EAR user guide

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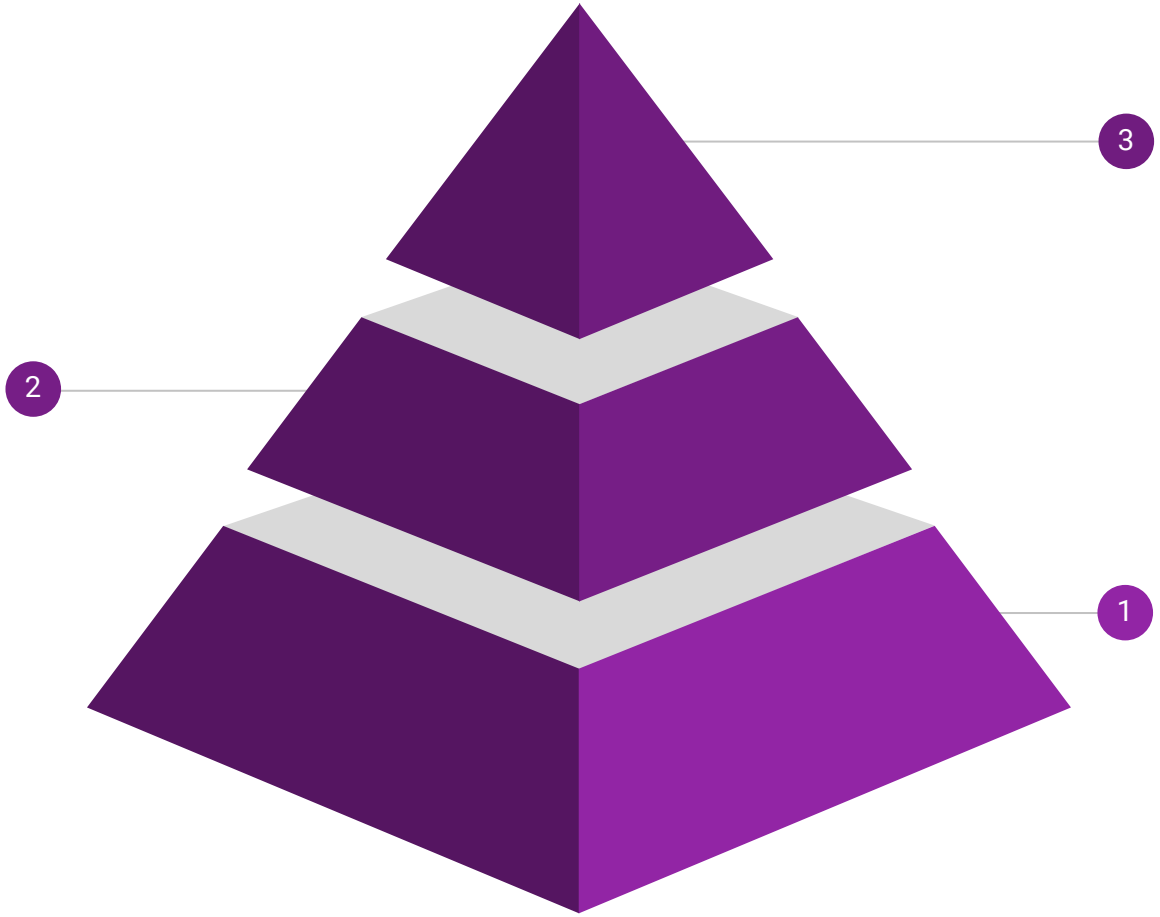
Topics

- EAR overview
- Running jobs with EAR
- Job Monitoring
- Static energy optimization
- Dynamic energy op
- EAR Data visualization with Grafana

https://gitlab.bsc.es/ear_team/ear/-/wikis/home

EAR overview

What's EAR: System software for energy management and optimization



Energy-efficient system

3

Runtime energy optimization, Cluster power management and Cluster and node powercap.

Powerful application performance and power monitoring

2

Runtime library to monitor performance and power dynamically **without any application modification**

System monitoring and Job Accounting

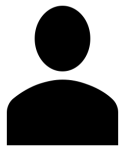
1

Reports system power consumption

Job energy accounting

What EAR can do for you?

0 effort



Evaluate my app

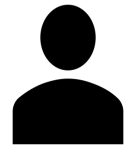
I want to know

Understand my app

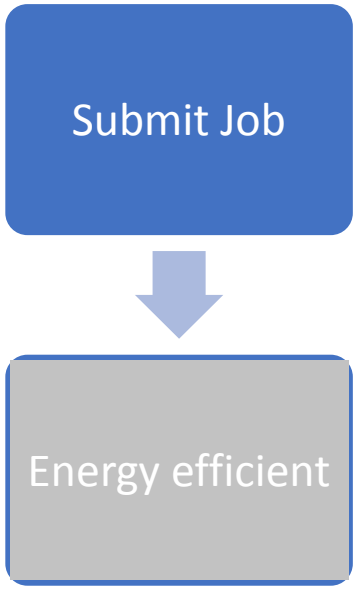
I want to understand

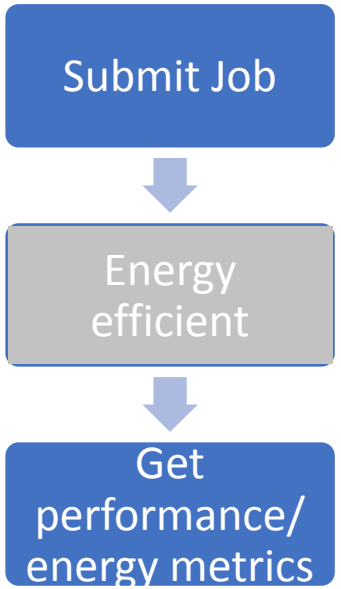
Optimize my app

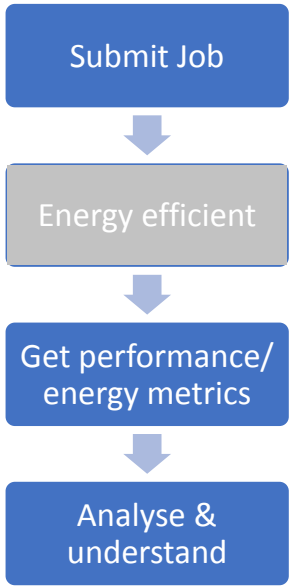
I want to improve my app

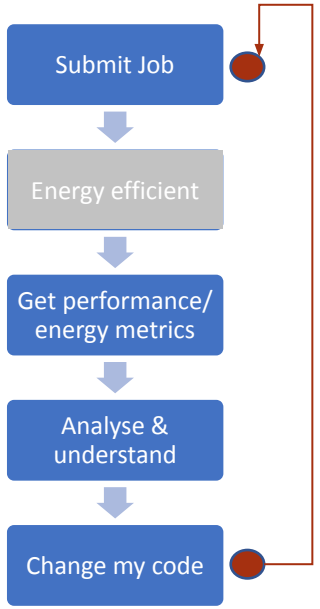


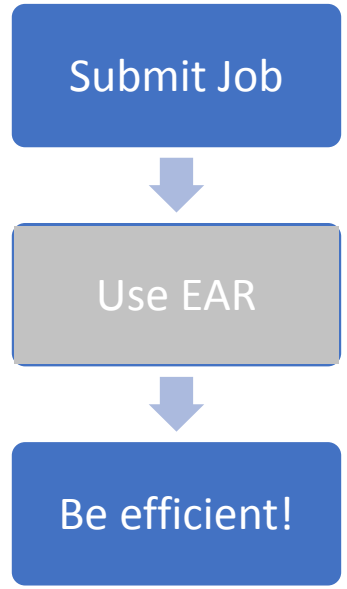
Be energy efficient





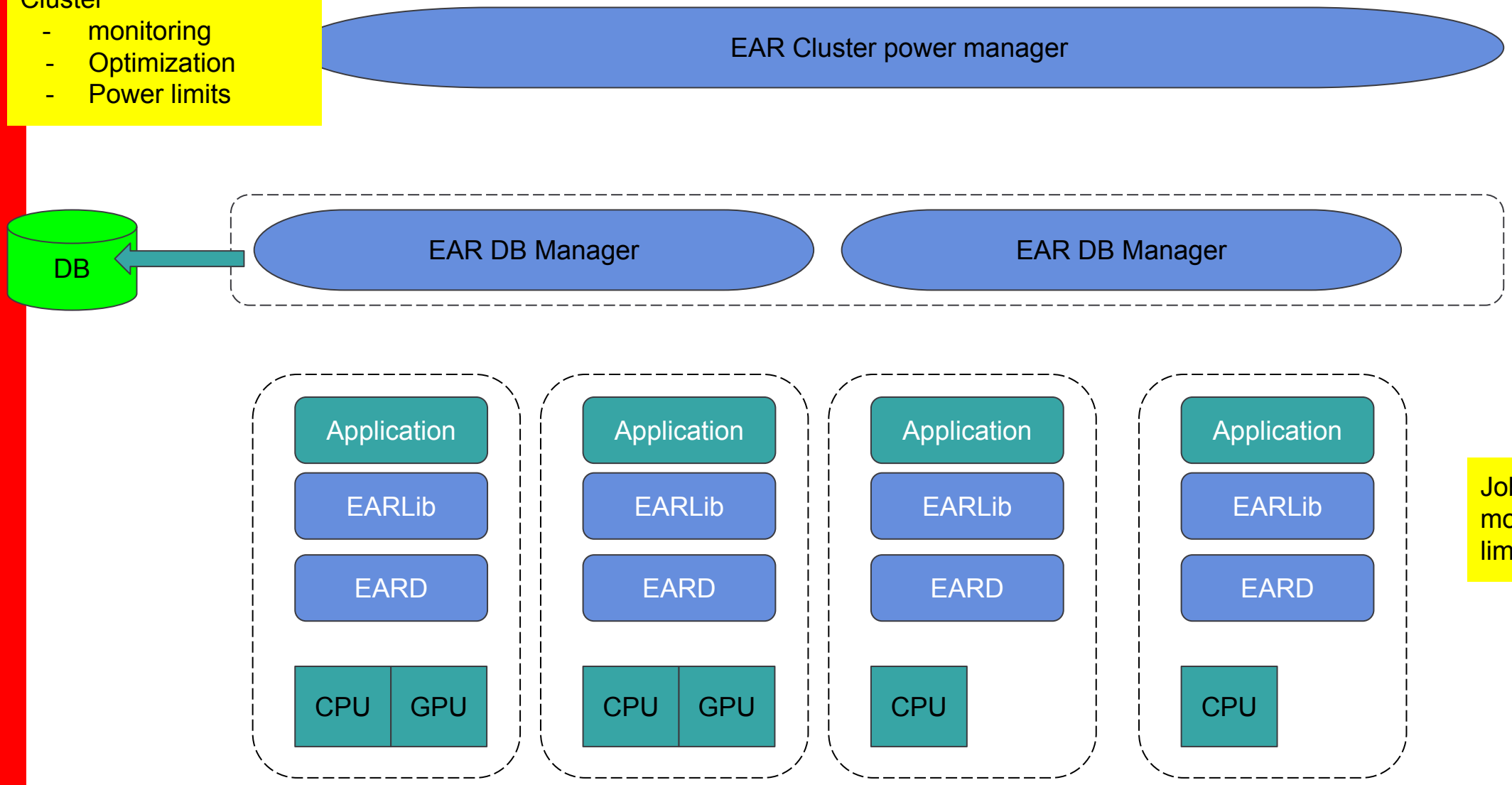






EAR architecture

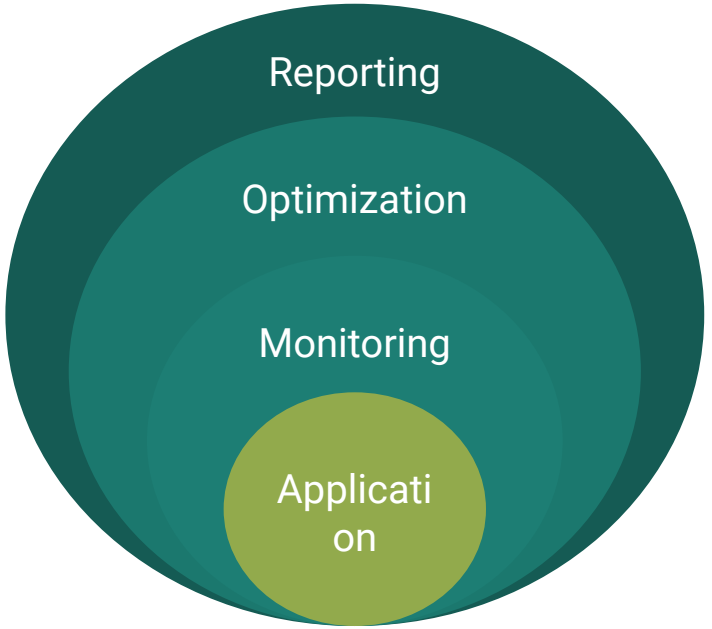
Cluster
- monitoring
- Optimization
- Power limits



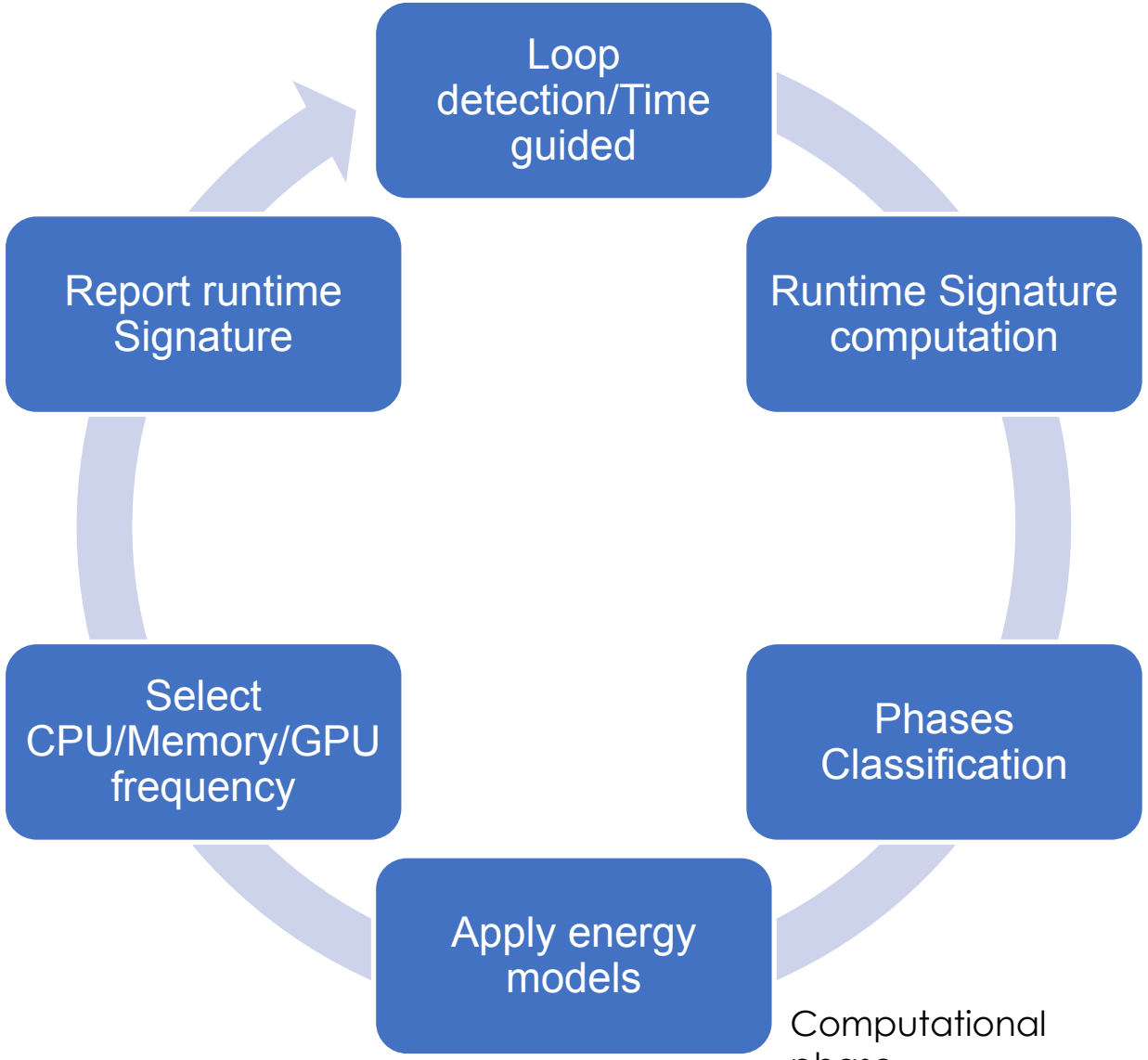
Job Optimization, monitoring, power limits

EAR Library

- User-level Runtime library
- Transparent to users through scheduler plugin (LD_PRELOAD used)
  - Few exceptions need some environment variables: Ex. Singularity
- Application energy and performance monitoring
- Application dynamic energy optimization
- Extensible design based on plugins
  - Multiple report plugins can be used: DB, CSV, etc
  - New policies
  - New energy models
  - ETC



EAR Library lifecycle/stages



Computational phase

- Monitoring
  - Runtime loop detection (MPI only).
  - OR Time guided.
  - Automatic configuration of ***chunks*** for performance and power accuracy.
- Signatures report
  - Average per jobid/stepid/node.
  - Runtime metrics computed for **chunks**.

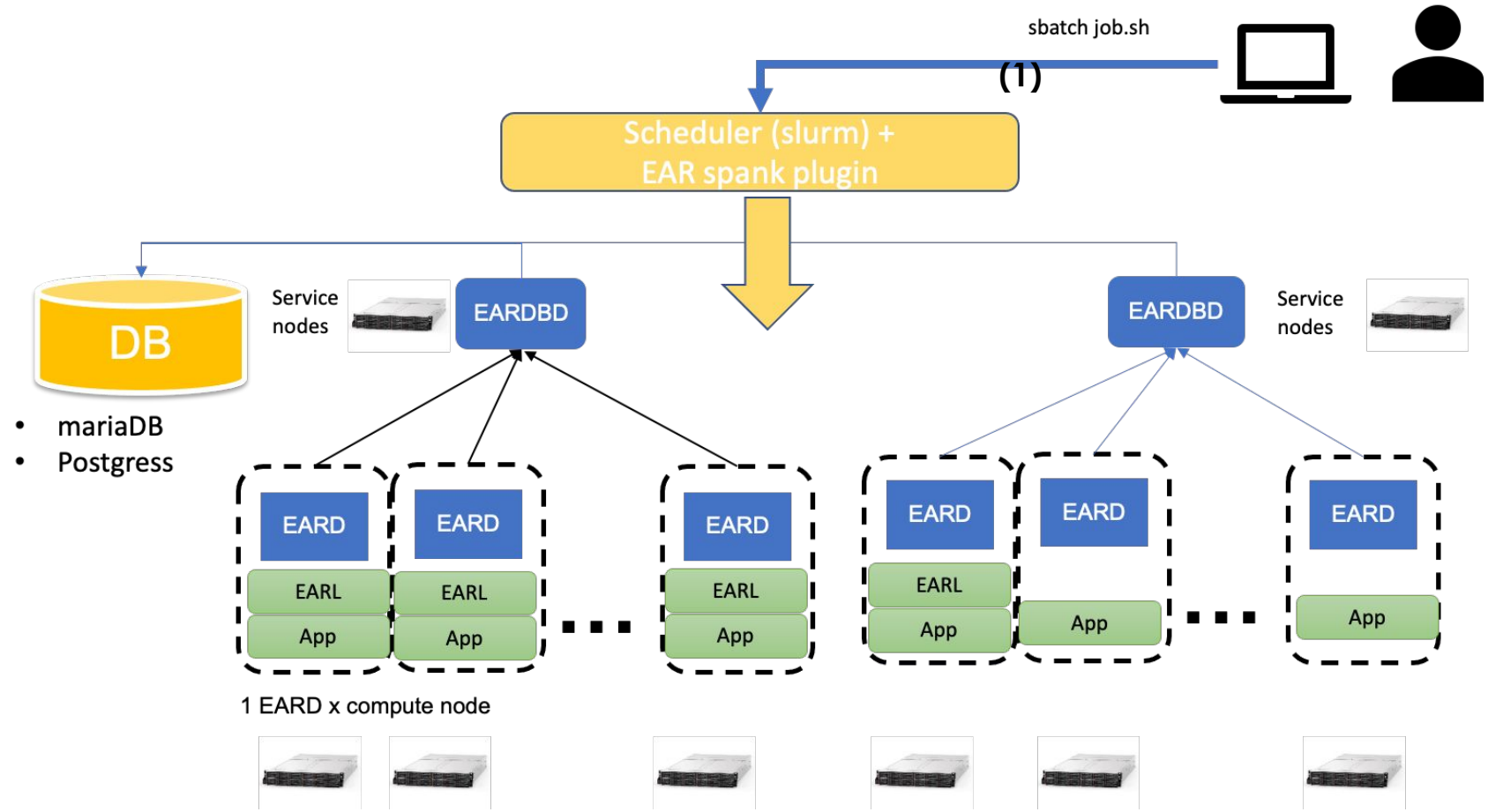
chunk = set of consecutive iterations with enough time to compute the power (def=10 sec.)

IO phase
GPU bound phase
GPU idle
CPU busy waiting
CPU and GPU

Specific Frequency settings

Running jobs with EAR

Jobs submission/accounting schema



Job submission use cases

- Without EAR library 100% transparent
- With EAR library: To be 100% automatic EAR library needs
  - Symbol detection
  - Scheduler support (sbatch, srun or salloc)
- erun command or environment variables for not 100% automatic cases

	Use case	Bootstrap	Automatic
MPI	Intel/OpenMPI [+ others]	srun	yes
	Intel [+ others]	mpirun	yes
	OpenMPI [+ others]	mpirun	no : use erun
OpenMP		srun	yes (or use erun)
CUDA		srun	yes (or use erun)
python		srun	yes (or use erun)
Singularity (+any use case)		srun	yes + module or env var support

https://gitlab.bsc.es/ear_team/ear/-/wikis/User-guide#use-cases

EAR Library job submission options

- Many of the job job scripts will work without modification.
- EAR flags in "help"

```
[julitac@int1 ~]$ sbatch --help|grep ear
      --ear=on|off                Enables/disables Energy Aware Runtime Library (default OFF)
      --ear-policy=type           Selects an energy policy for EAR (monitoring, min_energy, min_time)
      --ear-cpufreq=frequency Specifies the start frequency to be used by EAR , to be used with  monitoring
     --ear-user-db=file           Specifies the file to save the job applications metrics (csv format)
      --ear-verbose=value         Specifies the level of verbosity (0 default)
```

Special cases (I)

- **MPI+Python is not transparent**, the user (or the module) should define the MPI version because it cannot be detected.
  - export EAR_LOAD_MPI_VERSION="open mpi"
  - export EAR_LOAD_MPI_VERSION="intel"
- **Singularity**: EAR can be used but EAR paths and env vars must be exported: APPTAINER_ENV_XXX, APPTAINER_BIND
  - export APPTAINER_BIND="$EAR_INSTALL_PATH:$EAR_INSTALL_PATH:ro,$EAR_TMP:$EAR_TMP:rw"
  - export APPTAINERENV_EAR_INSTALL_PATH=$EAR_INSTALL_PATH
  - export APPTAINERENV_EAR_TMP=$EAR_TMP
  - export APPTAINERENV_EAR_ETC=$EAR_TMP

Special cases (II)

- **OpenMPI**
  - srun recommended
  - use mpirun + erun
- Other use cases/frameworks
  - Force EAR to be loaded with env var
  - export EAR_LOADER_APPLICATION="julia"

Monitoring: EAR metrics

https://gitlab.bsc.es/ear_team/ear/-/wikis/EAR-commands#ear-job-accounting-eacct

Monitoring

- Jobs executed without EAR library (ear = off) report basic job accounting
  - Job/step/node identification
  - Job/step/node execution time
  - Job/step/node energy consumption
- Jobs executed with EAR library (ear =on) report advanced job accounting
  - Job/step/node identification
  - Job/step/node/dynamic performance metrics (measured by EAR library)
  - Job/step/node/dynamic power metrics (measured by EAR library)
- Data is reported in EAR DB

How to get application data

1. **With EAR job accounting command eacct**: Command line with pre-defined queries. Multiple filters supported
    a. average
    b. per node
    c. runtime
    d. pre-selected column in stdout or full data in CSV file
2. **Directly from EAR library**
    a. csv with timestamp included: **--ear-user-db=filename** (prefix for the file)
    b. Additional report plugins can be used with env var.
        i. **EAR_REPORT_ADD**=plugin1.so:plug2.so

Example: https://gitlab.bsc.es/ear_team/ear/-/blob/master/src/report/log.c

Job submission examples

```
#!/bin/bash
#SBATCH –ntasks=YYY
#### EAR=ON will load all the steps with EAR library
#SBATCH --ear=on

mkdir -p logs
# CASE 1: Default: EAR library on because of headers
srun application
# Runtime metrics reported ON
export EARL_REPORT_LOOPS=1
# CASE 2:  mpirun + ear-user-db → CSV file
export I_MPI_HYDRA_BOOTSTRAP_EXEC_EXTRA_ARGS="--ear-user-db=logs/app"
mpirun application
# CASE 3: Using srun + ear-user-db → CSV file
srun --ear-user-db=logs/bt.srun application
# CASE 4: Using erun
module load ear
mpirun -n XXXX  erun --ear=on --program="application arg1 arg2…argn”
# CASE 5: EAR library off for this steps
srun --ear=off application
```

eacct: Energy accounting

- SLURM jobid/stepid
- Users can access its own data
- GPU support is per-cluster, Jobs executed in AMD partition will also show GPU metrics with null values.
- By default, average per job.step metrics: All nodes included. Most metrics are averaged, energy is accumulated.
- Main flags:
  - -l → per node
  - -r → runtime metrics (default is off in snellius. Use **export EARL_REPORT_LOOPS=1**
  - -c filename → save in CSV format in file

```
[julitac@int3 example]$ eacct -j 1483484
JOB-STEP USER      APPLICATION      POLICY NODES AVG/DEF/IMC(GHz) TIME(s)    POWER(W) GBS     CPI      ENERGY(J)    GFLOPS/W IO(MBs) MPI%  G-POW(T/U)   G-FREQ
G-UTIL(G/MEM)
1483484-sb julitac    128nodes_16cores NP    16    2.35/2.60/---    972.00    375.71   ---     ---        5843040     ---      ---     ---    ---          ---     ---
1483484-1  julitac    128nodes_16cores MT    16    2.35/2.40/1.47   492.26    373.53   28.44   0.46       2942015     0.0084   250.8   71.7   0.00/---     ---     ---
1483484-0  julitac    128nodes_16cores ME    16    2.55/2.60/1.47   460.68    381.00   30.37   0.47       2808271     0.0088   268.2   71.7   0.00/---     ---     ---
```

eacct metrics

- AVG/DEF/IMC(GHz): **Average** CPU frequency, default frequency and average memory frequency. Includes all the nodes for the step. In KHz.
- TIME(s): Step execution time, in **seconds**.
- **POWER: Average DC node power. (in Watts)**.
- **GBS: CPU Main memory bandwidth (GB/second). Hint for CPU/Memory bound classification.**
- **CPI: CPU Cycles per Instruction. Hint for CPU/Memory bound classification**.
- ENERGY(J): Accumulated node energy. Includes all the nodes. In Joules.
- **GFLOPS/WATT : CPU GFlops per Watt. Hint for energy efficiency.**
- IO(MBs) : IO (read and write) Mega Bytes per second.
- MPI% : **Percentage of MPI time** over the total execution time. It's the average including all the processes and nodes.
- GPU metrics
- G-POW (T/U) : Average GPU power. Accumulated per node and average of all the nodes.
  - T = Total (GPU power consumed even if the process is not using them).
  - U = GPUs used by the job.
- G-FREQ : Average GPU frequency. Per node and average of all the nodes.
- G-UTIL(G/MEM) : GPU utilization and GPU memory utilization.

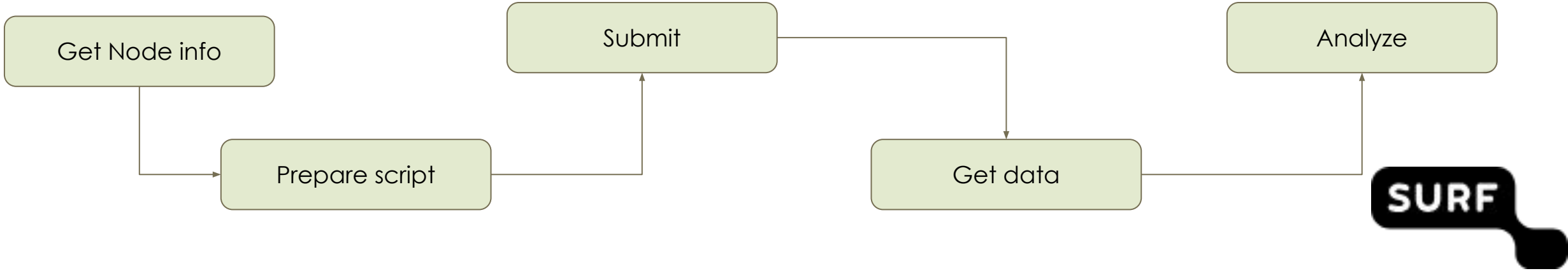
https://gitlab.bsc.es/ear_team/ear/-/wikis/User%20guide#job-accounting-eacct

Tensorflow: GPU application

```
[julitac@int5 ~]$ eacct -j 5687690
   JOB-STEP USER      APPLICATION      POLICY NODES AVG/DEF/IMC(GHz) TIME(s)    POWER(W) GBS     CPI   ENERGY(J)    GFLOPS/W IO(MBs) MPI%  G-POW
(T/U)    G-FREQ  G-UTIL(G/MEM)
5687690-sb   julitac   run_tensor.sh   NP    1    2.43/2.40/---   2612.00   448.98  ---    ---   1172725     ---     ---    ---   ---          ---    ---

5687690-8    julitac   DenseNet121_disa MO    1    2.38/2.40/2.19   358.55    897.17  2.03   0.66  321685      0.0000  0.1    0.0   257.92 /257.92  1.410   92%/44%
5687690-7    julitac   DenseNet121_mixe MO    1    2.38/2.40/2.19   189.30    876.59  0.82   0.67  165936      0.0000  0.2    0.0   238.88 /238.88  1.410   80%/52%
5687690-6    julitac   DenseNet121      MO    1    2.38/2.40/2.19   249.38    890.48  0.59   0.66  222070      0.0000  0.1    0.0   251.56 /251.56  1.410   88%/73%

5687690-5    julitac   VGG19_disable-tf MO    1    2.38/2.40/2.19   646.86    877.18  2.33   0.52  567419      0.0000  0.1    0.0   238.58 /238.58  1.410   98%/26%
5687690-4    julitac   VGG19_mixed      MO    1    2.38/2.40/2.19   248.40    897.64  0.52   0.67  222972      0.0000  0.1    0.0   257.04 /257.04  1.410   96%/51%
5687690-3    julitac   VGG19            MO    1    2.38/2.40/2.19   261.37    907.44  3.21   0.61  237176      0.0000  0.1    0.0   267.94 /267.94  1.410   96%/59%

5687690-2    julitac   ResNet50_disable MO    1    2.38/2.40/2.19   302.42    920.38  4.22   0.65  278338      0.0000  0.1    0.0   279.54 /279.54  1.410   94%/43%
5687690-1    julitac   ResNet50_mixed   MO    1    2.38/2.40/2.19   149.26    873.35  0.80   0.66  130356      0.0000  0.2    0.0   233.60 /233.60  1.403   84%/50%
5687690-0    julitac   ResNet50         MO    1    2.38/2.40/2.19   196.33    904.09  0.62   0.65  177504      0.0000  0.2    0.0   261.45 /261.45  1.372   87%/70%
```

Static energy optimization

- Optimal CPU/Memory/GPU depends on the application, input data, architecture, number of nodes etc etc
- However, you can be interested in applying DVFS in specific case
- With EAR is easy to ask for CPU frequencies
- EAR offers in some architectures more CPU frequencies than available from the OS
- The enode_info command reports the EAR technical specification for the computational node



```
$EAR_INSTALL_PATH/tools/enode_info --cpu
EAR CPU info in node tcn2
EAR CPU info Topology: cpu_count        : 128
core_count       : 128
socket_count     : 2
….. // CPU details
EAR CPU info load
EAR CPU info API: EARD
EAR CPU info num devices:128
EAR CPU info list of CPU frequencies
PS0: id0, 2600000 KHz
PS1: id1, 2500000 KHz
PS2: id2, 2400000 KHz
PS3: id3, 2300000 KHz
PS4: id4, 2200000 KHz
PS5: id5, 2100000 KHz
PS6: id6, 2000000 KHz
PS7: id7, 1900000 KHz
PS8: id8, 1800000 KHz
PS9: id9, 1700000 KHz
PS10: id10, 1600000 KHz
PS11: id11, 1500000 KHz
EAR CPU info pstate nominal is 0, CPU freq = 2600000 KHz
EAR CPU info governor CPU[0] = conservative
….
EAR CPU info governor CPU[127] = conservative
EAR CPU info curr CPUF[0] = 2601000
..
EAR CPU info curr CPUF[127] = 2601000
```

```
#!/bin/bash
#SBATCH --job-name=sp
#SBATCH --ntasks=128
#SBATCH --ear=on
module purge
module load 2022
module load iimpi/2022a

export OMP_NUM_THREADS=1
export EARL_REPORT_LOOPS=1
srun --ear-policy=monitoring --ear-cpufreq=2500000 ./sp-mz.D.128
srun --ear-policy=monitoring --ear-cpufreq=2400000 ./sp-mz.D.128
srun --ear-policy=monitoring --ear-cpufreq=2300000 ./sp-mz.D.128
srun --ear-policy=monitoring --ear-cpufreq=2200000 ./sp-mz.D.128
```

Energy policies: Computational phases

- Monitoring:
  - Application analysis
  - Static energy optimization (Manual CPU/Memory/GPU freq selection)

- Minimize energy to solution (min_energy)
  - EAR **reduces CPU frequency** to save energy with a maximum time penalty
  - Applications start at default frequency and CPU frequency is (potentially) reduced
  - default frequency = nominal frequency
  - Memory frequency selected with a linear search

- Minimize time to solution (min_time)
  - EAR **increases CPU frequency** to minimize time for "*frequency efficient*" codes
  - Applications that scale well with CPU frequency
  - Default frequency = lower than nominal frequency
  - Application will never run at CPU frequency below the default CPU frequency
  - Memory frequency selected with a linear search

Common to both policies

- GPU optimization when GPU idleness.
- IO phases detected.
- Turbo can be enabled if configured and CPU bound application.
- Intra-node Load balance .

- GPU frequency selection:
  - Maximum if GPU utilization > 0
  - Minimum if GPU utilization == 0 (power consumption is lower.)

sbatch --ntasks=192 --partition=genoa sp.D.sh
sbatch --ntasks=192 --partition=genoa **–ear-policy=min_energy** sp.D.sh

KERNEL SP-MZ.D : ROME (ME vs MO): Must be the same node for comparison

```
[julitac@int5]$ eacct -j 4896747.0
   JOB-STEP USER      APPLICATION      POLICY NODES AVG/DEF/IMC(GHz) TIME(s)    POWER(W) GBS     CPI   ENERGY(J)    GFLOPS/W IO(MBs) MPI%
G-POW (T/U)    G-FREQ  G-UTIL(G/MEM)
4896747-0    julitac    sp             ME     1    2.16/2.60/1.47   336.75     457.62    197.79  0.69  154102       2.9608   0.0      12.0  0.00/---       ---
---
[julitac@int5]$ eacct -j 4896738.0
   JOB-STEP USER      APPLICATION      POLICY NODES AVG/DEF/IMC(GHz) TIME(s)    POWER(W) GBS     CPI   ENERGY(J)    GFLOPS/W IO(MBs) MPI%
G-POW (T/U)    G-FREQ  G-UTIL(G/MEM)
4896738-0    julitac    sp             MO     1    2.57/2.60/1.47   329.67     519.01    202.73  0.79  171103       2.6666   0.0      11.0  0.00/---       ---
---
```

Visualization with Grafana

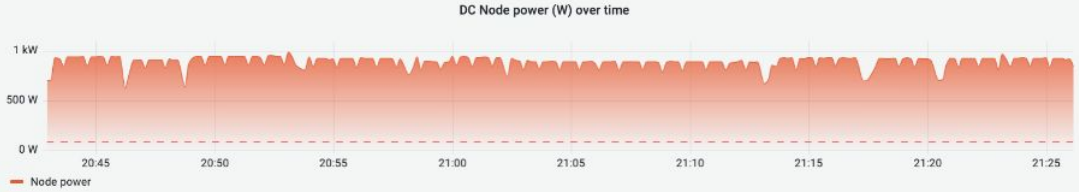
- Steps to use EAR data are in grafana with CSV are
  - Have a local grafana installation with CSV plugins supported
  - Export EAR application data in csv format using eacct (-l -c option) or –ear-user-db flag
  - Export EAR application runtime data in csv format using eacct (-r -c option) or –ear-user-db flag
  - Add a source data based on a local file (Public folder)
    - julita.corbalan$ cp tensorflow.csv **ear_data_apps.csv**
    - julita.corbalan$ cp tensorflow_loops.csv **ear_data_loops.csv**
  - Import the EAR json file with the dashboards for data visualization
    - "EAR job data visualization.json"
  - Reload the dashboards

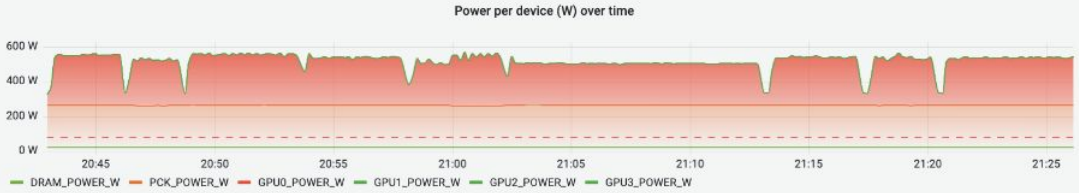
General / EAR job data visualization

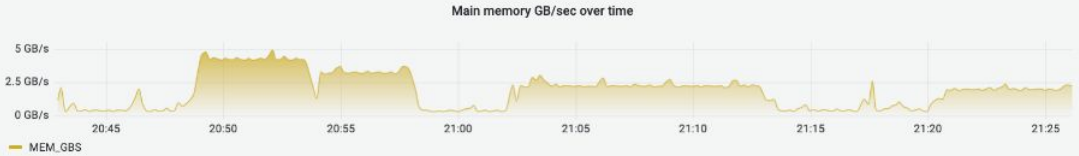
2024-03-25 20:42:55 to 2024-03-25 21:26:07

› Time lines-GPU (3 panels)

⌄ Time lines-CPU







⌄ Data

EAR collected data per-job/step/node

JOBID	STEPID	Node	Job name	Avg.CPU freq.(	Def. Freq (GHz)	Elapsed time	Avg.Power	CPI	Memory BW (GB/sec)	IO (MB/sec	Perc. MPI	CPU-GFLOPS	SPOPS_SINGLE	SPOPS_128	SPOPS_256	SPOPS_512	DPOPS_SINGLE	DPOPS_128	DP_256
5687690	0	gcn11	ResNet50	2.38 GHz	2.40 GHz	3.27 min	904 W	0.650	0.622	0.18	0%	0.0000100	1899742	0	0	0	145398	198	20
5687690	1	gcn11	ResNet50_...	2.38 GHz	2.40 GHz	2.49 min	873 W	0.658	0.803	0.24	0%	0.00000200	53038	0	0	0	177136	182	0
5687690	2	gcn11	ResNet50_...	2.38 GHz	2.40 GHz	5.04 min	920 W	0.651	4.22	0.12	0%	0.0000130	3722152	0	0	0	148370	194	20
5687690	3	gcn11	VGG19	2.38 GHz	2.40 GHz	4.36 min	907 W	0.613	3.21	0.14	0%	0.0000260	6691783	0	0	0	90405	130	8
5687690	4	gcn11	VGG19_mix...	2.38 GHz	2.40 GHz	4.14 min	898 W	0.675	0.522	0.14	0%	0	16145	0	0	0	105404	170	4
5687690	5	gcn11	VGG19_dis...	2.38 GHz	2.40 GHz	10.8 min	877 W	0.515	2.33	0.06	0%	0.0000340	21958413	0	0	0	92376	122	0
5687690	6	gcn11	DenseNet1...	2.38 GHz	2.40 GHz	4.16 min	890 W	0.659	0.591	0.14	0%	0.00000900	1957675	0	0	0	224686	306	0

‹ 1 2 ›

1 - 7 of 9 rows

EAR collected data per jobid-stepid

JOBID	STEPID	Job name	TIME_SEC (m	DC_NODE_POWER_W (sum)	CPI (mean)	MEM_GBS (sum)	PERC_MPI (mean)
5687690	8	DenseNet121_disabl...	5.98 min	897.17 W	0.66	2.03 GB/s	0.00%
5687690	7	DenseNet121_mixed	3.15 min	876.59 W	0.67	815.12 MB/s	0.00%
5687690	6	DenseNet121	4.16 min	890.48 W	0.66	591.23 MB/s	0.00%
5687690	5	VGG19_disable-tf32	10.78 min	877.18 W	0.52	2.33 GB/s	0.00%
5687690	4	VGG19_mixed	4.14 min	897.64 W	0.67	522.13 MB/s	0.00%
5687690	3	VGG19	4.36 min	907.44 W	0.61	3.21 GB/s	0.00%
5687690	2	ResNet50_disable-tf...	5.04 min	920.38 W	0.65	4.22 GB/s	0.00%

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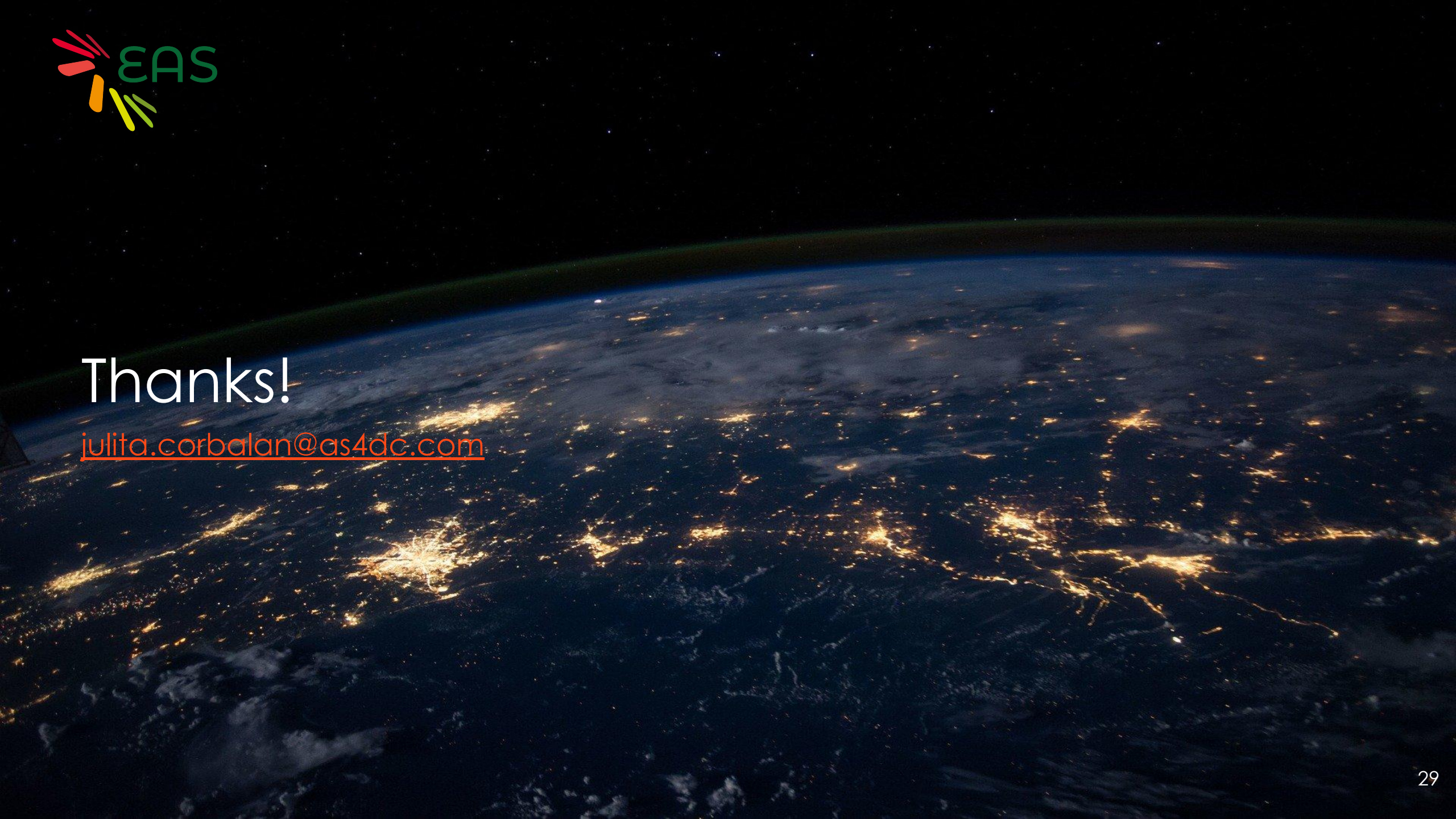
1 - 7 of 9 rows



Thanks!

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