Jessica Salguero, UIN: 937005006
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CSCE 735 Minor Project: Eagle vs Fugaku

High-Performance Computing (HPC) allows for complex calculations to be performed quickly, by using a combination of powerful computers and software configurations [12]. This advanced computational resource is often used in various aspects of scientific research and large-scale data analysis, but not all supercomputers are created equally. The TOP500 list ranks current advanced supercomputers based on computational power, performance, and execution twice a year [3]. High-Performance Linpack (HPL) and High-Performance Conjugate Gradient (HPCG) are utilized for determining system rankings; HPL scores are the primary scoring metric for determining final rankings and measures the system's ability to solve a dense system of linear equations using double-precision [6], whereas HPCG is an additional broader metric that is used to quantify other comprehensive attributes of each individual system [4]. The most recent version of this list was released in June of 2025. This paper aims to compare two of these top 10 systems - Eagle and Fugaku - focusing on each of the system's architecture, computational capability, forms of parallelism, power requirements, and typical applications being run on the computers [Table 1].

Each of these systems encompasses different approaches to advanced computing, beginning with the overall system architecture. Eagle was manufactured by Microsoft in 2023 and was ranked as number 5 on the most up-to-date TOP500 list. It is hosted in the Microsoft Azure Cloud and utilizes a combination of Intel Xeon Platinum 8480C CPUs and NVIDIA H100 GPUs, which totals to 2,073,600 cores. Eagle utilizes the Ubuntu 22.04 operating system, NVIDIA NVCC compiler, NVIDIA HPCX 2.16 MPI, and NVIDIA CUBLAS 12.2 math library for computations [2]. The Eagle system attempts to take advantage of a combination of CPUs and GPUs for improving computational performance, whereas Fugaku is a CPU-only system. It was manufactured by Fujitsu in 2020 and currently resides in the RIKEN Center for Computational Science (R-CCS) in Kobe, Japan. This system was ranked slightly lower on the TOP500 list at number 7. It is composed of 158,976 A64FX CPUs, which totals to 7,630,848 cores. The system's compiler, math library for computation, and MPI are built around the Fujitsu Software Technical Computing Suite V4.0. Additionally, the system utilizes the Red Hat Enterprise Linux operating system [9].

Differences in system architecture trickle down to noticeable differences in computational capability and overall performance, as seen through the TOP500 ranking results based on HPL benchmarks. Two of the important values for comparing benchmark results are Rmax and Rpeak. Rmax is the performance for the largest problem run on the system, with Nmax being the size of that large problem [6]. Additionally, the Rpeak score is the theoretical peak performance for each of the individual systems. Eagle has a recorded Rmax of 561.20 PFlop/s based on Nmax of 11,796,480, and a Rpeak of 846.84 PFlop/s [2]. On the other hand, Fugaku has an Rmax of 442.01 PFlop/s based on an Nmax of 21,288,960, and a Rpeak of 537.21 PFlop/s [9]. These results demonstrate that GPU utilization versus multi-core CPU architecture can directly affect the performance of a system.

Although measurable performance is an important attribute of any system, another key feature to discuss is the form of parallelism that is used for splitting up workloads. The Eagle system's utilization of a combination of CPU and GPU cores requires good inter-processor communication. Eagle uses MPI enabled through NVIDIA Infiniband NDR to split up and coordinate work among a large number of nodes [2]. Within each node, the work is able to be completed with thread-level parallelism, and tasks requiring more complex parallelism are able to be offloaded to GPUs through CUDA [5]. The use of GPUs is particularly efficient as it allows for large amounts of data parallelism and tensor core acceleration, which are designed to improve matrix operations [8]. On the other hand, Fugaku's approach to parallelism has to be different due to only being able to use CPUs. Parallel processing can be done through either shared-memory multithreading or distributed-memory parallelism with easy communication between nodes [10]; communication between A64FX processors is executed through Tofu Interconnect D [9]. Using only CPUs may seem restrictive, but it decreases the overhead required for inter-processor communication.

Differences in approaches for computational work also results in significant differences in power requirements and efficiency for both systems. The specific power requirements and consumption is not publicized for Eagle, likely since it is hosted in a cloud-based environment. However, the efficiency of this system can still be calculated by dividing the previously mentioned Rmax value by its Rpeak [6]. Thus, the Eagle system has an Refficiency of 0.6627, or 66.27% of its peak potential. Conversely, the power requirements for the Fugaku system are more easily accessible for the public to view. Running this system utilizes approximately 29,899.23 kW of power, but optimized jobs can have a power consumption as low as 26,248.36 kW. It has an HPCG score of 16,004.5 TFlop/s, and a Refficiency of 0.8228 or 88.28%. Additionally, optimized runs can also affect the benchmark results, with a new HPL score of 404.69 PFlop/s [9].

With the unique attributes of each system, they are typically well-equipped for different applications. The combination of CPU and GPU capabilities in the Eagle system makes it well-equipped for tasks that require large amounts of data and large amounts of parallel processing. Due to this, Eagle is often used for AI, machine learning, deep learning, and other similar tasks [7]. The GPU nodes are integral for AI because of the way they parallelize work; computations are able to be split amongst a large number of nodes simultaneously, which helps in reducing the overall computational time needed, especially when tensor core is involved to aid in matrix operations [8]. A CPU-only system like Fugaku would have a harder time dealing with these large-data tasks and likely take much longer to complete. However, Fugaku is ideal for simulation and real-world modeling. For example, Fugaku was utilized for COVID-19 drug development, specifically to aid in the complex molecular-level simulations [1]. CPU-only systems were particularly useful for this drug development project and other similar simulations because each CPU core typically has higher amounts of accessible memory and higher bandwidth [11]. Additionally, the Tofu Interconnect D utilized for Fugasku requires less overhead for inter-processor communication.

The Eagle and Fugaku supercomputers are both excellent HPC systems. Eagle is more flexible in parallel implementation due to its cloud-based design and utilization of both CPUs and GPUs, making it ideal for complex computations including AI. However, this system's flexibility is also a bit of a hindrance, which can be seen in its benchmark performance; Eagle has a more than 20% reduction in efficiency (Refficiency) and lower maximum size for problems (Nmax). On the other hand, Fugaku is better suited for traditional high-performance computing. The CPU-only design does limit the type of applications that this system can be used for, but it has higher efficiency (Refficiency) when performing on large problems and allows for easier inter-processor communication. In conclusion, each of these HPC systems have their own benefits and drawbacks as they have been optimized for their specific intended uses. Both systems appearing in the Top 10 supercomputers highlights their effectiveness in the field of HPC. With the correct computational workload, both of these systems should provide great results.

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Table 1. Comparing primary attribute of Eagle and Fugaku supercomputers

Attribute	Eagle	Fugaku
Ranking	#5	#7
Manufacturer	Microsoft Azure	Fujitsu
Location	Microsoft Azure Cloud	RIKEN Center for Computation Science
Cores	2,073,600	7.630,848
Processor	Intel Xeon Platinum 8480C CPUs, NVIDIA H100 GPUs	A64FX CPUs
Interprocessor Communication	NVIDIA Infiniband NDR	Tofu interconnect D
Installation Year	2023	2020
Rmax	561.20 PFlop/s	442.01 PFlop/s
Rpeak	846.84 PFlop/s	537.21 PFlop/s
Refficiency	0.6627	0.8228
Nmax	11,796,480	21,288,960
Power	Specifics unknown	29,899.23 kW
Operating System	Ubuntu 22.04	Red Hat Enterprise Linux
Compiler	NVIDIA NVCC	FUJITSU Software Technical Computing Suite V4.0
Math Library	NVIDIA CUBLAS 12.2	FUJITSU Software Technical Computing Suite V4.0
MPI	NVIDIA HPCX 2.16	FUJITSU Software Technical Computing Suite V4.0
Typical Applications	AI, machine learning, deep learning	Simulations, modeling, drug development