USC University of Southern California

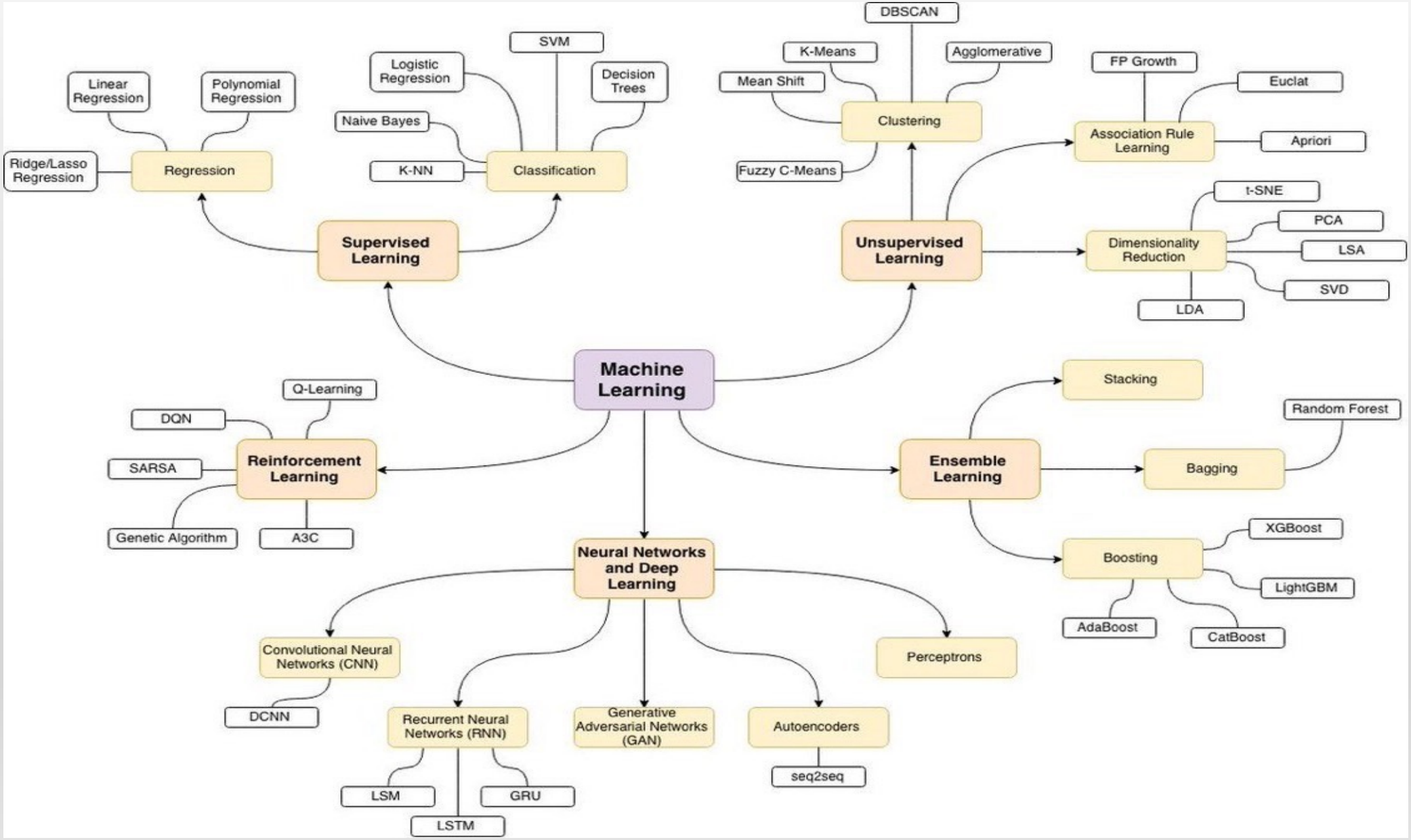
Running Deep Learning Applications in Production Level

Hao Ji, Data Scientist

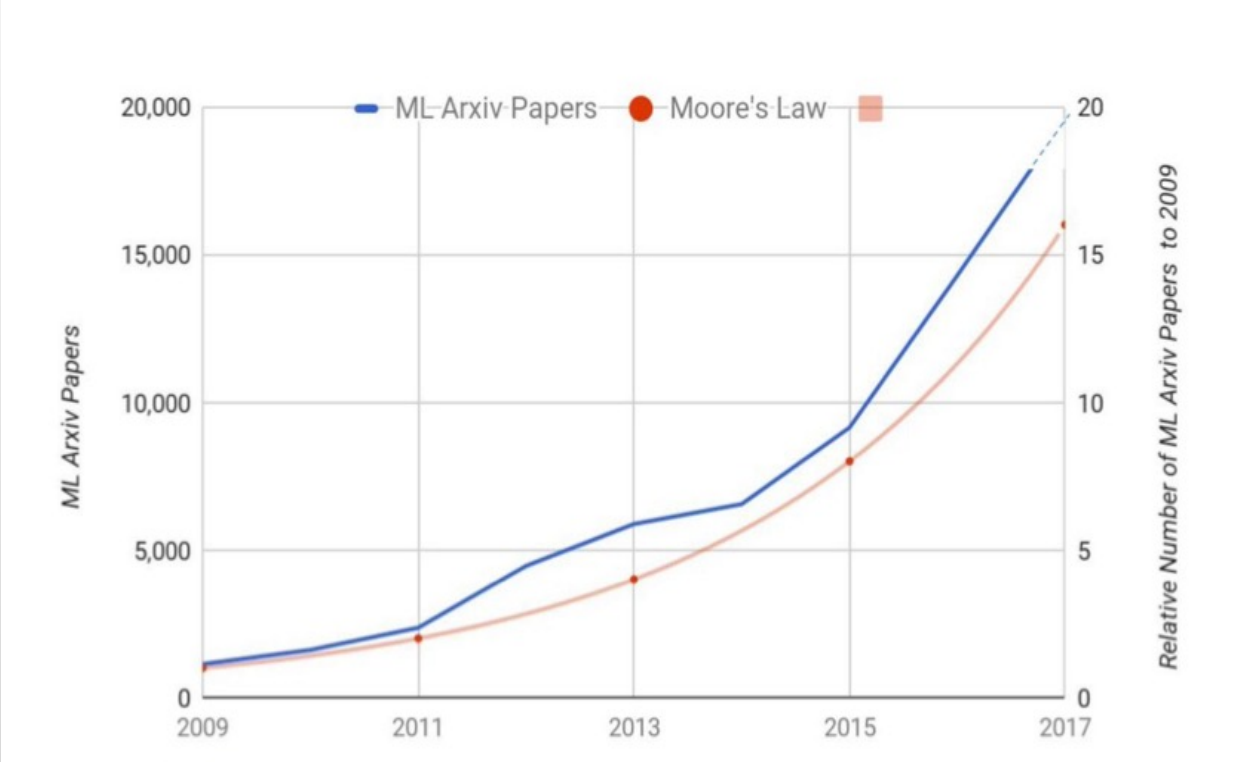
USC Center for Advanced Research Computing

Content

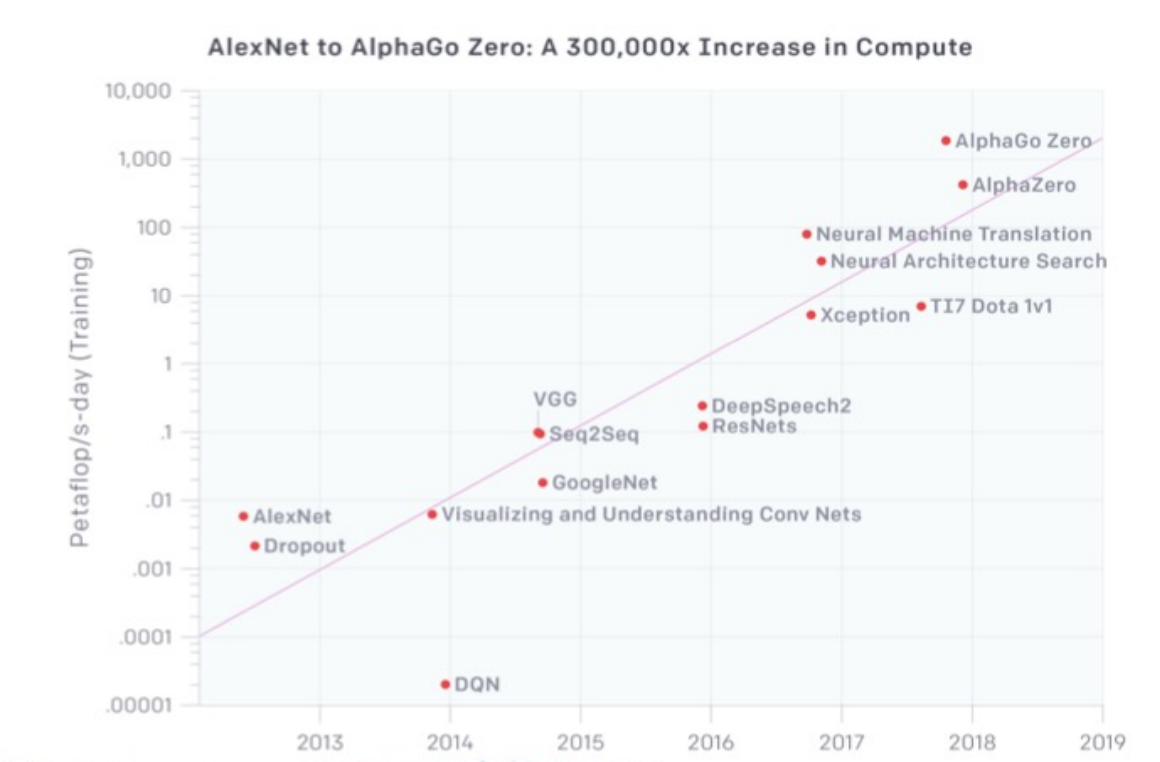
Introduction of Machine Learning



Introduction to Machine Learning



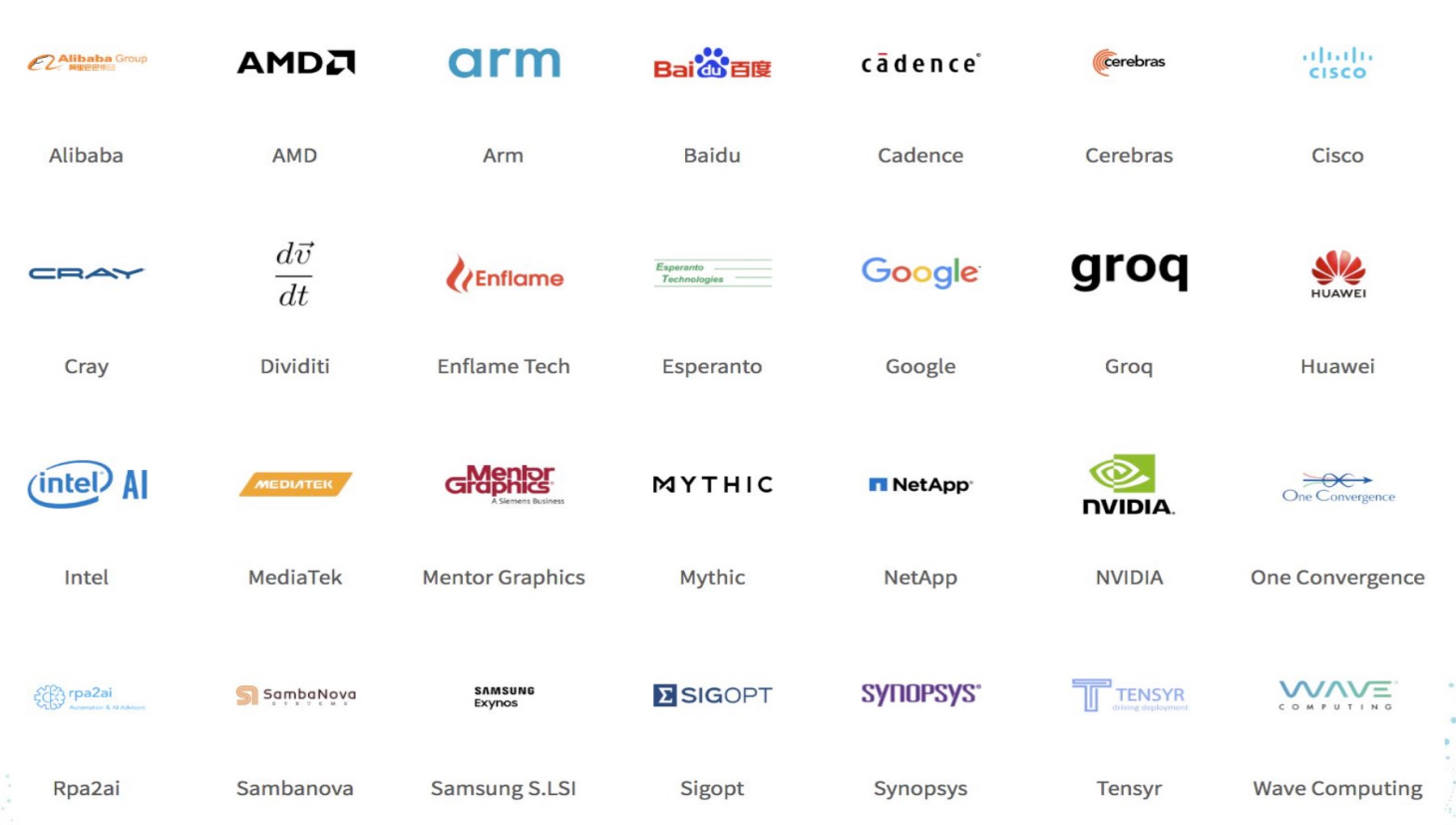
Rapid Rise of ML

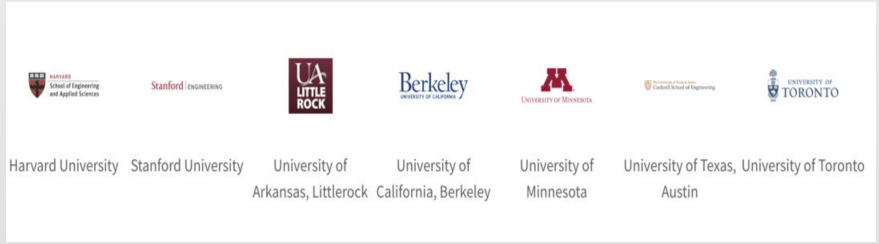


AI to Compute

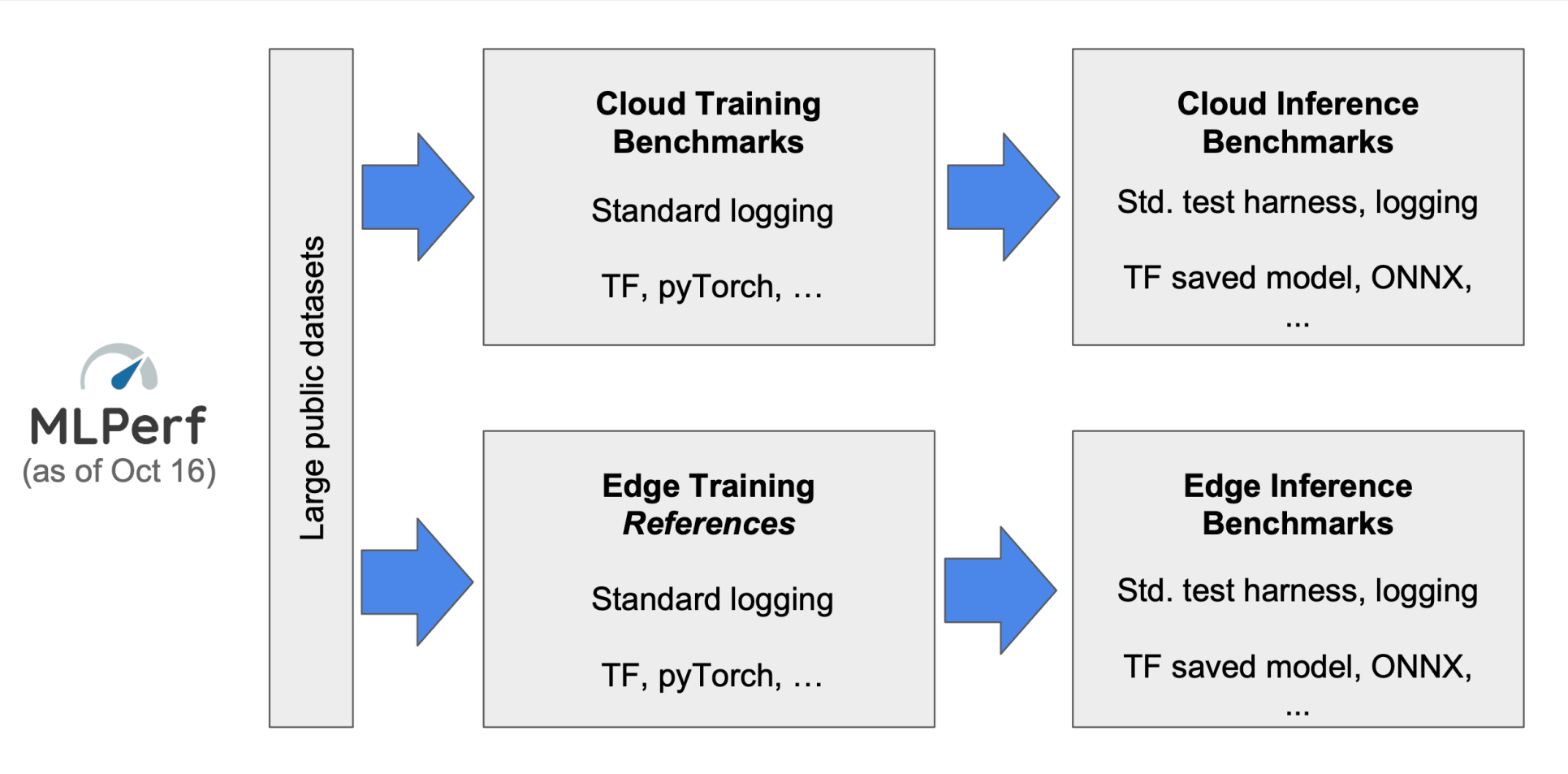
ML Perf Benchmark

ML Perf: A broad ML benchmark suite for measuring the performance of ML software frameworks, ML hardware accelerators, and ML cloud and edge platforms





ML Perf Benchmark



ML Perf Benchmark

Task	Model	Dataset
Image Classification	ResNet-50	ImageNet
Object Detection	Mask-RCNN SSD	MS-COCO 2017
Translation	Google NMT Transformer	WMT 16 WMT 17
Recommendation	Neural Collaborative Filtering	MovieLens ml-20m
Reinforcement Learning	Minigo	NA
Speech Recognition	DeepSpeech2*	Librispeech

ML Perf Benchmark

Task	Task Description	Dataset	Quality metric	Sample Apps
Recognition	Classify an input into one of many categories. Alternatively, generate a high dimensional embedding that can be used for recognition	Imagenet/COCO Input: RGB image of size XX x YY Output: label index	Top-1 error rate	Face authenticati on, Music recognition

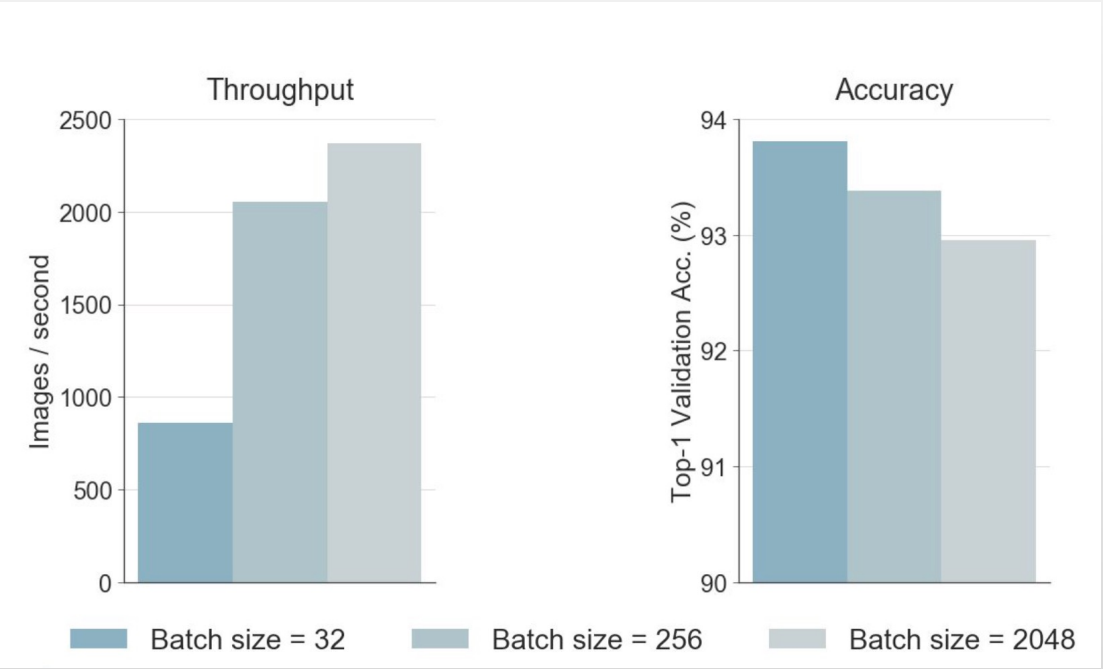
ML Perf Benchmark

Performance

How fast is a model for training, inference?

Quality

How good are a model's predictions?



- End to end training of a Resnet56 CIFAR10 model
- Nvdia P100 with 512GB of memory and 28 CPU cores
- TensorFlow 1.2 compiled from source with CUDA 8.0 and CuDNN 5.1

ML Perf Benchmark

Closed division submissions

- Requires using the specified model
- Limits overfitting
- Enables apples-to-apples comparison
- Simplifies work for HW groups

Open division submissions

- Open division allows using any model
- Encourages innovation
- Ensures Closed division does not stagnate

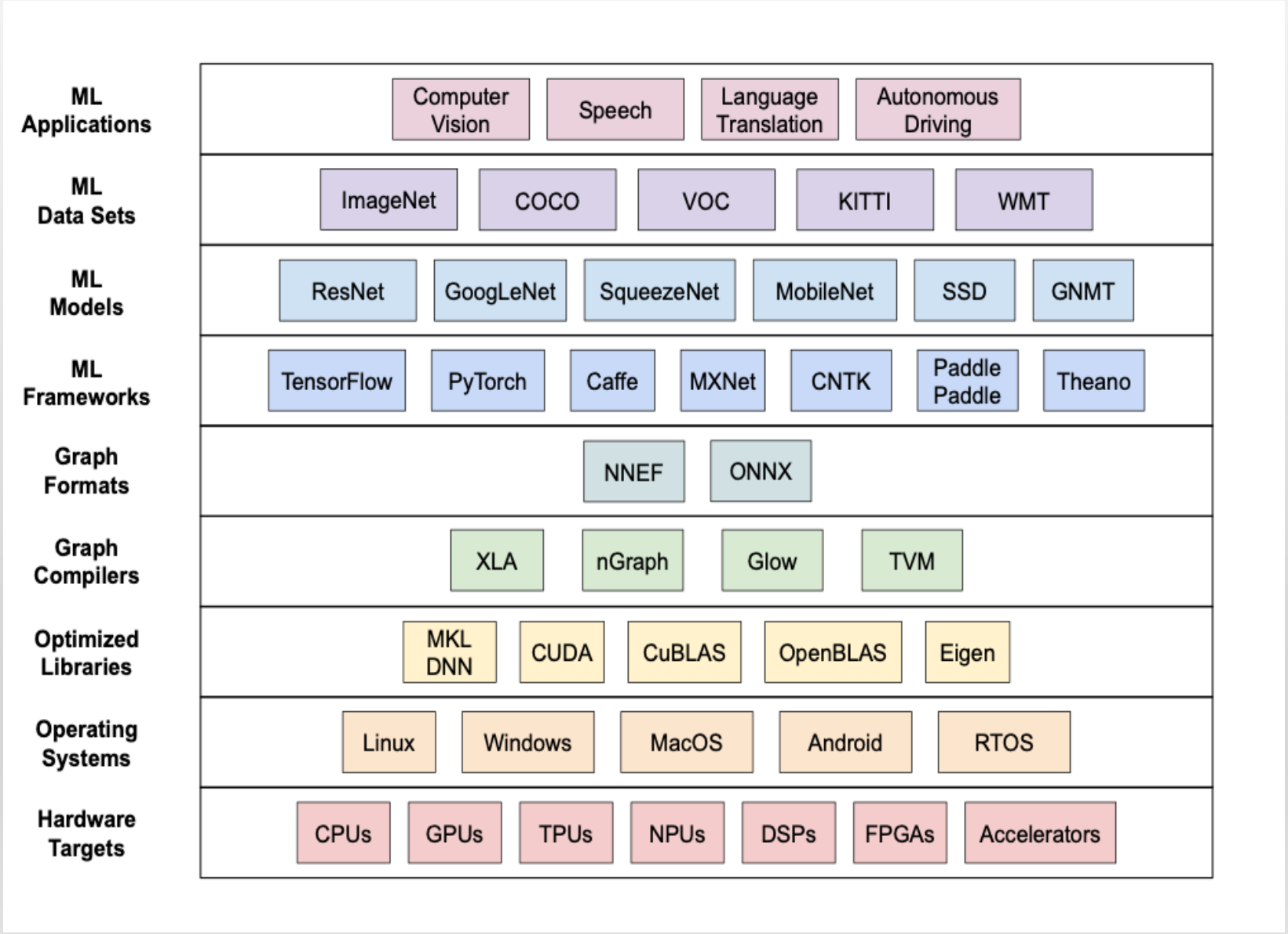
ML Perf Benchmark

Training v1.1

Closed | Open

ID	Submitter	System	Processor	#	Accelerator	#	Software	Benchmark results (minutes)								Details	Code
								Image classification	Image segmentation (medical)	Object detection, light-weight	Object detection, heavy-weight	Speech recognition	NLP	Recom-mendation	Reinforce-ment Learning		
								ImageNet	KiTS19	COCO	COCO	LibriSpeech	Wikipedia	1TB Clickthrough	Go		
								ResNet	3D U-Net	SSD	Mask R-CNN	RNN-T	BERT [1]	DLRM	Minigo		
Available cloud																	
1.1-2000	Azure	nd96amsr_a100_v4_ngc21.09_merlin_hugectr	AMD EPYC 7V12	2	NVIDIA A100-SXM4-80GB (400W)	8	Merlin HugeCTR with NVIDIA DL Frameworks Release 21.09							1.875		details	code
1.1-2001	Azure	nd96amsr_a100_v4_ngc21.09_mxnet	AMD EPYC 7V12	2	NVIDIA A100-SXM4-80GB (400W)	8	MXNet NVIDIA Release 21.09	29.720	25.400	8.309						details	code
1.1-2002	Azure	nd96amsr_a100_v4_ngc21.09_pytorch	AMD EPYC 7V12	2	NVIDIA A100-SXM4-80GB (400W)	8	PyTorch NVIDIA Release 21.09				47.064	37.550	21.213			details	code
1.1-2003	Azure	nd96amsr_a100_v4_ngc21.09_tensorflow	AMD EPYC 7V12	2	NVIDIA A100-SXM4-80GB (400W)	8	TensorFlow NVIDIA Release 21.09								319.410	details	code
1.1-2004	Azure	nd96amsr_a100_v4_n4_ngc21.09_pytorch	AMD EPYC 7V12	8	NVIDIA A100-SXM4-80GB (400W)	32	PyTorch NVIDIA Release 21.09				14.912					details	code
1.1-2005	Azure	nd96amsr_a100_v4_n8_ngc21.09_mxnet	AMD EPYC 7V12	16	NVIDIA A100-SXM4-80GB (400W)	64	MXNet NVIDIA Release 21.09	4.587		1.517						details	code
1.1-2006	Azure	nd96amsr_a100_v4_n8_ngc21.09_pytorch	AMD EPYC 7V12	16	NVIDIA A100-SXM4-80GB (400W)	64	PyTorch NVIDIA Release 21.09						3.111			details	code
1.1-2007	Azure	nd96amsr_a100_v4_n9_ngc21.09_mxnet	AMD EPYC 7V12	18	NVIDIA A100-SXM4-80GB (400W)	72	MXNet NVIDIA Release 21.09		3.800							details	code
1.1-2008	Azure	nd96amsr_a100_v4_n16_ngc21.09_pytorch	AMD EPYC 7V12	32	NVIDIA A100-SXM4-80GB (400W)	128	PyTorch NVIDIA Release 21.09					4.533				details	code
1.1-2009	Azure	nd96amsr_a100_v4_n32_ngc21.09_tensorflow	AMD EPYC 7V12	64	NVIDIA A100-SXM4-80GB (400W)	256	TensorFlow NVIDIA Release 21.09								30.714	details	code
1.1-2010	Azure	nd96amsr_a100_v4_n34_ngc21.09_pytorch	AMD EPYC 7V12	68	NVIDIA A100-SXM4-80GB (400W)	272	PyTorch NVIDIA Release 21.09				3.908					details	code
1.1-2011	Azure	nd96amsr_a100_v4_n48_ngc21.09_tensorflow	AMD EPYC 7V12	96	NVIDIA A100-SXM4-80GB (400W)	384	TensorFlow NVIDIA Release 21.09								24.802	details	code
1.1-2012	Azure	nd96amsr_a100_v4_n96_ngc21.09_mxnet	AMD EPYC 7V12	192	NVIDIA A100-SXM4-80GB (400W)	768	MXNet NVIDIA Release 21.09		1.262							details	code
1.1-2013	Azure	nd96amsr_a100_v4_n128_ngc21.09_mxnet	AMD EPYC 7V12	256	NVIDIA A100-SXM4-80GB (400W)	1024	MXNet NVIDIA Release 21.09	0.583		0.455						details	code
1.1-2014	Azure	nd96amsr_a100_v4_n128_ngc21.09_pytorch	AMD EPYC 7V12	256	NVIDIA A100-SXM4-80GB (400W)	1024	PyTorch NVIDIA Release 21.09						0.656			details	code
1.1-2015	Azure	nd96amsr_a100_v4_n192_ngc21.09_pytorch	AMD EPYC 7V12	384	NVIDIA A100-SXM4-80GB (400W)	1536	PyTorch NVIDIA Release 21.09					3.205				details	code
1.1-2016	Azure	nd96amsr_a100_v4_n224_ngc21.09_tensorflow	AMD EPYC 7V12	448	NVIDIA A100-SXM4-80GB (400W)	1792	TensorFlow NVIDIA Release 21.09								17.439	details	code
1.1-2017	Azure	nd96amsr_a100_v4_n256_ngc21.09_mxnet	AMD EPYC 7V12	512	NVIDIA A100-SXM4-80GB (400W)	2048	MXNet NVIDIA Release 21.09	0.438								details	code
1.1-2018	Azure	nd96amsr_a100_v4_n256_ngc21.09_pytorch	AMD EPYC 7V12	512	NVIDIA A100-SXM4-80GB (400W)	2048	PyTorch NVIDIA Release 21.09						0.422			details	code
Available on-premise																	
1.1-2019	Baidu	1_node_8_A100_NGC21.05_MXNet	Intel(R) Xeon(R) Platinum 8350C	2	NVIDIA A100-SXM4-80GB (400W)	8	MXNet NVIDIA Release 21.05	28.605								details	code
1.1-2020	Baidu	1_node_8_A100_PaddlePaddle	Intel(R) Xeon(R) Platinum 8350C	2	NVIDIA A100-SXM4-80GB (400W)	8	PaddlePaddle (branch: develop, commitID: 605e7f0)	28.613								details	code
1.1-2021	Dell	DSS8440x8A100-PCIE-40GB	Intel(R) Xeon(R) Gold 6248R CPU @ 3.00GHz	2	NVIDIA A100-PCIE-40GB (250W)	8	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	38.871		11.193	61.505		66.631		393.431	details	code
1.1-2022	Dell	DSS8440x8A100-PCIE-40GB-NVBridge	Intel(R) Xeon(R) Gold 6248R CPU @ 3.00GHz	2	NVIDIA A100-PCIE-40GB (250W)	8	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	37.083		10.899	58.571				405.424	details	code
1.1-2023	Dell	R750xax4A100-PCIE-80GB	Intel(R) Xeon(R) Gold 6338 CPU @ 2.00GHz	2	NVIDIA A100-PCIE-80GB (300W)	4	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	62.949	60.586	18.321	93.134	84.025	56.260		590.009	details	code
1.1-2024	Dell	R750xax4A100-PCIE-80GB-8368	Intel(R) Xeon(R) Platinum 8368 CPU @ 2.40GHz	2	NVIDIA A100-PCIE-80GB (300W)	4	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	64.131		18.390	91.562		56.131			details	code
1.1-2025	Dell	2xR750xax4A100-PCIE-80GB	Intel(R) Xeon(R) Gold 6338 CPU @ 2.00GHz	4	NVIDIA A100-PCIE-80GB (300W)	8	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	32.087								details	code
1.1-2026	Dell	DSS8440x8A100-PCIE-80GB	Intel(R) Xeon(R) Gold 6248R CPU @ 3.00GHz	2	NVIDIA A100-PCIE-80GB (300W)	8	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	33.553	28.543	9.835	55.033	60.763	41.269			details	code
1.1-2027	Dell	DSS8440x10A100-PCIE-80GB	Intel(R) Xeon(R) Gold 6248R CPU @ 3.00GHz	2	NVIDIA A100-PCIE-80GB (300W)	10	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	28.187		8.223	46.948		36.859			details	code
1.1-2028	Dell	4xR750xax4A100-PCIE-80GB	Intel(R) Xeon(R) Gold 6338 CPU @ 2.00GHz	8	NVIDIA A100-PCIE-80GB (300W)	16	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	17.336								details	code
1.1-2029	Dell	8xR750xax4A100-PCIE-80GB	Intel(R) Xeon(R) Gold 6338 CPU @ 2.00GHz	16	NVIDIA A100-PCIE-80GB (300W)	32	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	10.586		3.477						details	code
1.1-2030	Dell	XE8545x4A100-SXM-40GB	AMD EPYC 7763 64-Core Processor	2	NVIDIA A100-SXM4-40GB (400W)	4	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	61.820		16.998	95.157	79.563				details	code
1.1-2031	Dell	XE8545x4A100-SXM-80GB	AMD EPYC 7713 64-Core Processor	2	NVIDIA A100-SXM4-80GB (500W)	4	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	56.326	55.999	16.244	83.774	106.542	38.855	9.522	451.293	details	code
1.1-2032	Dell	2xXE8545x4A100-SXM-80GB	AMD EPYC 7713 64-Core Processor	4	NVIDIA A100-SXM4-80GB (500W)	8	NGC MXNet 21.09 , NGC PyTorch 21.09 , NGC TensorFlow 21.09-tf1	30.123		8.735	48.788	35.068	26.547			details	code
1.1-2033	Fujitsu	PRIMERGY-GX2460M1-mxnet	AMD EPYC 7502 32-Core Processor	2	NVIDIA A100-PCIe-40GB (250W)	4	MXNet NGC21.09	70.294	49.946	20.916						details	code
1.1-2034	Fujitsu	PRIMERGY-GX2460M1-pytorch	AMD EPYC 7502 32-Core Processor	2	NVIDIA A100-PCIe-40GB (250W)	4	Pytorch NGC21.09					109.216	127.843			details	code

ML Perf Benchmark



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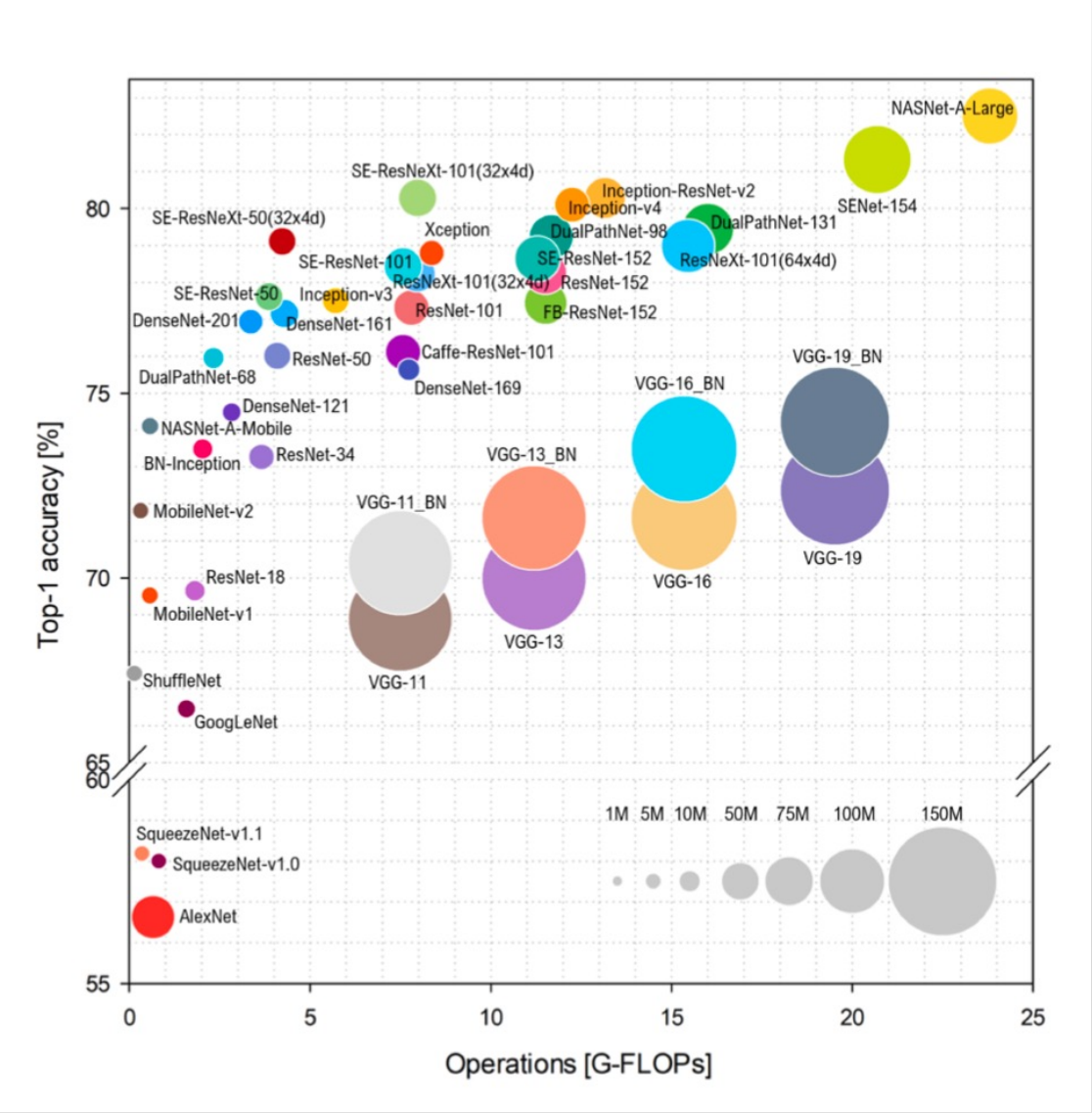
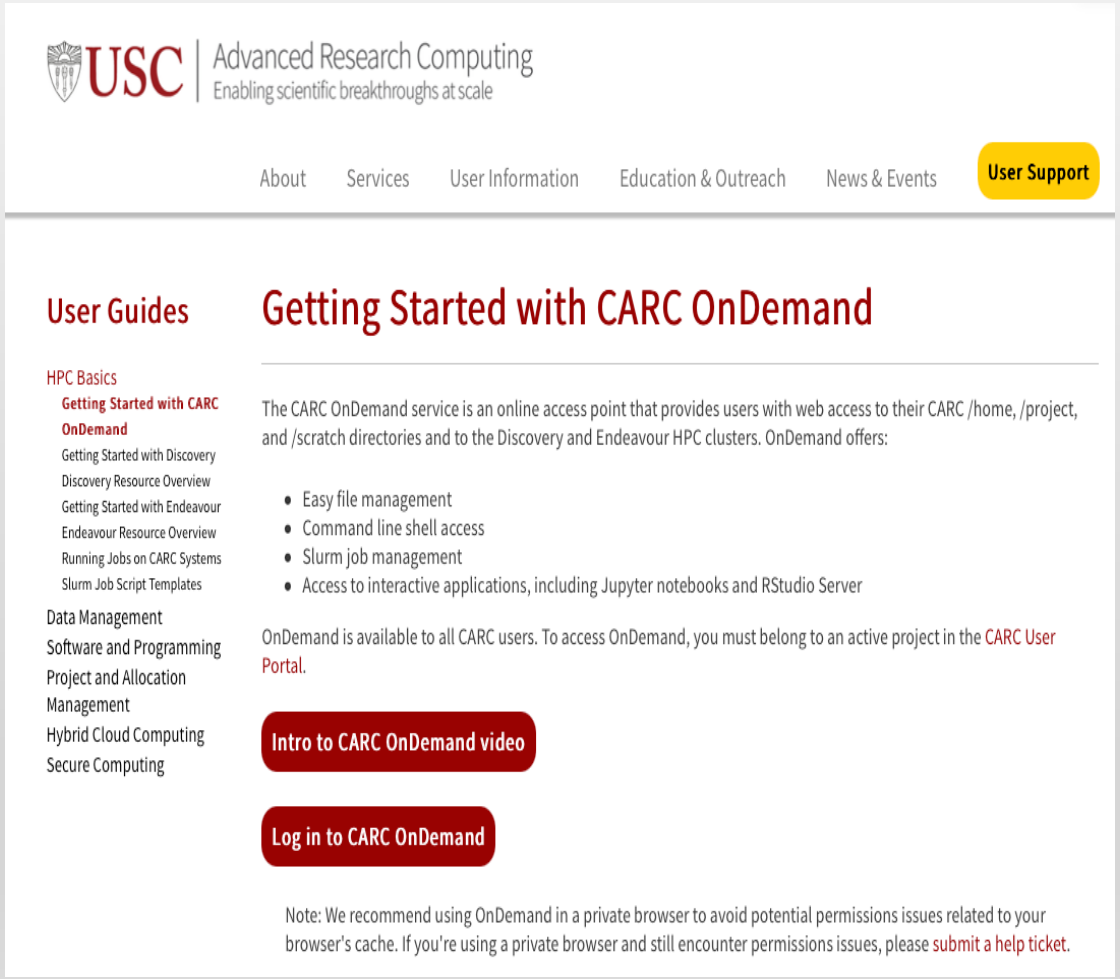
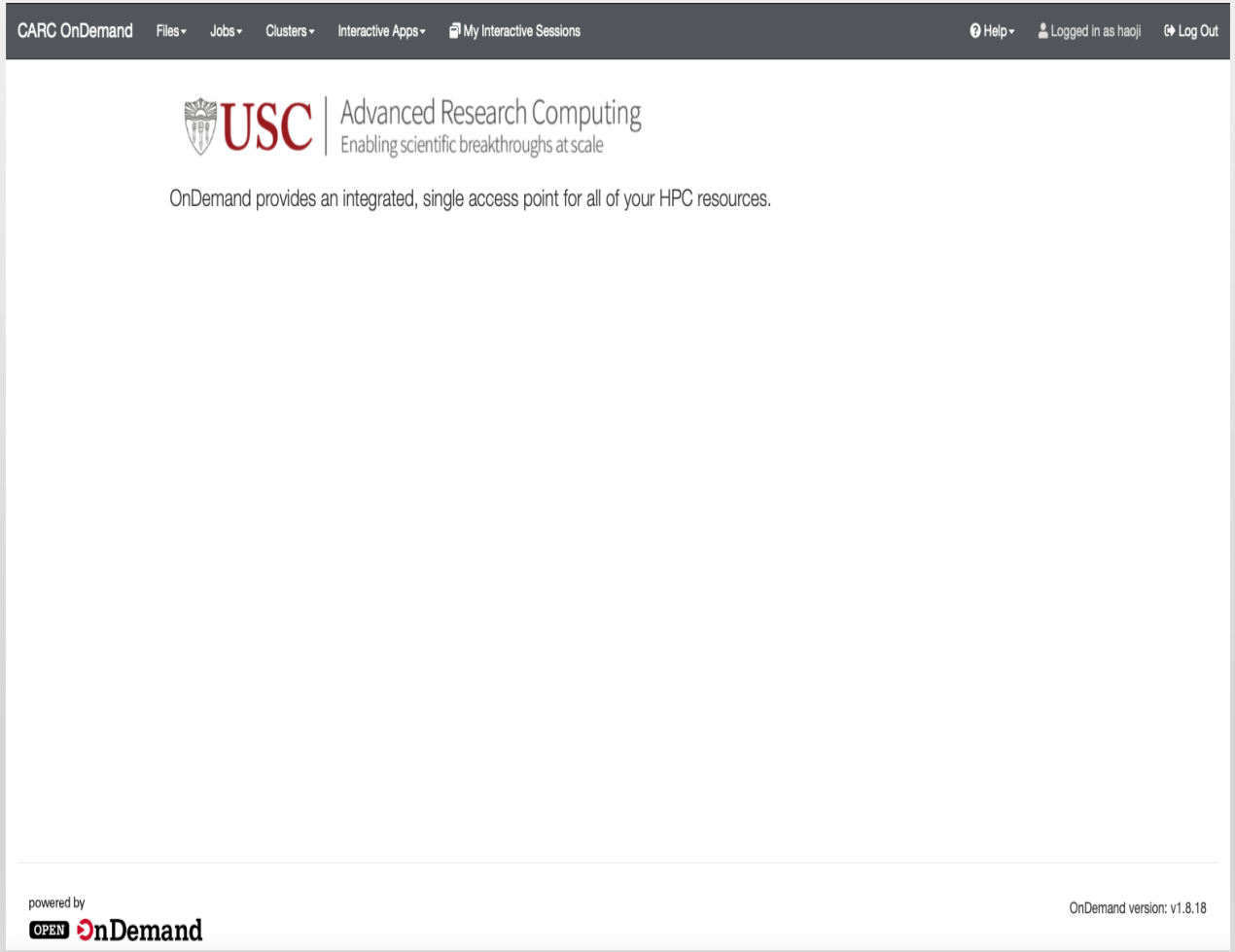


CARC OnDemand

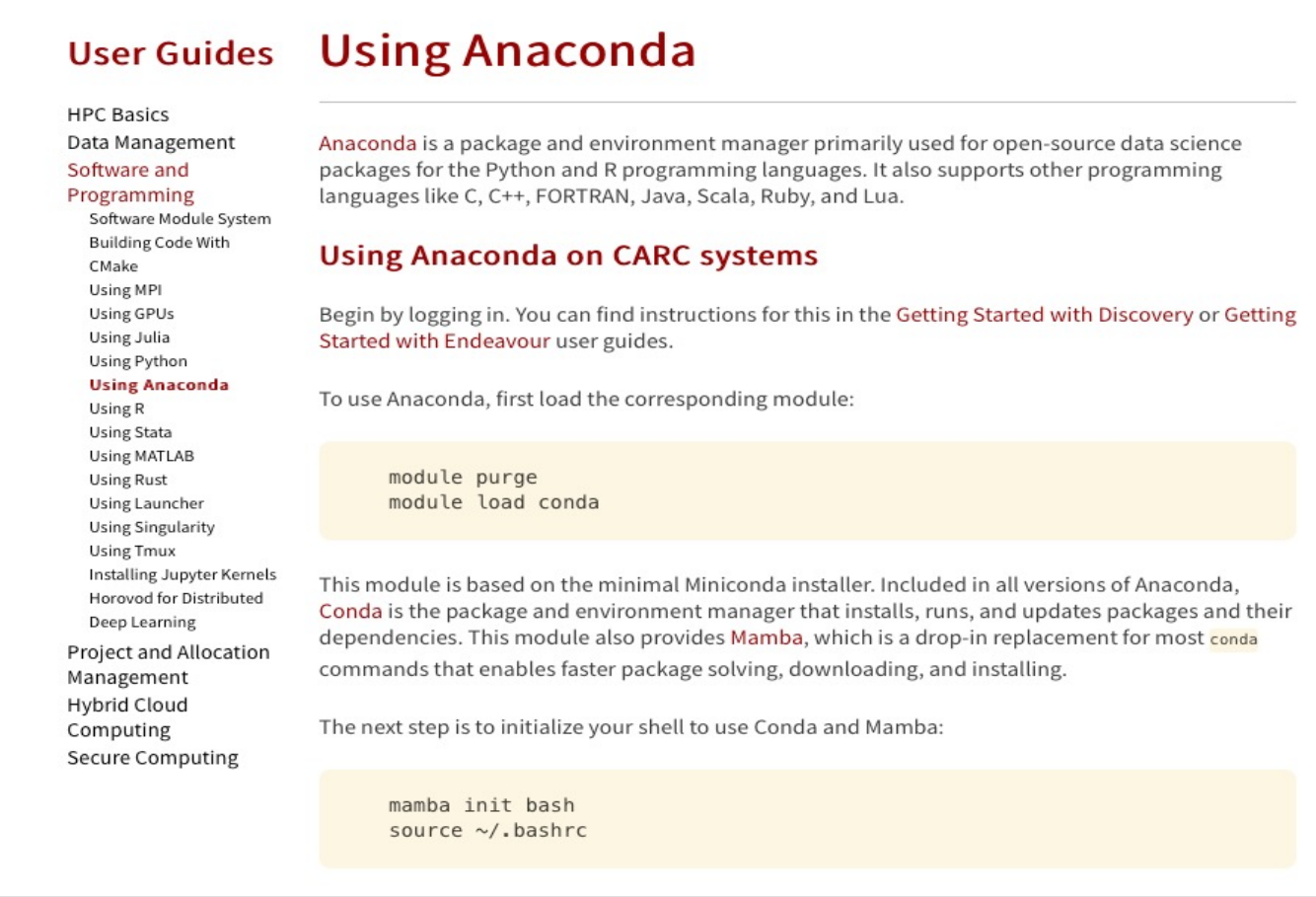
Web Address: https://carc-ondemand.usc.edu





Using Anaconda on CARC

Anaconda: package and environment manager primarily used for open-source data science packages for the Python and R programming languages.



User Guides

- HPC Basics
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- Software and Programming
  - Software Module System
  - Building Code With CMake
  - Using MPI
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- Hybrid Cloud Computing
- Secure Computing

Using Anaconda

Anaconda is a package and environment manager primarily used for open-source data science packages for the Python and R programming languages. It also supports other programming languages like C, C++, FORTRAN, Java, Scala, Ruby, and Lua.

Using Anaconda on CARC systems

Begin by logging in. You can find instructions for this in the Getting Started with Discovery or Getting Started with Endeavour user guides.

To use Anaconda, first load the corresponding module:

```
module purge
module load conda
```

This module is based on the minimal Miniconda installer. Included in all versions of Anaconda, Conda is the package and environment manager that installs, runs, and updates packages and their dependencies. This module also provides Mamba, which is a drop-in replacement for most `conda` commands that enables faster package solving, downloading, and installing.

The next step is to initialize your shell to use Conda and Mamba:

```
mamba init bash
source ~/.bashrc
```

https://www.carc.usc.edu/user-information/user-guides/software-and-programming/anaconda

Using Anaconda on CARC

https://pytorch.org

INSTALL PYTORCH

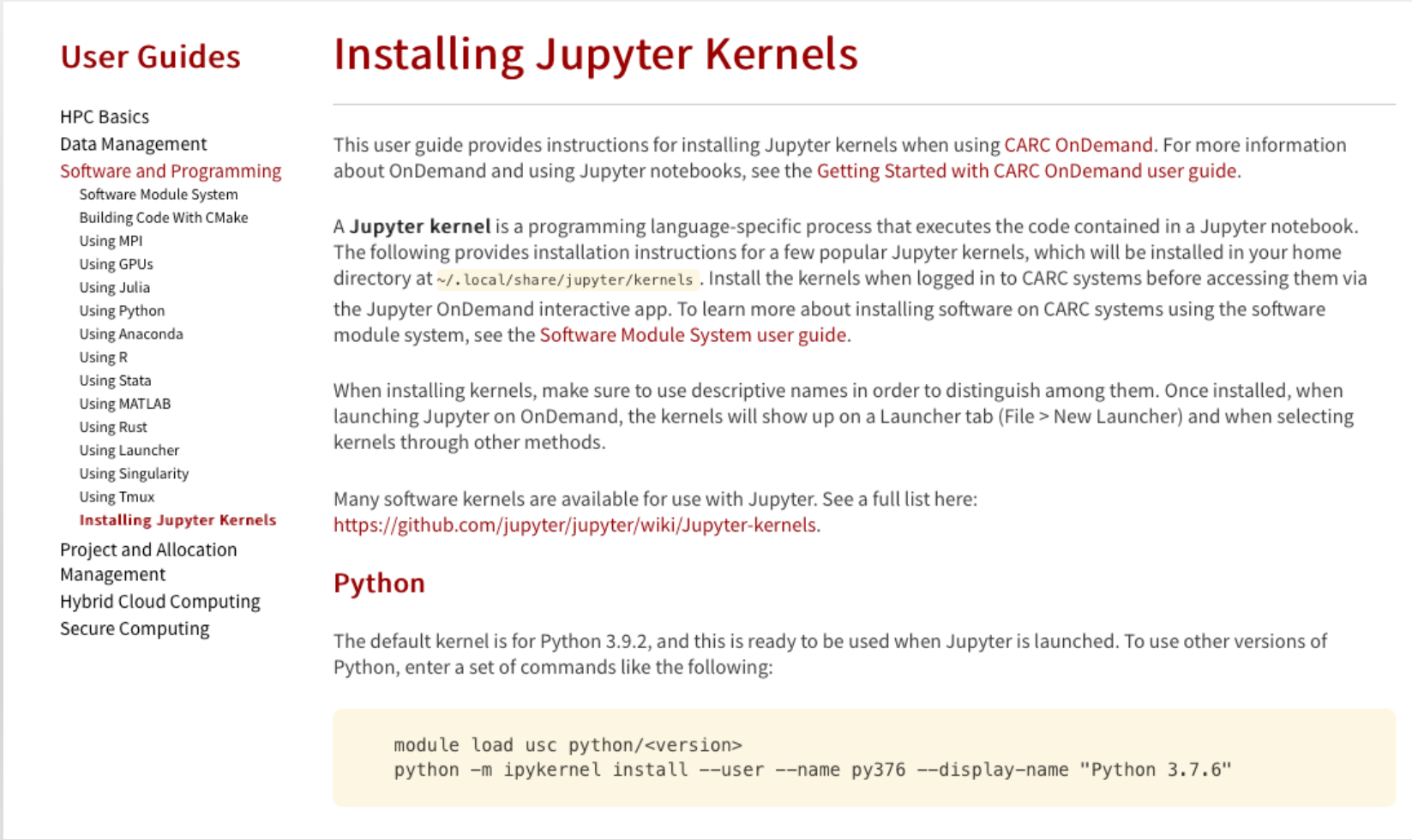
Select your preferences and run the install command. Stable represents the most currently tested and supported version of PyTorch. This should be suitable for many users. Preview is available if you want the latest, not fully tested and supported, 1.12 builds that are generated nightly. Please ensure that you have **met the prerequisites below (e.g., numpy)**, depending on your package manager. Anaconda is our recommended package manager since it installs all dependencies. You can also install previous versions of PyTorch. Note that LibTorch is only available for C++.

Additional support or warranty for some PyTorch Stable and LTS binaries are available through the PyTorch Enterprise Support Program.

PyTorch Build	**Stable (1.11.0)**	Preview (Nightly)	LTS (1.8.2)	
Your OS	**Linux**	Mac	Windows	
Package	**Conda**	Pip	LibTorch	Source
Language	**Python**	C++ / Java		
Compute Platform	CUDA 10.2	**CUDA 11.3**	ROCm 4.2 (beta)	CPU
Run this Command:	`conda install pytorch torchvision torchaudio cudatoolkit=11.3 -c pytorch`			

Creating Jupyter Kernel

A **Jupyter kernel** is a programming language-specific process that executes the code contained in a Jupyter notebook.



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  - **Installing Jupyter Kernels**
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- Secure Computing

Installing Jupyter Kernels

This user guide provides instructions for installing Jupyter kernels when using CARC OnDemand. For more information about OnDemand and using Jupyter notebooks, see the Getting Started with CARC OnDemand user guide.

A **Jupyter kernel** is a programming language-specific process that executes the code contained in a Jupyter notebook. The following provides installation instructions for a few popular Jupyter kernels, which will be installed in your home directory at `~/.local/share/jupyter/kernels`. Install the kernels when logged in to CARC systems before accessing them via the Jupyter OnDemand interactive app. To learn more about installing software on CARC systems using the software module system, see the Software Module System user guide.

When installing kernels, make sure to use descriptive names in order to distinguish among them. Once installed, when launching Jupyter on OnDemand, the kernels will show up on a Launcher tab (File > New Launcher) and when selecting kernels through other methods.

Many software kernels are available for use with Jupyter. See a full list here: https://github.com/jupyter/jupyter/wiki/Jupyter-kernels.

Python

The default kernel is for Python 3.9.2, and this is ready to be used when Jupyter is launched. To use other versions of Python, enter a set of commands like the following:

```
module load usc python/<version>
python -m ipykernel install --user --name py376 --display-name "Python 3.7.6"
```

https://www.carc.usc.edu/user-information/user-guides/software-and-programming/jupyter-kernels

Slurm script for job submission

Sample Job Script for running training jobs on GPU partition

```
#!/bin/bash
#SBATCH --nodes=1
#SBATCH --ntasks=1
#SBATCH --cpus-per-task=2
#SBATCH --mem=32g
#SBATCH --time=02:00:00
#SBATCH --partition=gpu
#SBATCH --gres=gpu:a40:1
#SBATCH --account=wjendrze_120

module purge
eval "$(conda shell.bash hook)”
conda activate torch_benchmark
python CIFAR10_RestNet50.py
```

Common types of GPU

https://www.carc.usc.edu/user-information/user-guides/hpc-basics/discovery-resources

Partition	CPU model	CPU frequency	CPUs/node	GPU model	GPUs/node	Memory/node	Nodes
gpu	xeon-6130	2.10 GHz	32	V100	2	184 GB	29
gpu	xeon-2640v4	2.40 GHz	20	P100	2	123 GB	38
gpu	epyc-7282	2.80 GHz	32	A40	2	248 GB	12
gpu	epyc-7513	2.60 GHz	64	A100	2	248 GB	12

Common types of GPU

https://www.carc.usc.edu/user-information/user-guides/hpc-basics/discovery-resources

GPU specifications in the GPU partition

There are four kinds of GPUs in the GPU partition: A100, A40, V100, P100. The following is a summary table for the GPU specifications:

GPU model	Architecture	Memory	Memory Bandwidth	Base Clock Speed	Cuda Cores	Tensor Cores	Single Precision Performance (FP32)	Double Precision Performance (FP64)
A100	ampere	40GB	1.6TB/s	765MHz	6912	432	19.5TFLOPS	9.7TFLOPS
A40	ampere	48GB	696GB/s	1305MHz	10752	336	37.4TFLOPS	584.6GFLOPS
V100	volta	32GB	900GB/s	1230MHz	5120	640	14TFLOPS	7TFLOPS
P100	pascal	16GB	732GB/s	1189MHz	3584	n/a	9.3TFLOPS	4.7TFLOPS