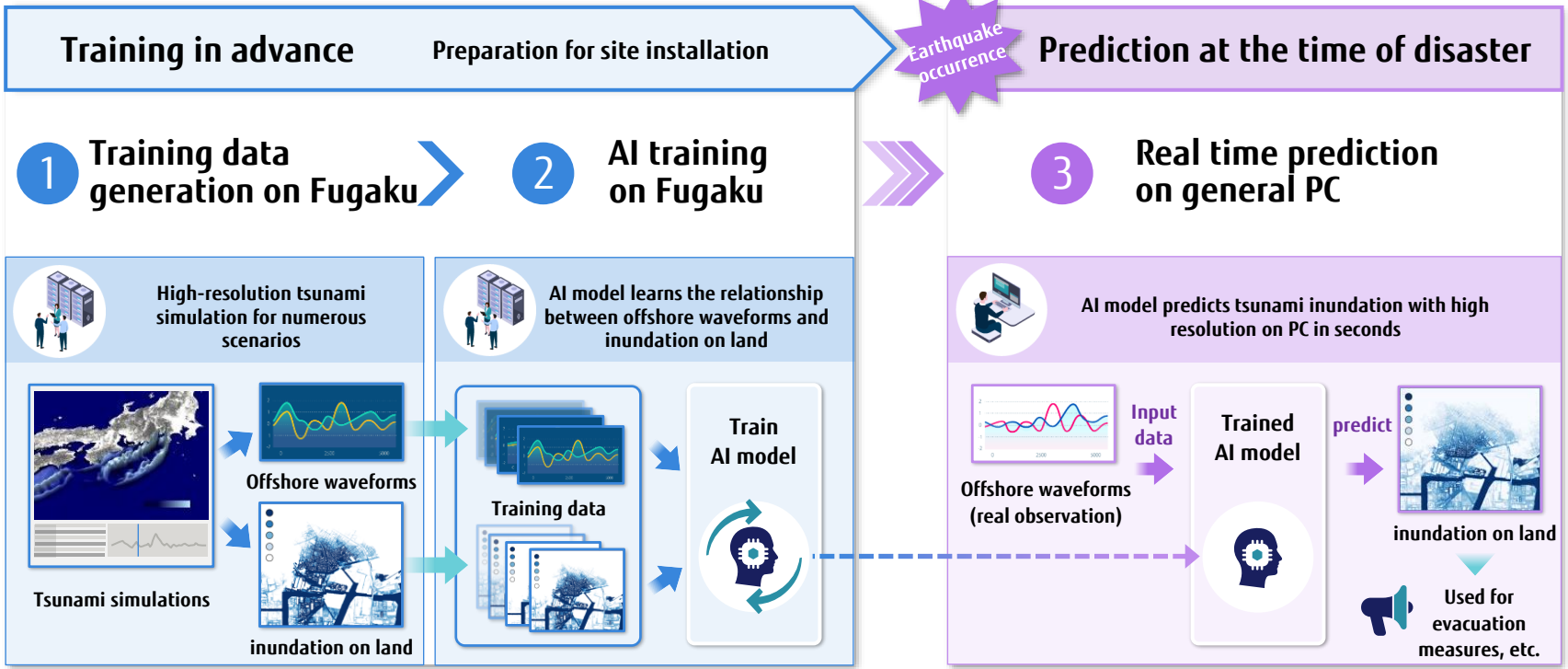
- 20,000 high-resolution tsunami simulations were carried out using the supercomputer “Fugaku". An AI model was constructed using these simulation results about the offshore tsunami waveforms and the inundation conditions in the coastal areas as training data.



Comparison with the conventional method

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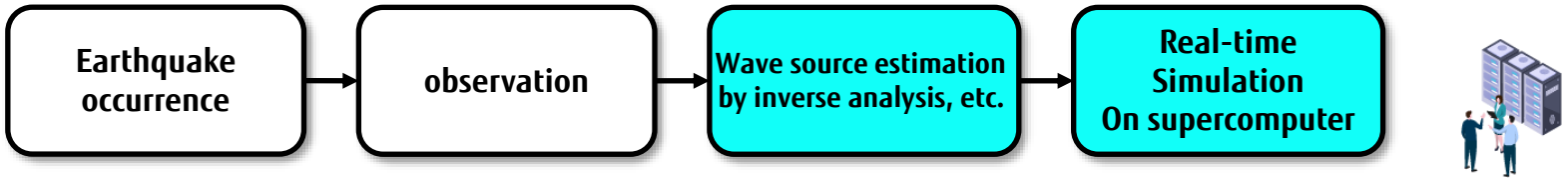
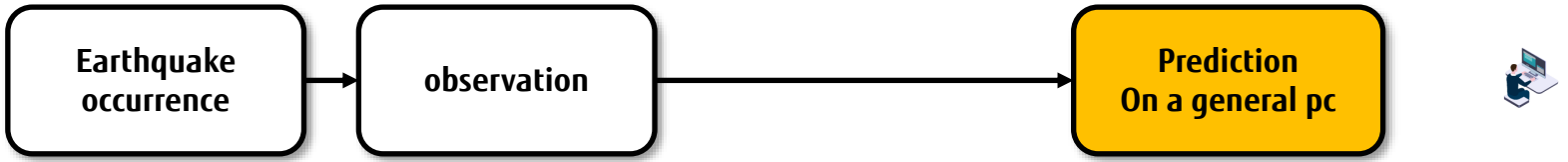
- The AI model learned in advance using “Fugaku" can be executed in a few seconds even on a general personal computer, making it easier to build a real-time inundation prediction system that previously required a supercomputer.

Before (conventional method)



◆ Supercomputer is required at the time of disaster to predict flooding (e.g., Oishi et al., 2015, GRL)

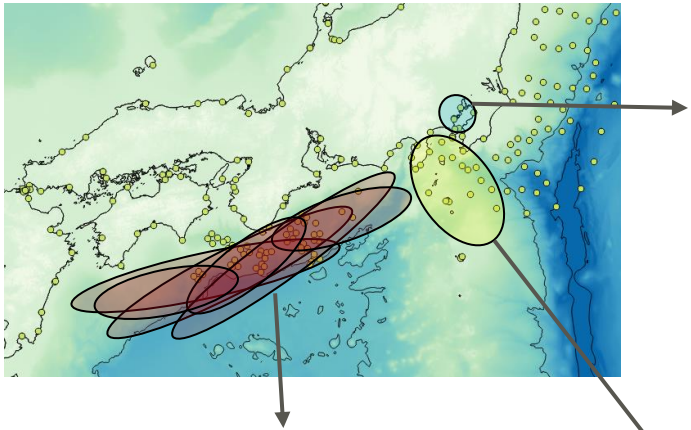
After (this study)



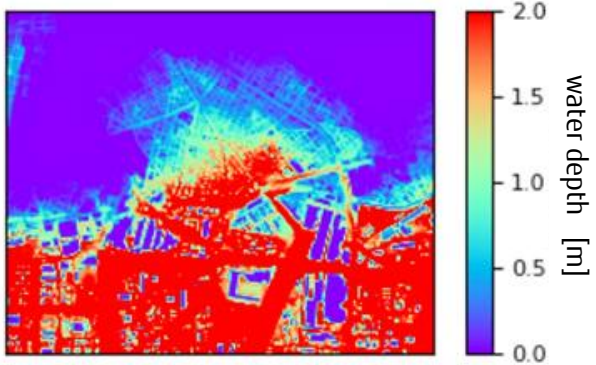
◆ Perform large-scale calculations in advance. In the event of a disaster, tsunami can be predicted with a high resolution of 3 m on a familiar PC

Training data generation on Fugaku

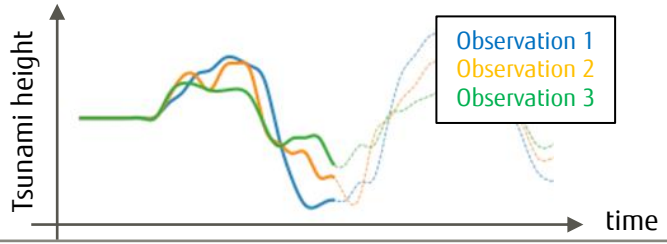
- The training data of AI was generated by assuming the tsunami source of the Nankai trough megathrust earthquake for various cases and performing a number of tsunami simulations.



Tsunami inundation

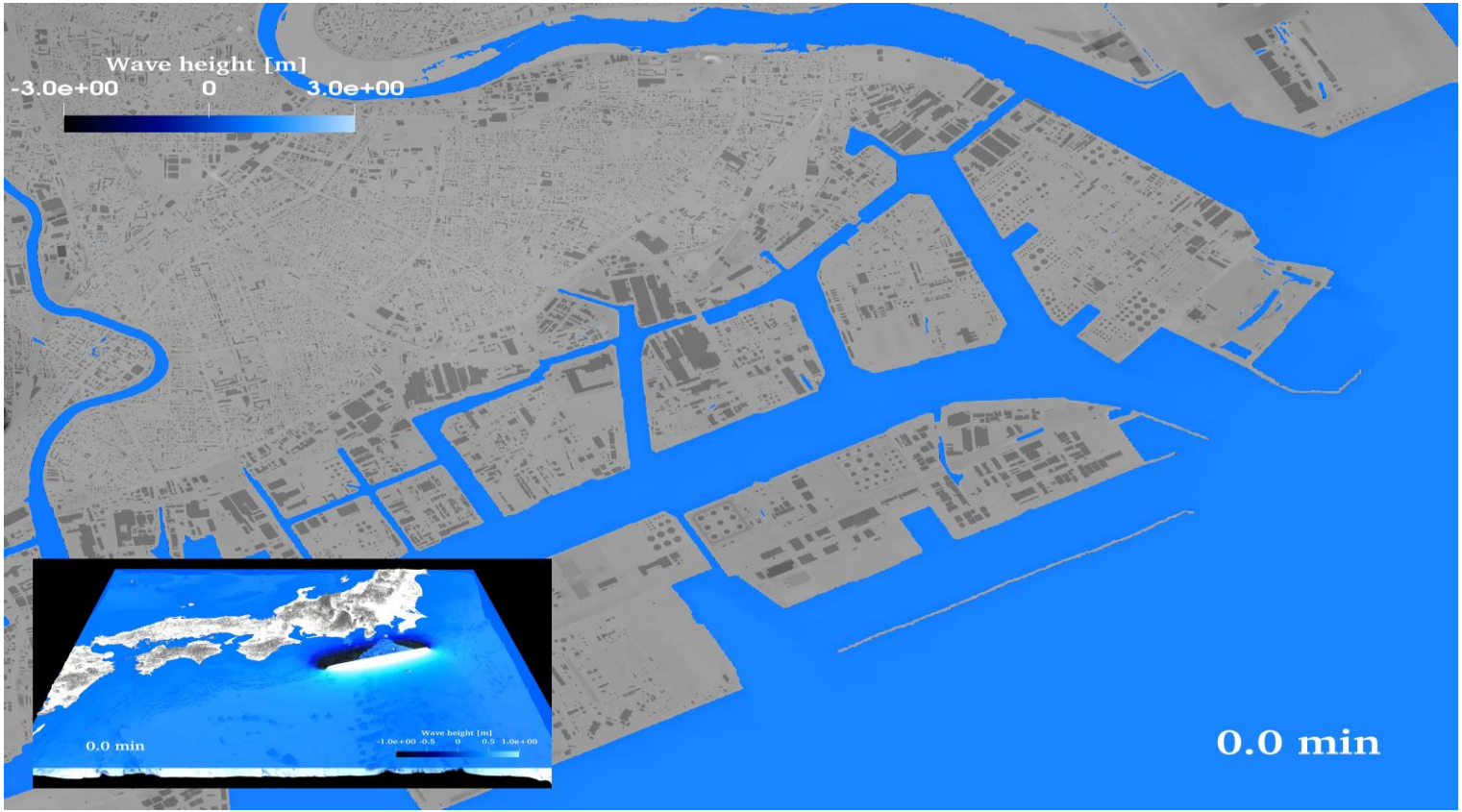


Offshore waveform



Conducted tsunami inundation simulations using nonlinear long-wave equations for various tsunami sources

20,000 cases of 3 m resolution simulations



With resolution of 3m, local tsunami behavior can be predicted

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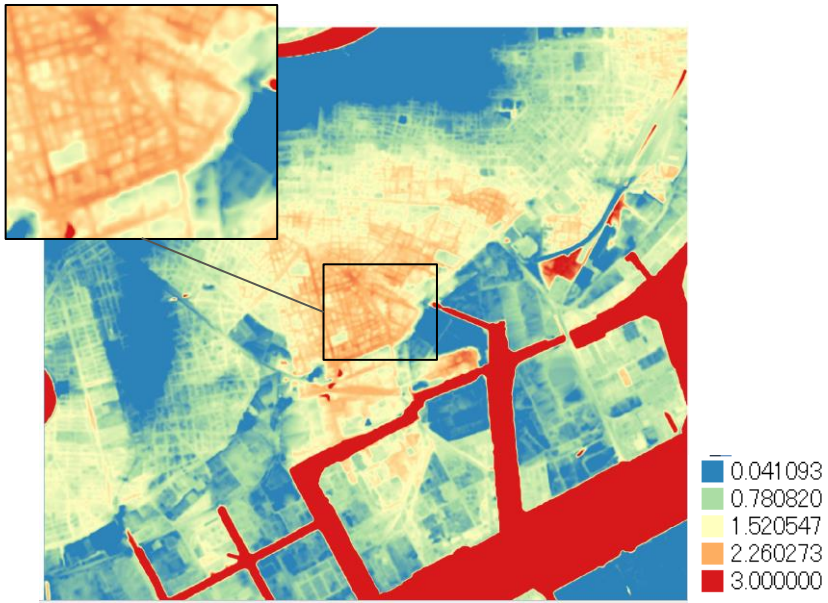
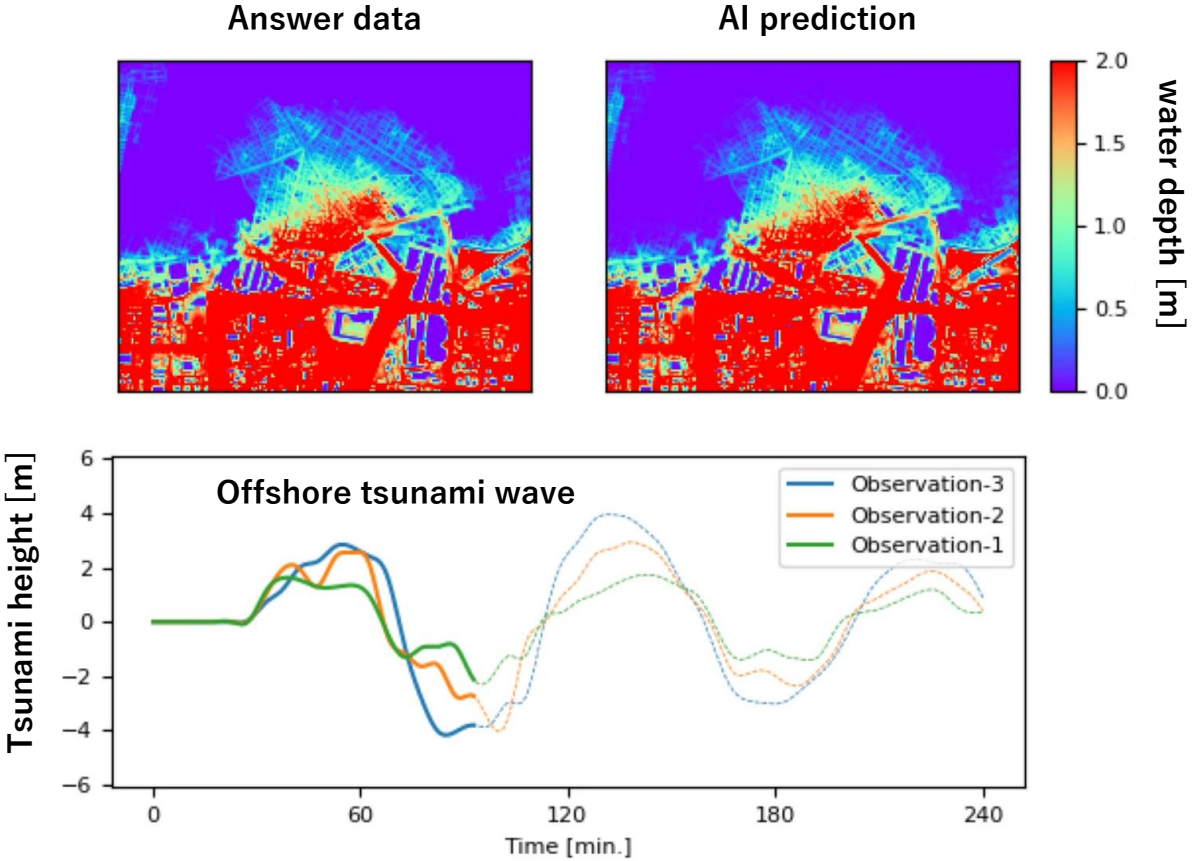
- High spatial resolution enables the predictions that incorporate the effects of buildings and roads in coastal cities. This will help you to understand detailed inundation forecast information for each section, such as the occurrence of a local tsunami, and support safe evacuation behavior.

3 m resolution simulation



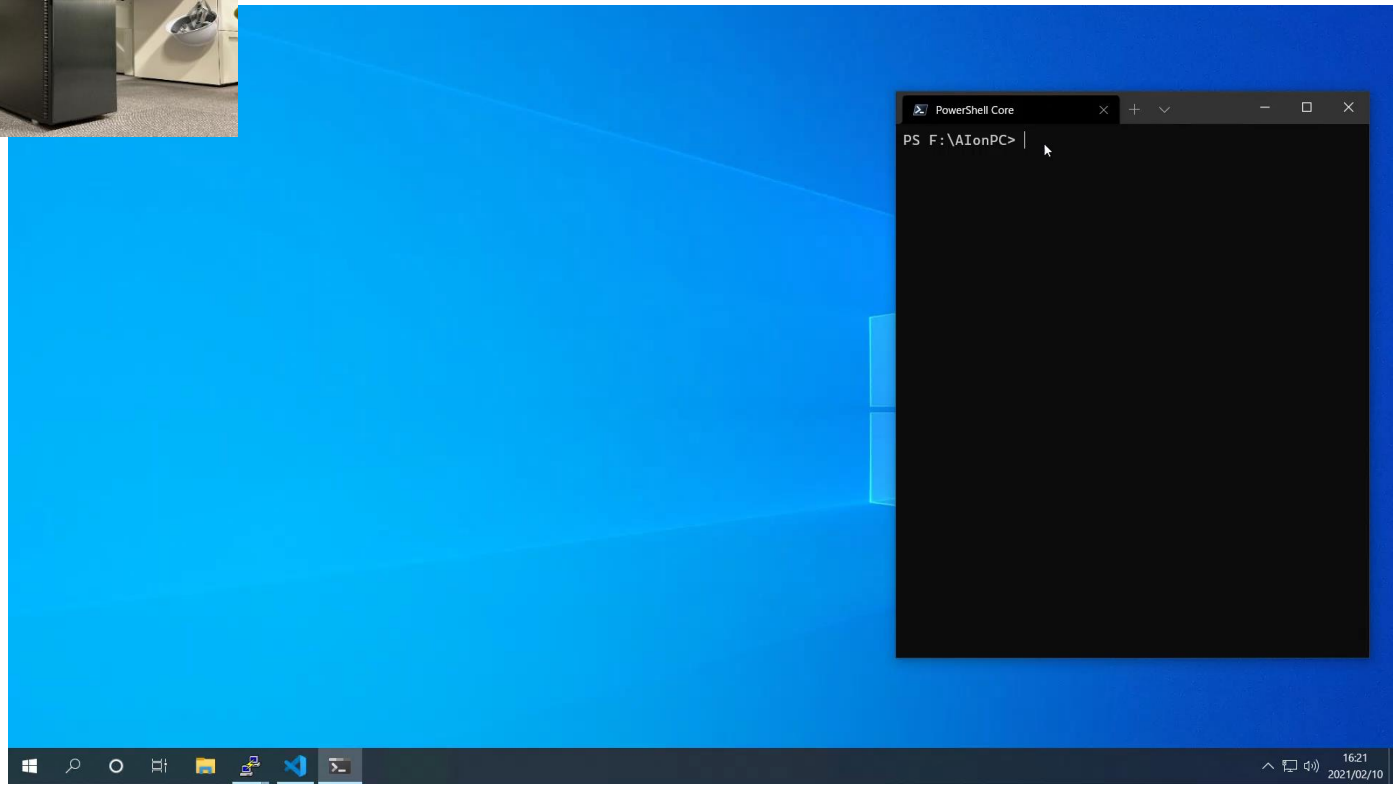
10 m resolution simulation

AI training on Fugaku

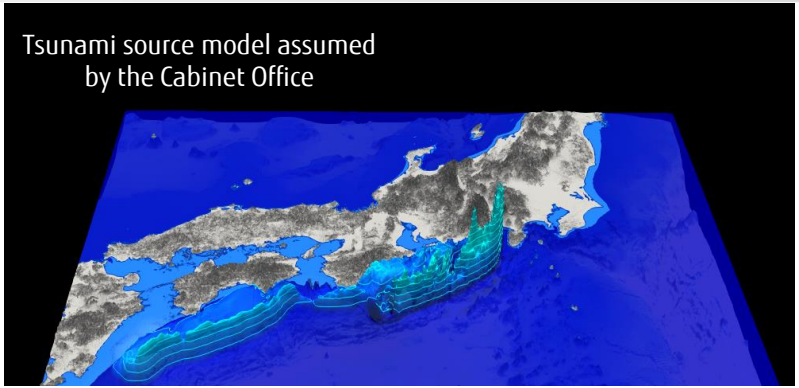


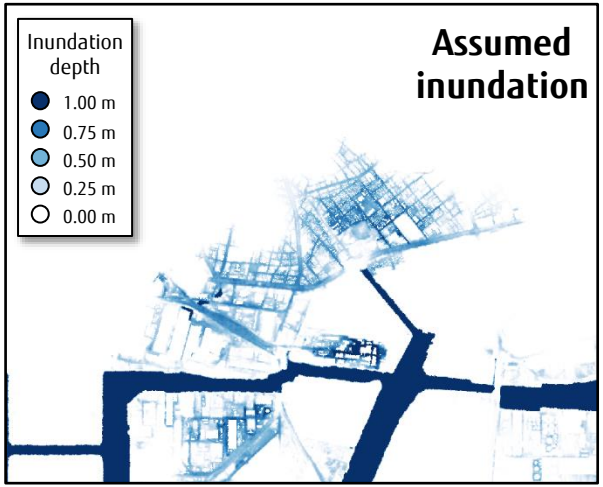
Real time prediction on general PC

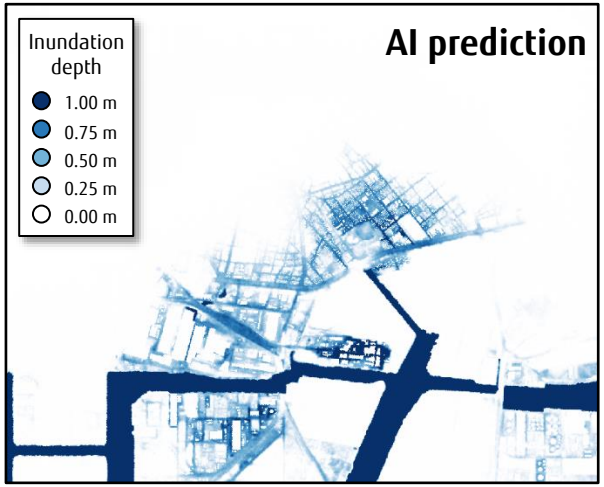
"A few seconds" on a general PC



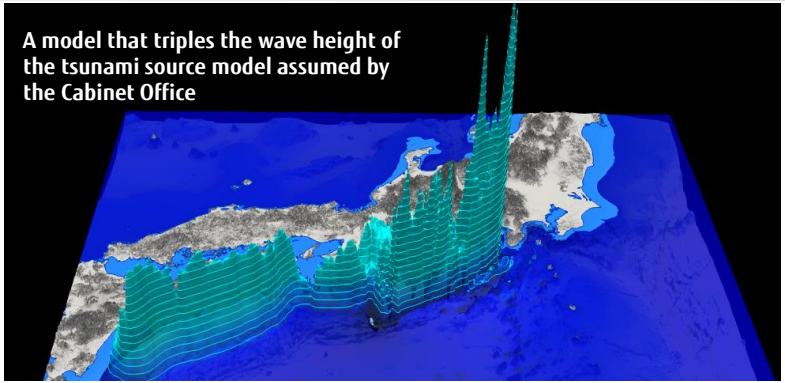
Nankai Trough megathrust earthquake

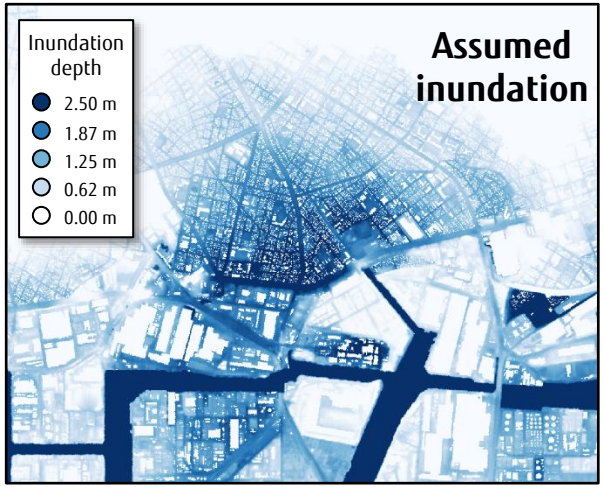


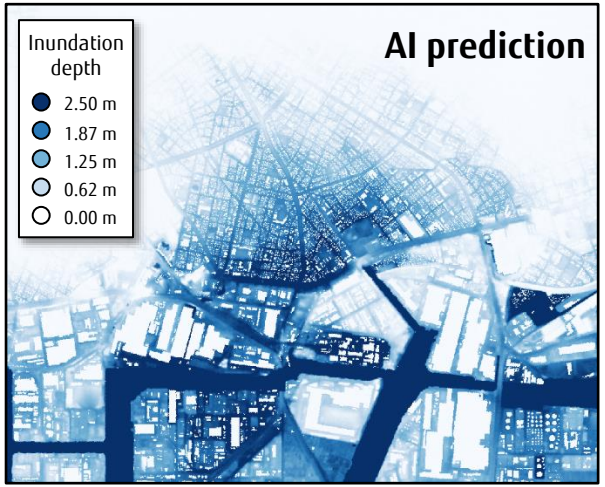




Triple the wave height







Tsunami arrival time can also be predicted

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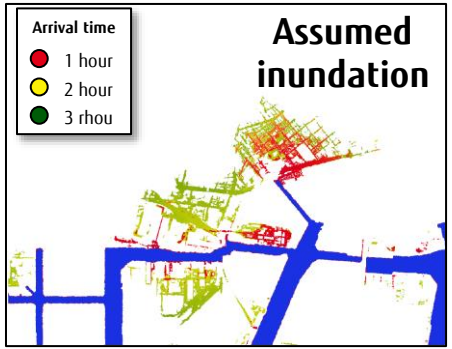
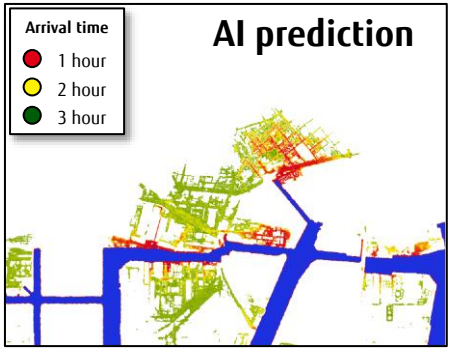
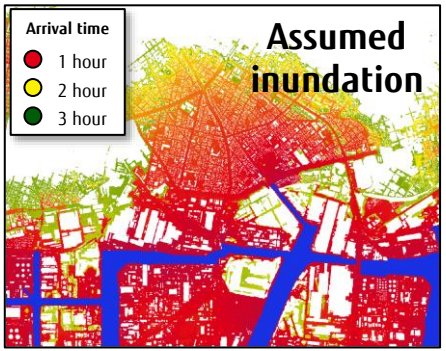
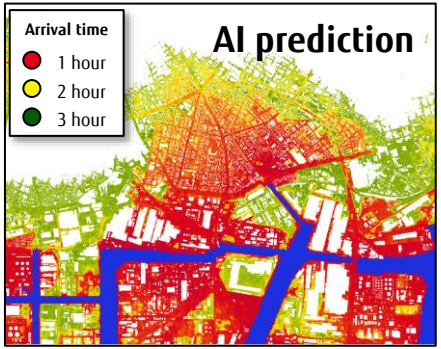
(a) Tsunami source model assumed by the Cabinet Office





(b) A model that triples the wave height of the tsunami source model assumed by the Cabinet Office



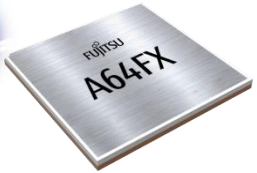


Summary

- "Fugaku" has been co-designed, was ranked #1 in 4 major supercomputer rankings, and runs apps at high performance w/ optimal power consumption
- Fugaku started *shared use* from March 19, 2021
- Fugaku and AI technologies for high-resolution, real-time tsunami inundation prediction

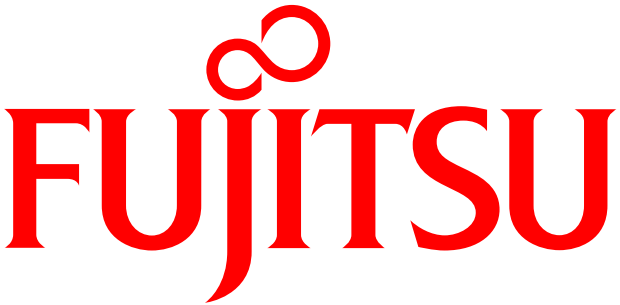
Fugaku

- Fujitsu Supercomputer PRIMEHPC FX1000 & FX700 based on Fugaku tech.



PRIMEHPC FX700

Fujitsu PRIMEHPC FX1000



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