E4S: The Extreme-scale Scientific Software Stack Release 23.02

Release 23.02 notes

February 28, 2023

EXASCALE COMPUTING PROJECT

National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY | Office of Science

E4S 23.02: What's New?

- E4S supports Hopper architecture H100 (sm90) GPUs from NVIDIA with CUDA 12.0 and NVHPC 23.1
  - AI/ML frameworks such as TensorFlow and PyTorch support for A100 as well as H100 GPUs is integrated in E4S 23.02
- E4S supports a Julia software stack:
  - CUDA
  - MPI
- E4S supports EDA tools
  - Xyce in containers on x86_64, ppc64le, aarch64
  - Cloud EDA on AWS [https://e4s.io/eda] with 50+ EDA tools (Xschem, Xyce, OpenROAD, OpenFASOC, OpenLane, …)
- E4S supports and ships with ROCm 5.4.3 with support for MI100 as well as MI210/MI250X AMD GPUs
  - AI/ML frameworks TensorFlow and PyTorch support these new GPU architectures with ROCm 5.4.3
- E4S supports updates to 106 HPC packages on x86_64, aarch64, and ppc64le
- Detailed documentation for installing E4S on bare-metal and using containers

E4S: Extreme-scale Scientific Software Stack

- E4S is a community effort to provide open-source software packages for developing, deploying and running scientific applications on HPC platforms.
- E4S has built a comprehensive, coherent software stack that enables application developers to productively develop highly parallel applications that effectively target diverse exascale architectures.
- E4S provides a curated, Spack based software distribution of 100+ HPC, EDA (e.g., Xyce), and AI/ML packages (e.g., TensorFlow, PyTorch).
- With E4S Spack binary build caches, E4S supports both bare-metal and containerized deployment for GPU based platforms.
  - X86_64, ppc64le (IBM Power 9), aarch64 (ARM64) with support for GPUs from NVIDIA, AMD, and Intel
  - HPC and AI/ML packages are optimized for GPUs and CPUs.
- Container images on DockerHub and E4S website of pre-built binaries of ECP ST products.
- Base images and full featured containers (with GPU support).
- Commercial support for E4S through ParaTools, Inc. for installation, maintaining an issue tracker, and ECP AD engagement.
  - https://dashboard.e4s.io https://e4s.io/talks/E4S_Support_Jan23.pdf
- E4S for commercial cloud platforms: AWS image supports MPI implementations and containers with remote desktop (DCV).
  - Intel MPI, NVHPC, MVAPICH2, MPICH, MPC, OpenMPI
- e4s-cl container launch tool allows binary distribution of applications by substituting MPI in the containerized app with the system MPI.
- Quarterly releases: E4S 23.02 released on February 28, 2023: https://e4s.io/talks/E4S_23.02.pdf

Extreme-scale Scientific Software Stack (E4S)

- E4S: HPC Software Ecosystem – a curated software portfolio
- A **Spack-based** distribution of software tested for interoperability and portability to multiple architectures with support for GPUs from NVIDIA, AMD, and Intel in a single distribution
- Available from **source**, **containers**, **cloud, binary caches**
- Leverages and enhances SDK interoperability thrust
- Not a commercial product – an open resource for all
- Oct 2018: E4S 0.1 - 24 full, 24 partial release products
- Jan 2019: E4S 0.2 - 37 full, 10 partial release products
- Nov 2019: E4S 1.0 - 50 full, 5 partial release products
- Feb 2020: E4S 1.1 - 61 full release products
- Nov 2020: E4S 1.2 (aka, 20.10) - 67 full release products
- Feb 2021: E4S 21.02 - 67 full release, 4 partial release
- May 2021: E4S 21.05 - 76 full release products
- Aug 2021: E4S 21.08 - 88 full release products
- Nov 2021: E4S 21.11 - 91 full release products
- Feb 2022: E4S 22.02 – 100 full release products
- May 2022: E4S 22.05 – 101 full release products
- August 2022: E4S 22.08 – 102 full release products
- November 2022: E4S 22.11 – 103 full release products
- February 2023: E4S 23.02 – 106 full release products

https://e4s.io

Lead: Sameer Shende
(U Oregon)

Also include other products .e.g.,
AI: PyTorch, TensorFlow (CUDA, ROCm)
Co-Design: AMReX, Cabana, MFEM
EDA: Xyce

E4S Download from https://e4s.io

E4S 23.02 container images now available!

See Downloads for more information on E4S 23.02.

What is E4S?

The Extreme-scale Scientific Software Stack (E4S) is a community effort to provide open source software packages for developing, deploying and running scientific applications on high-performance computing (HPC) platforms. E4S provides from-source builds and containers of a broad collection of HPC software packages.

E4S Download from https://e4s.io

Acquiring E4S Containers

The current E4S container offerings include Docker images based on Red Hat Enterprise Linux 7, Red Hat Enterprise Linux 8, Ubuntu 18.04 (Bionic), and Ubuntu 20.04 (Focal Fossa) for Continuous Integration. Our images can run on X86_64, PPC64LE, and AARCH64 depending on the particular image. Our full E4S Release images (not for Continuous Integration) are based on Ubuntu 20.04 (x86_64, aarch64, ppc64le). In addition to offering a full E4S image containing a comprehensive selection of E4S software released on a quarterly cycle, we also offer a set of minimal base images suitable for use in Continuous Integration (CI) pipelines where Spack is used to build packages.

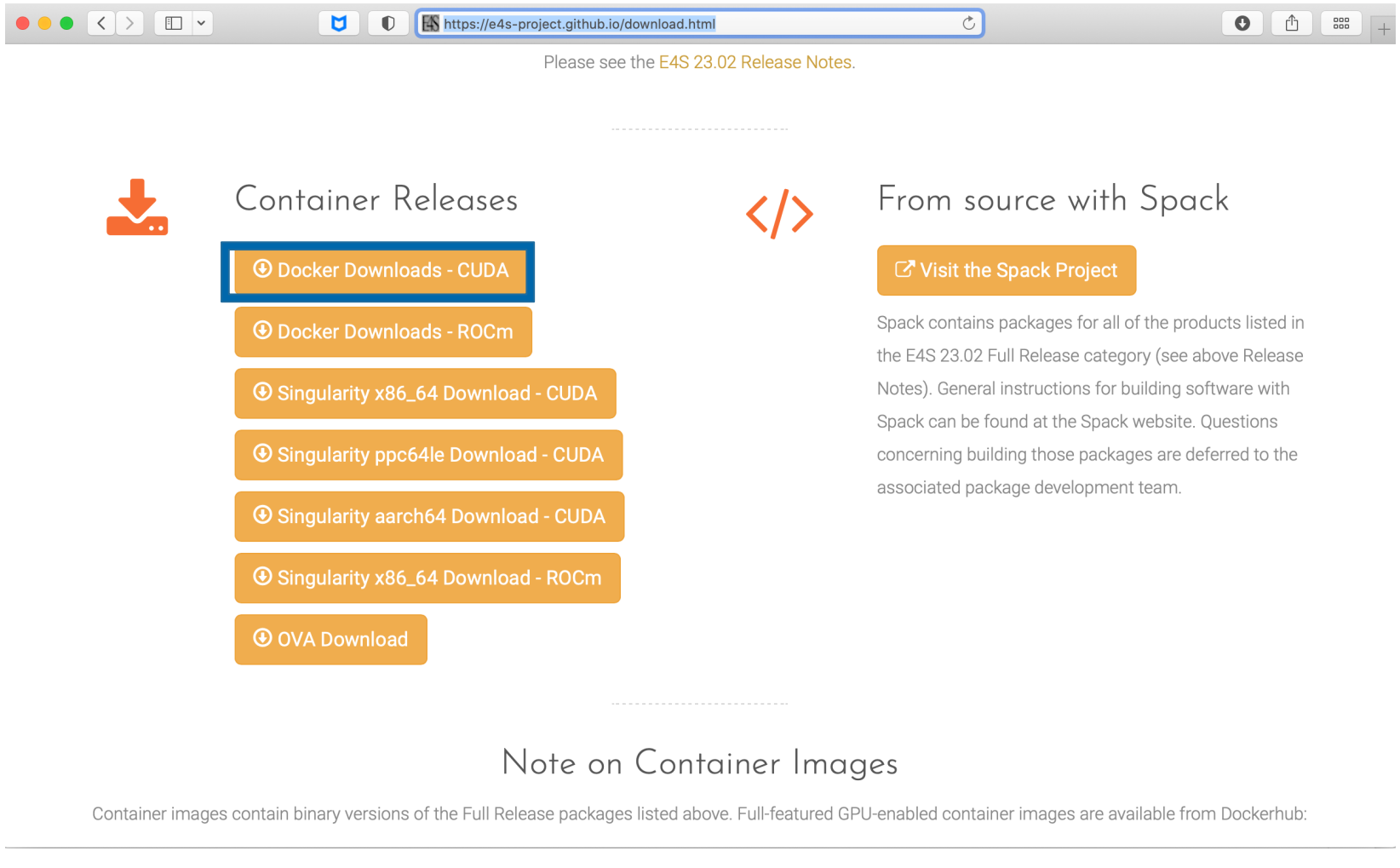
Docker images are available on the E4S Docker Hub.

Please see the E4S 23.02 Release Notes.

Container Releases

From source with Spack

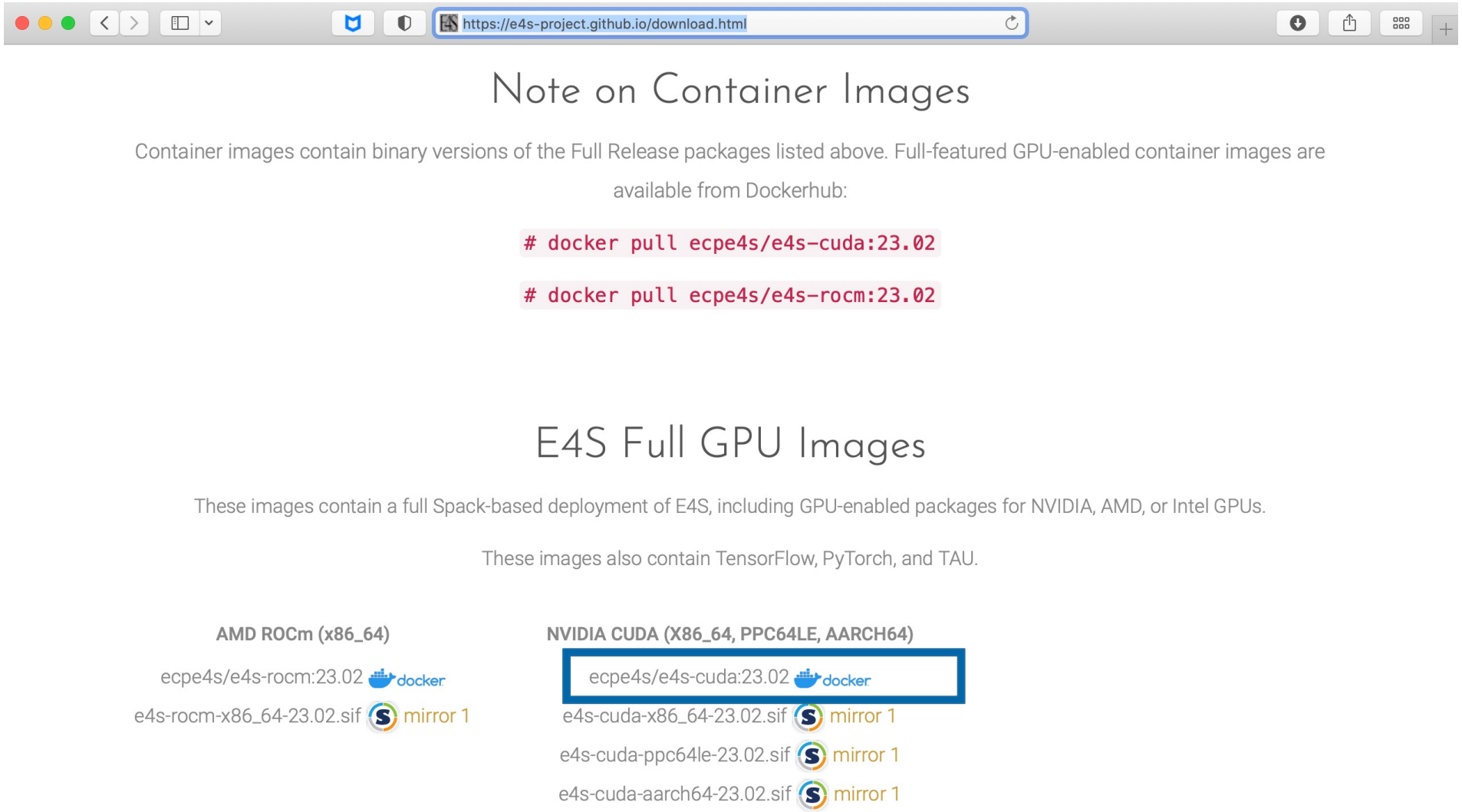
Download E4S 23.02 GPU Container Images: NVIDIA, AMD, Intel



- Separate full featured Singularity images for 3 GPU architectures
- GPU full featured images for
  - x86_64 (Intel, AMD, NVIDIA)
  - ppc64le (NVIDIA)
  - aarch64 (NVIDIA)
- Full featured images available on Dockerhub
- 100+ products on 3 architectures

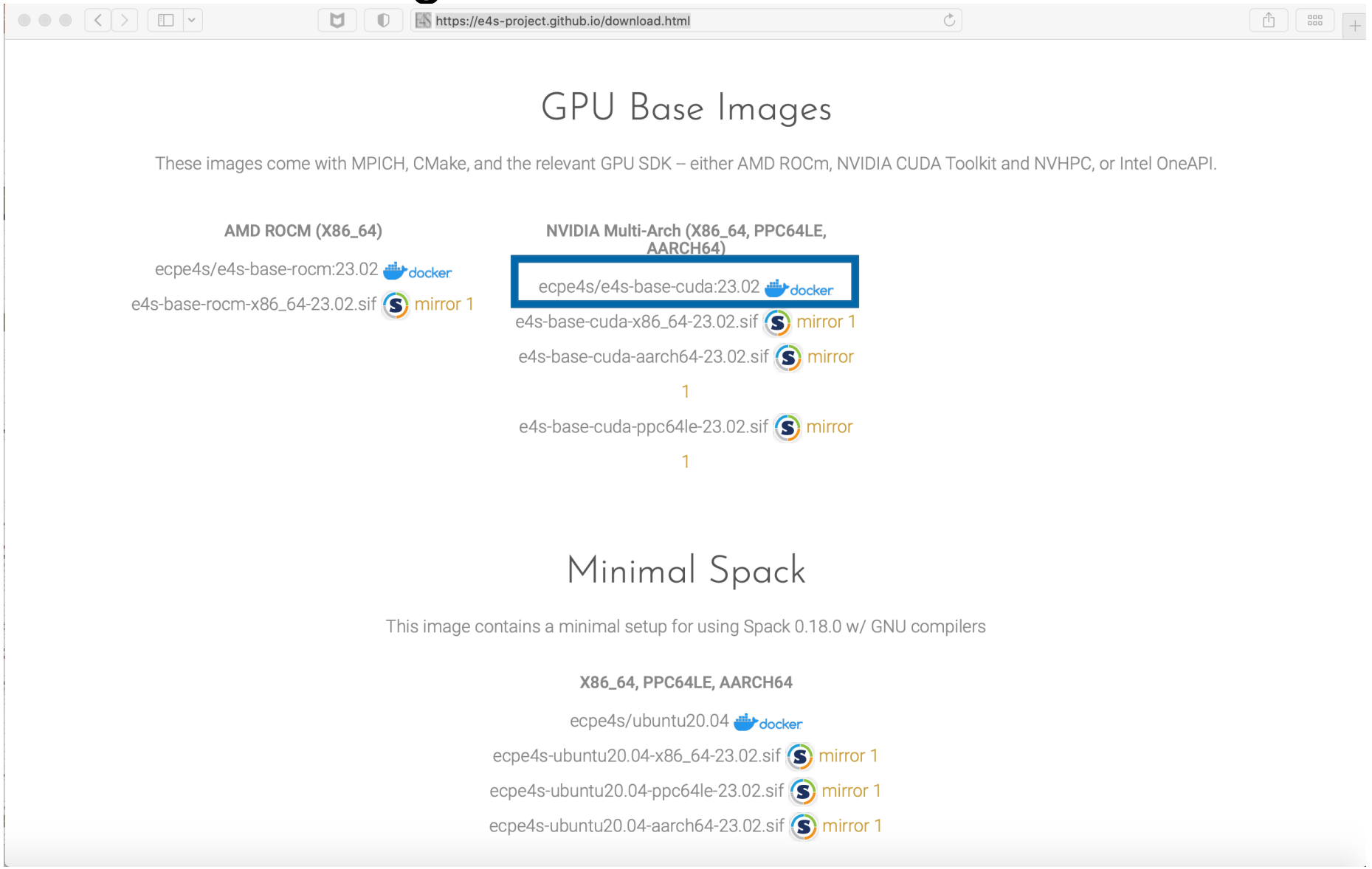
https://e4s.io

Download E4S 23.02 GPU Container Images: NVIDIA and AMD



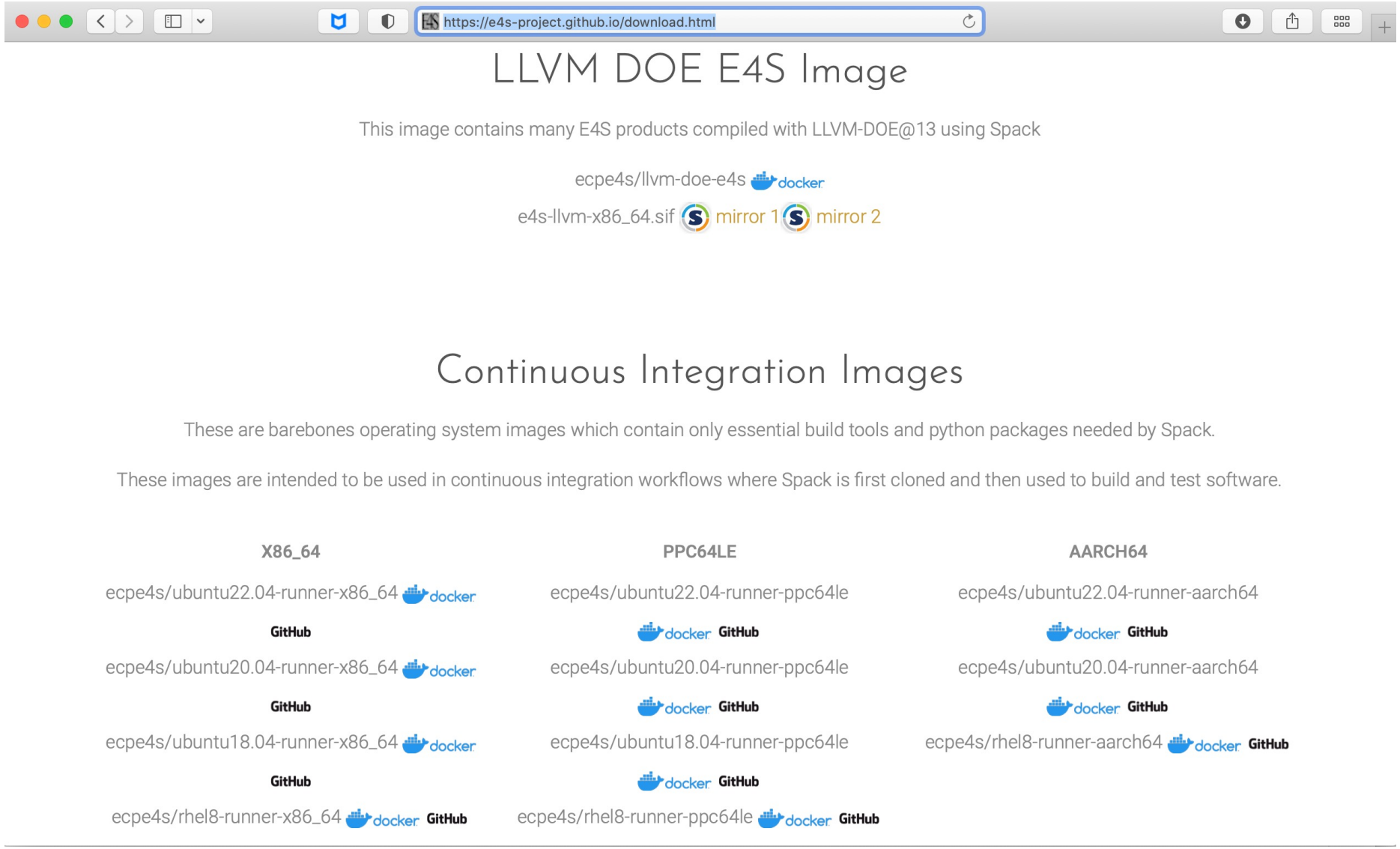
https://e4s.io

E4S base container images allow users to customize their containers



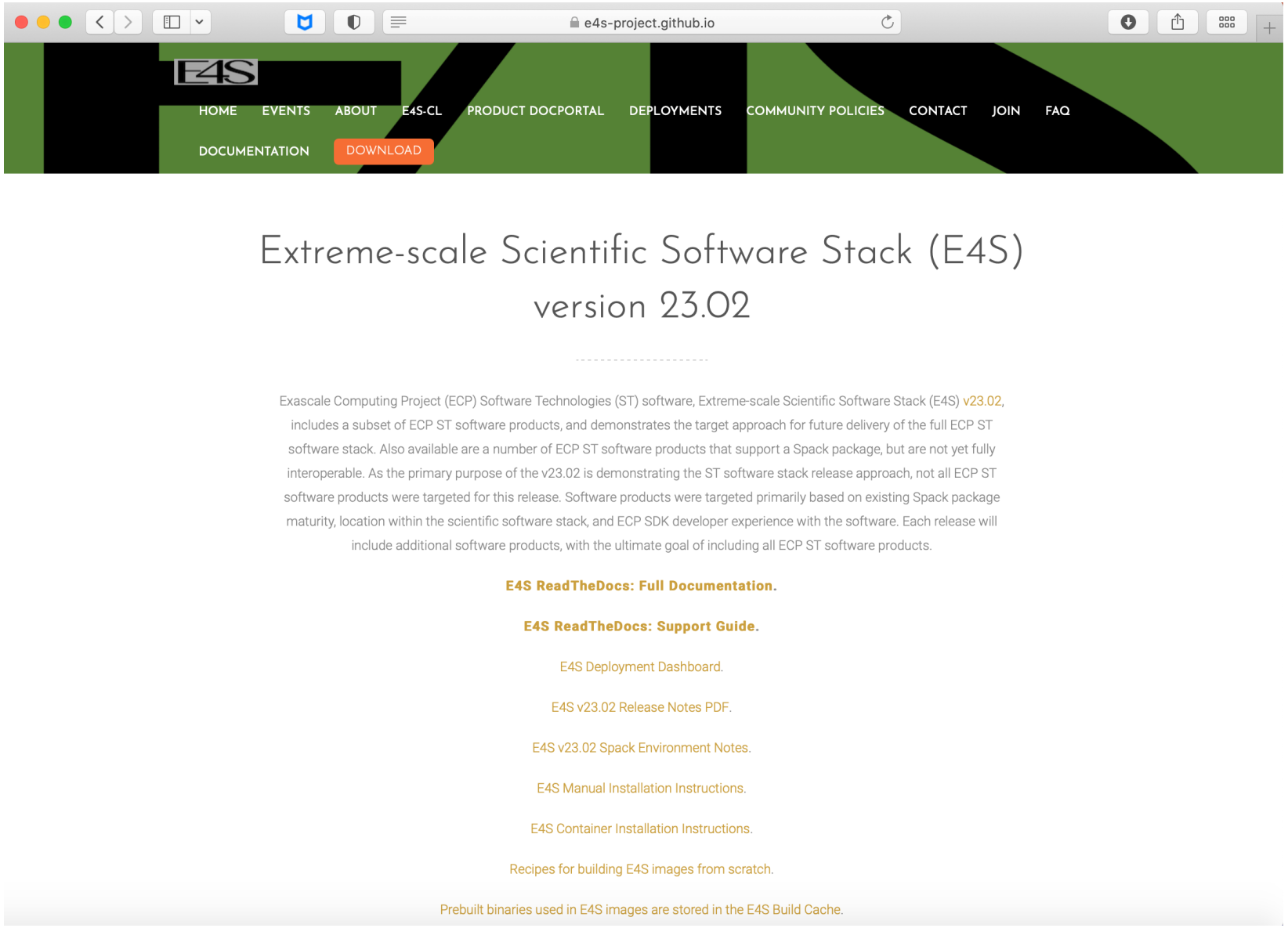
https://e4s.io

E4S 23.02 LLVM and CI images



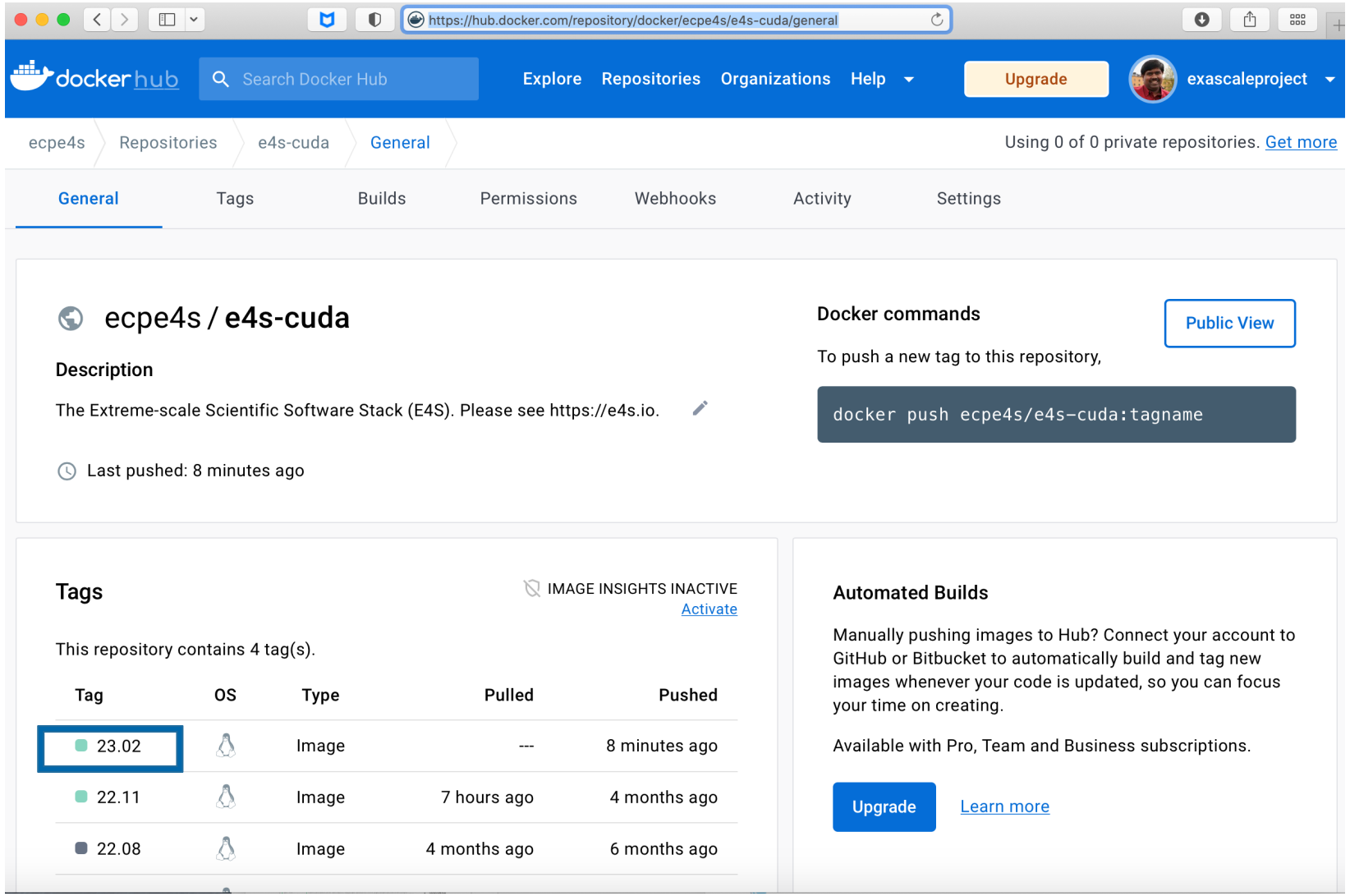
https://e4s.io

E4S 23.02 Detailed Documentation for Bare-metal Installation



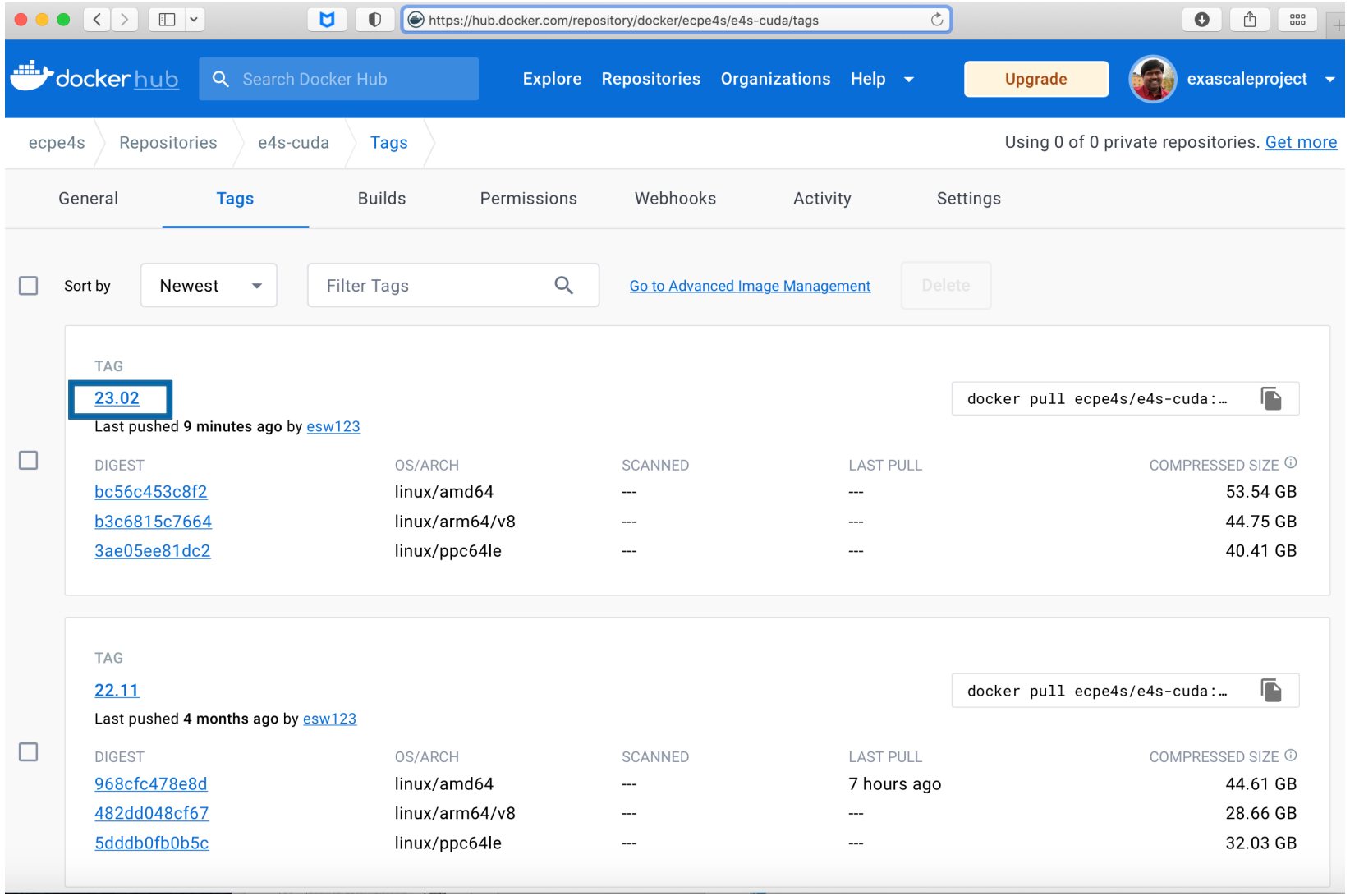
https://e4s.io

E4S 23.02 full featured container release on Dockerhub



docker pull ecpe4s/e4s-cuda:23.02

E4S 23.02 full featured release on Dockerhub is multi-architecture

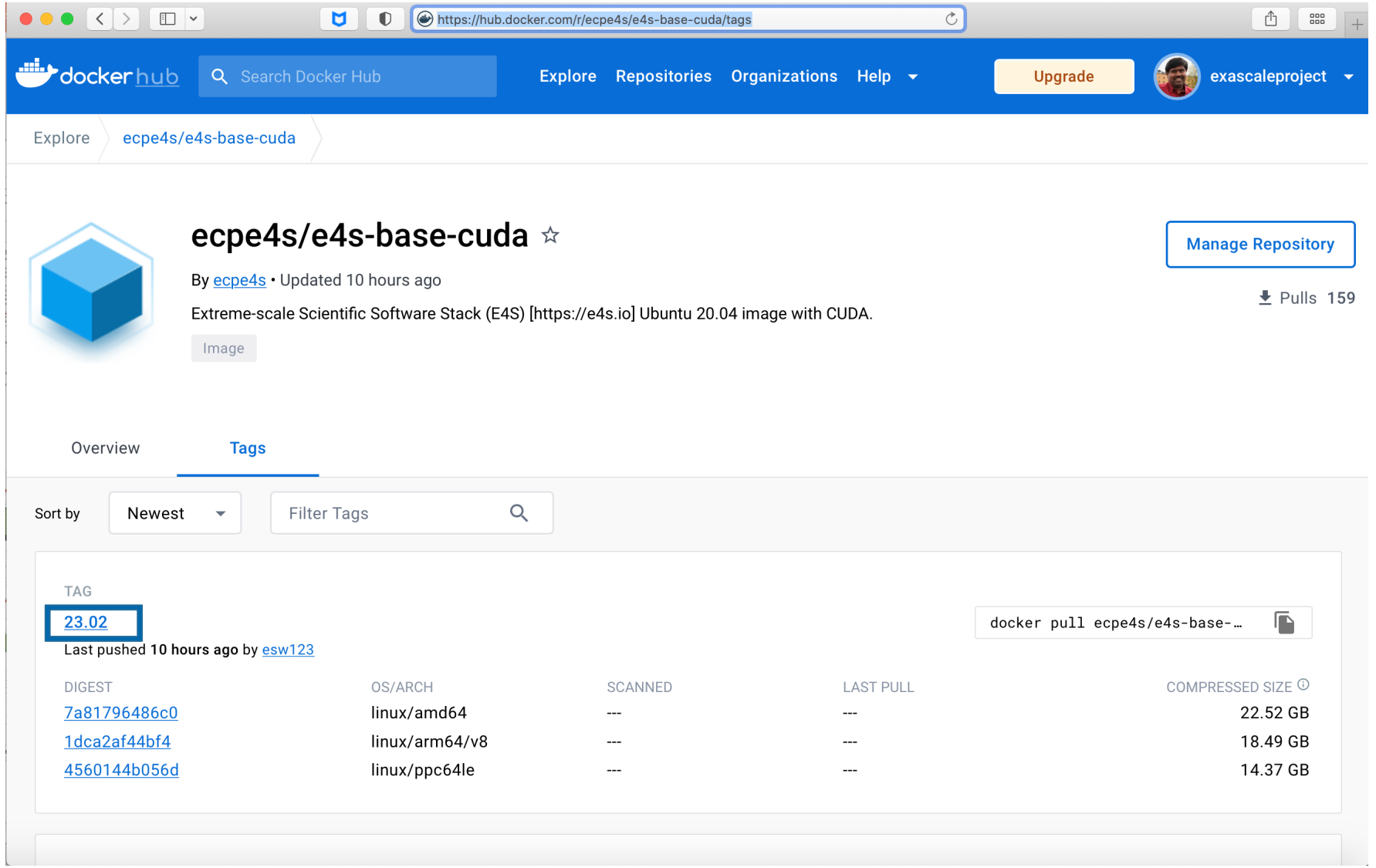


Architectures:
- x86_64
- aarch64
- ppc64le

Software:
- CUDA 12.0
- NVHPC 23.1

docker pull ecpe4s/e4s-cuda

E4S 23.02 base container release is multi-architecture as well

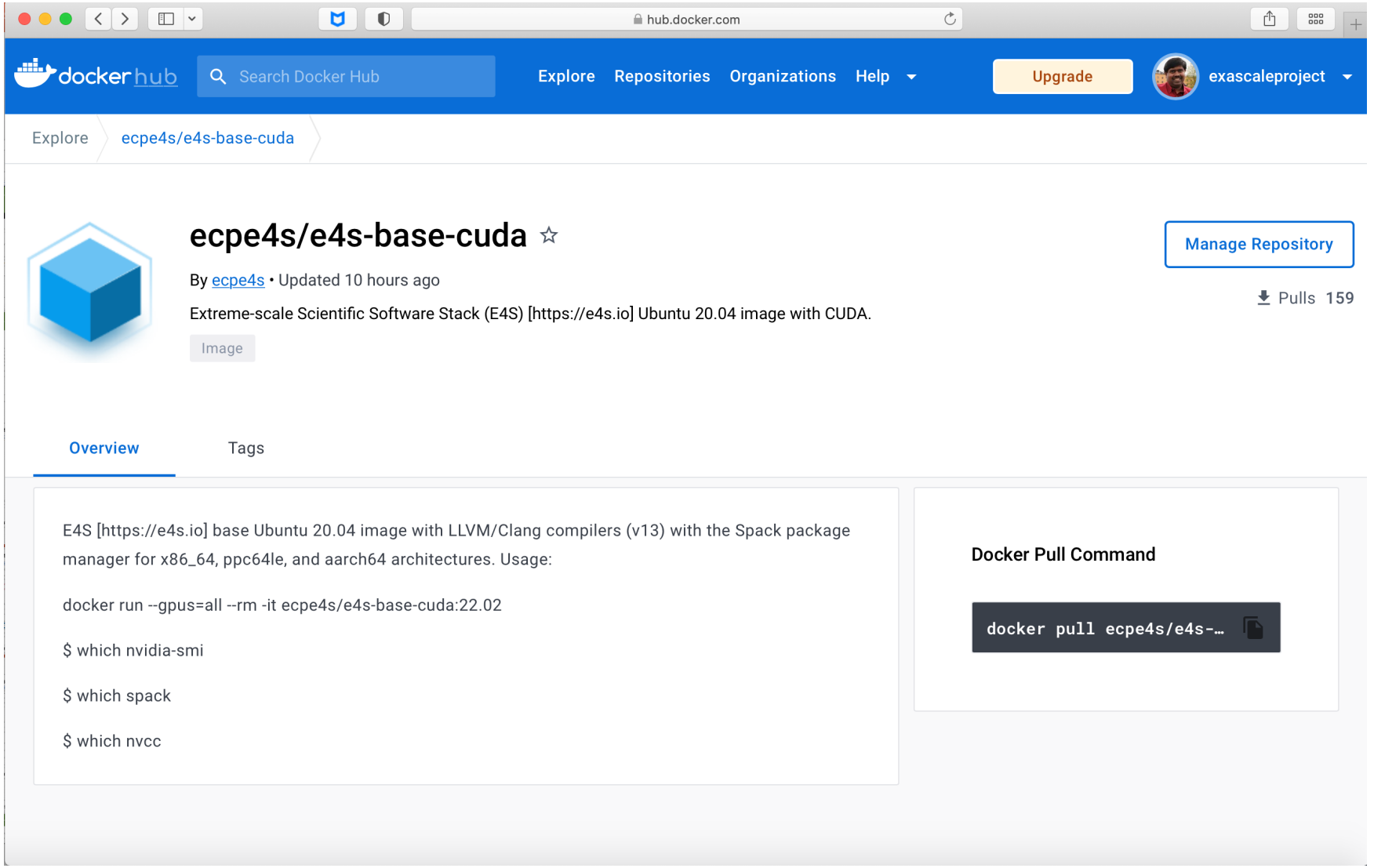


Architectures:
- x86_64
- aarch64
- ppc64le

Software:
- CUDA 12.0
- NVHPC 23.1

docker pull ecpe4s/e4s-base-cuda

E4S 23.02 base container release on DockerHub

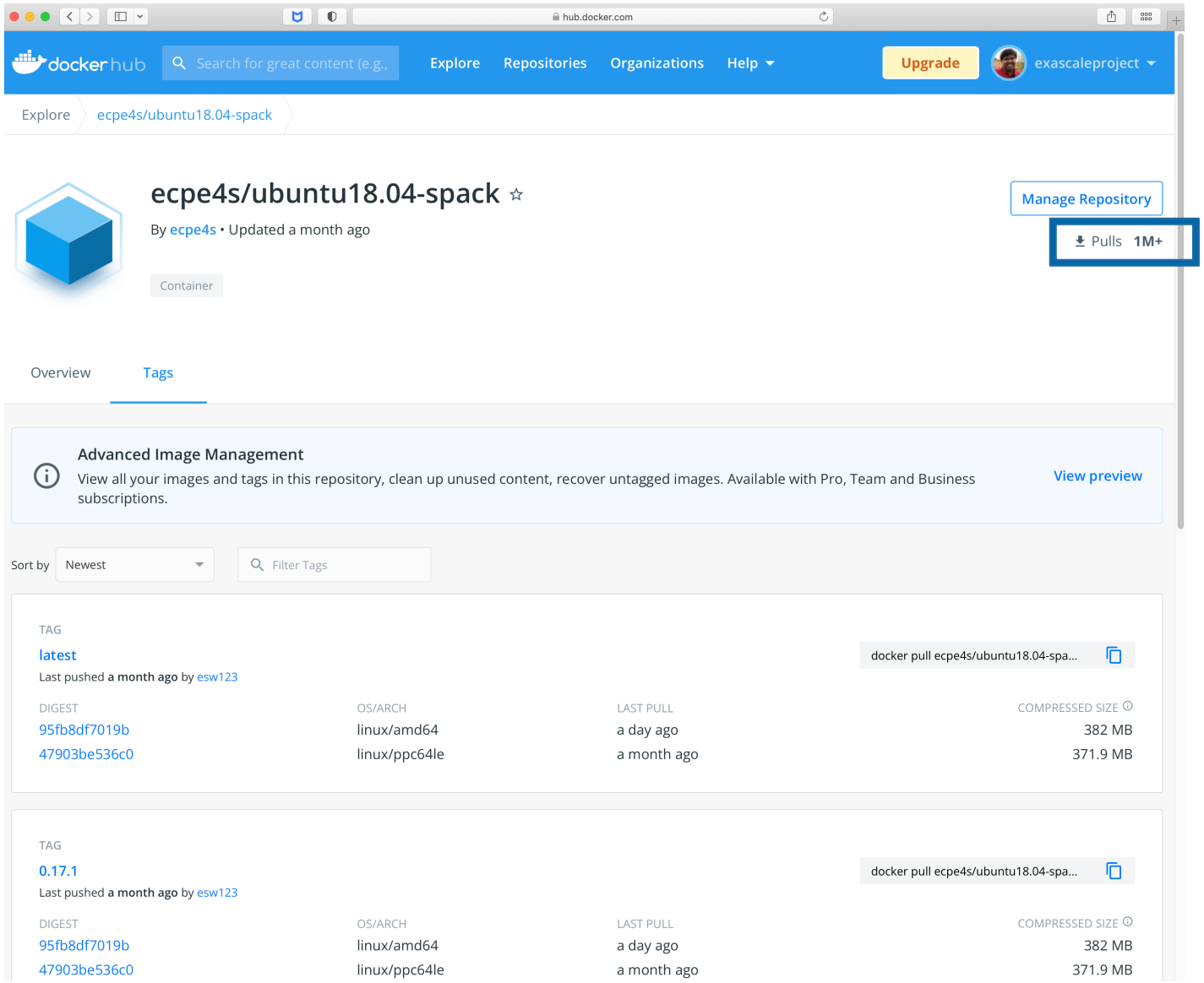


docker pull ecpe4s/e4s-base-cuda

Architectures:
- x86_64
- aarch64
- ppc64le

Software:
- CUDA 12.0
- NVHPC 23.1

Minimal Spack base image on Dockerhub



- Create custom container images
- 1M+ downloads!

23.02 Release: 100+ Official Products + dependencies (gcc, x86_64)

```
 1:  adios2                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/adios2-2.8.3-nubapcbybpwlgkin3rkko5izvfcsjsi5
 2:  alquimia              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/alquimia-1.0.10-od7x4tkdet73pfq4besx77csydguw3wf
 3:  aml                   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/aml-0.2.0-inr7dxl5ddocs522gnjwqfvhrnsf22un
 4:  amrex                 /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/amrex-23.02-s3xw2hy6ma3wx7dq6fgaxcv4izx5o7t7
 5:  arborx                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/arborx-1.3-nhu67mk22hg25q2stehtxpivkix4wpfq
 6:  archer                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/archer-2.0.0-fglk5kesgfzamgjtcjsr4dxumgtpkmy3
 7:  argobots              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/argobots-main-ofyr6ee43nejlz6z3ll7scq25xncmdgv
 8:  ascent                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/ascent-0.8.0-naiomvijdwsarev5kjsji6nhtproneys
 9:  axom                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/axom-0.7.0-shvk25oj3sbk7ddv5opw6ap5dqho7fgp
10:  bolt                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/bolt-2.0-3osqry75nwhu2itp4udqj4xrqrdlxj3b
11:  bricks                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/bricks-r0.1-ej6viooynwkuhll3x7a6t7u3lf7wzp4s
12:  butterflypack         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/butterflypack-2.2.2-kplnowsy6nxflk3wc2mx5kifn37kyyic
13:  cabana                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/cabana-0.5.0-lul72nwihpfnj7snw7riqenfk5aqzwcf
14:  caliper               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/caliper-2.9.0-cfoiwyzxvwchcc7xksel2ffkoosetsxu
15:  chai                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/chai-2022.03.0-abollkdmz2hmxbtlnjrumbwzx57wesaa
16:  charliecloud          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/charliecloud-0.30-vwuvo34pi264zmnn3hnq2vt63irxdcdf
17:  conduit               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/conduit-0.8.6-rxg6cap3pncbryytdgnrmfsy25eywtoh
18:  darshan-runtime       /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/darshan-runtime-3.4.2-cciydtndlofmig2d2owb4hyvusxuhe3b
19:  datatransferkit       /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/datatransferkit-3.1-rc3-fkfxftbzcz4lcltkauo5xqrjgr664w7k
20:  dealii                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/dealii-9.4.0-3xm3qzh5f77qaa26i6epkullrp3qdym4
21:  dyninst               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/dyninst-12.2.1-h7cjcz7atu6pqm5de3luob34g23s6hcp
22:  ecp-data-vis-sdk      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/ecp-data-vis-sdk-1.0-v5hsdt3ltighxzagpemt3xolokqupzdh
23:  exaworks              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/exaworks-0.1.0-adwnmto76ml4jx3iwqesahws7u4wys7k
24:  faodel                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/faodel-1.2108.1-cucsyvmftptykeckrizpplt7daz5b2f7
25:  flecsi                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/flecsi-2.1.0-2h23jn77e5acfeednpxerwmeutrza3rx
26:  flit                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/flit-2.1.0-bi5v4uhkzmayhrmumuj2w2on2yfp3z3u
27:  flux-sched            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/flux-sched-0.26.0-h67gnhvhilyblissrvluhdz5p4yyoj67
28:  fortrilinos           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/fortrilinos-2.2.0-cozctrvtrgycyzg3eq3bj73xr7hayiey
29:  gasnet                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/gasnet-2022.9.2-3butckp7jlzphpoz6t5hdfjo62bzupxp
30:  ginkgo                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/ginkgo-1.5.0-ldidl2tobha6ews36wk5anqdvdhex2uf
31:  globalarrays          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/globalarrays-5.8-4xbewu7l3cyxzxnhruwo5d2g3nahee2n
32:  gotcha                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/gotcha-1.0.4-rtapu26myuembj7m5lmdabm27mchd3bj
33:  gptune                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/gptune-3.0.0-cmddwp7d6nn67ddlace4mekkdwutaqs3
34:  h5bench               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/h5bench-1.3-zo2fmcc2gmouj2fy6dclguekbvqyqfal
35:  hdf5                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hdf5-1.14.0-27iizuzgmi7klsicgigfylfuotbsrwsl
36:  hdf5-vol-async        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hdf5-vol-async-1.4-rd5yyzhdbdruzjhl27j4bedccstq4fiq
```

GPU runtimes

- AMD (ROCm)
  - 5.4.3
- NVIDIA (CUDA)
  - 12.0
- NVHPC
  - 23.1

23.02 Release: 100+ Official Products + dependencies (gcc, x86_64)

37:	heffte	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/heffte-2.3.0-4wfa7cv2prc6jpwtslzqa5cjmtd3brkv
38:	hpctoolkit	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hpctoolkit-2022.10.01-qxddeaox47zfgwxxdp2zkqvratgmhyrt
39:	hpx	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hpx-1.8.1-wypr35o7d2jpbnmulqx4ss5tjeh43n2b
40:	hypre	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hypre-2.27.0-d2q2ozmxjzc37sb6rm5ay5yin73mbqnu
41:	kokkos	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/kokkos-3.7.01-ocpxne3dvrosu52lo5e6ghaa5pcddtco
42:	kokkos-kernels	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/kokkos-kernels-3.7.00-mxomtbi224lptveit6bokvwpxonjc27n
43:	lammps	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/lammps-20221103-kjssj627izystqyockyvjbdz4trljrop
44:	legion	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/legion-21.03.0-3erf2k5pmdmoknfustdn443b5yv5xni4
45:	libnrm	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/libnrm-0.1.0-w722g5lvr3ootoh5j42j2zs4ug2yjsh2
46:	libpressio	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/libpressio-0.90.2-ldyfdmdrb5mzuwh252vwonz34bqud6aq
47:	libquo	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/libquo-1.3.1-v6gw2uicfoiofinmzu2g5rhnmjfzsuf7
48:	magma	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/magma-2.7.0-viznxiabcbbvwq5jnvje5ah3rn73fgva
49:	mercury	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mercury-2.2.0-6g4akiqin3jin42yunsdbectpz5l3nk2
50:	metall	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/metall-0.23.1-sgxcgbq4qxgyx67pjvm4jasxgutz5l23
51:	mfem	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mfem-4.5.0-qnnwtocz5ctaa5mk6lzmsyxj2xuue5re
52:	mpark-variant	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mpark-variant-1.4.0-uvwp4sm2fwhluf4teegfr3hju5l5tbpp
53:	mpich	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mpich-4.1-v4dkt2ix3bqppjyinewjkxudxfiubr7b
54:	mpifileutils	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mpifileutils-0.11.1-c2veonah2syuz4phk57mn6yzxwmhdcds
55:	nccmp	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/nccmp-1.9.0.1-ngf7ke5zu6wyzewknqmusmy2vpoa4ifw
56:	nco	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/nco-5.0.6-r3xbxkvrkmmdjy7vekswzpiakd7mhdbw
57:	netlib-scalapack	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/netlib-scalapack-2.2.0-5t7gxddf25mbdxvirhpg55bjoxc3y2k3
58:	nrm	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/nrm-0.1.0-afxxttsabuhyjqxvkgb6s44mesqdgaa6
59:	omega-h	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/omega-h-9.34.13-obxpqlhpxpdkctyvartvhqepadiz44x5
60:	openmpi	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/openmpi-4.1.4-gohyy3buwvtpvkrpisvej2iorqchnyzj
61:	openpmd-api	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/openpmd-api-0.14.5-3in2543a4vfj4fewn7yjsfruaunbc5la
62:	papi	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/papi-6.0.0.1-achx3tknnj2x5c5e7hx665apu3nynrmg
63:	papyrus	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/papyrus-1.0.2-ayurdsox6t5wgks3vqc764z2hynn2q5f
64:	parallel-netcdf	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/parallel-netcdf-1.12.3-nznwrmp5iveotx62d47r7ctxquln7fqr
65:	paraview	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/paraview-5.11.0-r3yq6hhuadnjufymbb632gjhidrxw53s
66:	parsec	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/parsec-3.0.2209-g6p5llbgwghmpdjudxq3pm7i4chzsehd
67:	pdt	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/pdt-3.25.1-lx67nrs24pkbnmnj7am3t75swtowtfc5
68:	petsc	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/petsc-3.18.3-wbx3oqmsogsk5celdhrdeixrbdsfk6h3
69:	phist	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/phist-1.11.2-ly3rm7wgjkd5rtpods42xcikw57ib2tk
70:	plasma	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/plasma-22.9.29-a2w75e6l3vpeavtescidtqomqhna32l2
71:	plumed	/spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/plumed-2.8.1-75zn4e6akike5luf7d2bx6lbqvzujcmf

23.02 Release: 100 Official Products + dependencies (gcc, x86_64)

```
 72:  precice          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/precice-2.5.0-d75k3norm5smtgupyerul2zg77gewbq6
 73:  pumi             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/pumi-2.2.7-vtyyseohxw3c45yruhzpjhdhqpw6ysex
 74:  py-cinemasci     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-cinemasci-1.3-eivaemojwnpgqsbusvrxpm7pkbvurrz7
 75:  py-jupyterhub    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-jupyterhub-1.4.1-nreb3q3wcczveo6zqw2zsqgiitgzlzfx
 76:  py-libensemble   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-libensemble-0.9.3-giornxmpnhh5dqes6lrjetg4lodvskdq
 77:  py-parsl         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-parsl-1.1.0-gmuzq4joeoobocxxh2w2656r3ga7vnr2
 78:  py-radical-saga  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-radical-saga-1.20.0-p4nvjdbz4aq727dsglwx2oedsnunhpsf
 79:  qthreads         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/qthreads-1.16-unsgzwmofxfr2bxhh24kh5rtfsgpwtem
 80:  quantum-espresso /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/quantum-espresso-7.1-kifrbk3grb4wryui3hwm7uxqarwpmjcl
 81:  raja             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/raja-2022.03.0-iayqvhwjthlmkjis2oyv5zifatwbjdpl
 82:  scr              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/scr-3.0.1-c6wuntarletoorrttki22lxutoodzzri
 83:  slate            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/slate-2022.07.00-qe4fshhoyq3nutk3hpwbb55ci4xwztjt
 84:  slepc            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/slepc-3.18.2-v3aywpinj2nttfn6523lscjnal6rod3h
 85:  stc              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/stc-0.9.0-e3j5k45z6pbhky3tnz6ra4u34thbtjux
 86:  strumpack        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/strumpack-7.0.1-5a4spgocgkx6czoczcpb5jq6giw4f2a5
 87:  sundials         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/sundials-6.4.1-lxndi2jv64a7k2e45vokm6nzet76ujuv
 88:  superlu-dist     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/superlu-dist-8.1.2-mxp6x3svae7iihadikv3j4knfy3lt3fm
 89:  swig             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/swig-4.1.1-jnv74fa2osnbsvq3t5flhzbtuusqs5ry
 90:  sz               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/sz-2.1.12.2-j6a5qlch333v5db2jez7np36kfyqmv5o
 91:  tasmanian        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/tasmanian-7.9-okxdjiopltizbo5iz2myu7dmpne52ses
 92:  tau              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/tau-2.32-zi7e6lcmycsxmtdxxpgj66zatwpt2ydd
 93:  trilinos         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/trilinos-13.4.1-x7hgo3xqfpmleyyeyqtmlh2llkfb5y7b
 94:  turbine          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/turbine-1.3.0-snfqzs6cuisfiq3u3rzpmw7p7sywpdbf
 95:  umap             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/umap-2.1.0-pcbzfhdfdgeifzm5xpsdsxfophmgfnyo
 96:  umpire           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/umpire-2022.03.1-dvb7ewnskq2l7qxi6jlfaqazxxlkr4q5
 97:  unifyfs          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/unifyfs-1.0.1-nvyafo6ywgzkgti7xw5abhb3c72ay5fx
 98:  upcxx            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/upcxx-2022.9.0-z2v2rs6jtegdm6vqc6y67g4vzl46tbrf
 99:  variorum         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/variorum-0.6.0-gaxplhylnbvh2kap6fonqcovopfqf5z2
100:  veloc            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/veloc-1.6-yktuomgxkfr2e6znpjqr37ndqbulbadq
101:  visit            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/visit-3.2.2-faqkznvldztxeqplreckkl3kbaqujcvp
102:  vtk-m            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/vtk-m-1.9.0-ijy7ak5npqbvb2d7uvbenysigrgdln2n
103:  wannier90        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/wannier90-3.1.0-pxcs6esoy6dhjxdcbpc6motxqmy5milg
104:  warpx            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/warpx-23.01-mdiv64h3yxblpekn2pjqp3v2pdxzvm6v
105:  xyce             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/xyce-7.5.0-ds5oq7hncqe32j5xgm3ajp5txnj4gyn6
106:  zfp              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/zfp-1.0.0-zcp6zihh33r2tlqgxyxeqpsas6zytjeg
```

Languages:
- Julia with support for MPI, and CUDA
- Python

AI products with GPU support
- Tensorflow
- Pytorch

EDA Tools:
- Xyce

3D Visualization
- Paraview
- VisIt
- TAU's paraprof …

E4S Support for CUDA variants on x86_64

```
Singularity> spack find +cuda cuda_arch=80
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 ------------------------
adios2@2.8.3        camp@2022.03.2         heffte@2.3.0           lapackpp@2022.07.00  raja@2022.03.0      trilinos@13.4.1
amrex@23.02         chai@2022.03.0         hpx@1.8.1              magma@2.7.0          slate@2022.07.00    umpire@2022.03.1
arborx@1.3          dealii@9.4.0           hypre@2.27.0           mfem@4.5.0           slepc@3.18.2        vtk-h@0.8.1
ascent@0.8.0        ecp-data-vis-sdk@1.0   kokkos@3.7.00          omega-h@9.34.13      strumpack@7.0.1     vtk-m@1.7.1
blaspp@2022.07.00   flecsi@2.1.0           kokkos@3.7.01          paraview@5.11.0      sundials@6.4.1      vtk-m@1.9.0
caliper@2.9.0       ginkgo@1.5.0           kokkos@3.7.01          petsc@3.18.3         superlu-dist@8.1.2  zfp@0.5.5
camp@2022.03.2      hdf5-vfd-gds@1.0.2     kokkos-kernels@3.7.00  py-torch@1.13.1      tasmanian@7.9
==> 41 installed packages
Singularity> spack find +cuda cuda_arch=90
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 ------------------------
blaspp@2022.07.00   chai@2022.03.0   heffte@2.3.0          mfem@4.5.0        raja@2022.03.0     sundials@6.4.1
caliper@2.9.0       dealii@9.4.0     hpx@1.8.1             omega-h@9.34.13   slate@2022.07.00   superlu-dist@8.1.2
camp@2022.03.2      flecsi@2.1.0     hypre@2.27.0          petsc@3.18.3      slepc@3.18.2       tasmanian@7.9
camp@2022.03.2      ginkgo@1.5.0     lapackpp@2022.07.00   py-torch@1.13.1   strumpack@7.0.1    umpire@2022.03.1
==> 24 installed packages
Singularity>
```

E4S 23.02 adds support for NVIDIA A100 (sm80) as well as H100 (sm90) GPUs!

E4S Support for ROCm variants for MI250X (gfx90a) on x86_64

```
Singularity> spack find +rocm amdgpu_target=gfx90a
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 ------------------------
amrex@23.02         chai@2022.03.0         hpx@1.8.1            paraview@5.11.0   strumpack@7.0.1     umpire@2022.03.1
arborx@1.3          ecp-data-vis-sdk@1.0   hypre@2.27.0         petsc@3.18.3      sundials@6.4.1      upcxx@2022.9.0
blaspp@2022.07.00   gasnet@2022.9.2        kokkos@3.7.01        raja@2022.03.0    superlu-dist@8.1.2  vtk-m@1.9.0
camp@2022.03.2      ginkgo@1.5.0           lapackpp@2022.07.00  slate@2022.07.00  tasmanian@7.9
camp@2022.03.2      heffte@2.3.0           magma@2.7.0          slepc@3.18.2      trilinos@13.4.1
==> 28 installed packages
Singularity> spack find +rocm amdgpu_target=gfx908
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 ------------------------
amrex@23.02         chai@2022.03.0         hpx@1.8.1            paraview@5.11.0   strumpack@7.0.1     umpire@2022.03.1
arborx@1.3          ecp-data-vis-sdk@1.0   hypre@2.27.0         petsc@3.18.3      sundials@6.4.1      upcxx@2022.9.0
blaspp@2022.07.00   gasnet@2022.9.2        kokkos@3.7.01        raja@2022.03.0    superlu-dist@8.1.2  vtk-m@1.9.0
camp@2022.03.2      ginkgo@1.5.0           lapackpp@2022.07.00  slate@2022.07.00  tasmanian@7.9
camp@2022.03.2      heffte@2.3.0           magma@2.7.0          slepc@3.18.2      trilinos@13.4.1
==> 28 installed packages
Singularity>
```

E4S 23.02 adds support for AMD MI100 (gfx908) as well as MI250X (gfx90a) GPUs!

E4S Support for AI/ML frameworks with A100 and H100 GPUs

```
Singularity> python
Python 3.8.10 (default, Nov 14 2022, 12:59:47)
[GCC 9.4.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> import numpy
>>> import scipy
>>> import matplotlib
>>> import tensorflow
>>> tensorflow.__version__
'2.11.0'
>>> import torch
>>> torch.__version__
'1.13.1'
>>> torch.cuda.get_device_name(torch.cuda.current_device())
'NVIDIA H100 PCIe'
>>>
```

E4S 23.02 supports H100 GPUs with TensorFlow and PyTorch!

23.02 Release: 100+ Official Products + dependencies (gcc, ppc64le)

1:	adios2	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/adios2-2.8.3-3fnxmxdfk3ikgu5z4w6jdvu22qr2kmuo
2:	alquimia	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/alquimia-1.0.10-7p5izcaumienrnoeywaj3yn4ekqzzxyg
3:	aml	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/aml-0.2.0-k3qoshcfi7lcfeaak3zwc743fcgx7rbx
4:	amrex	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/amrex-23.02-ht3i4k3sxscjk7kpu4ompxp73i3gzicx
5:	arborx	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/arborx-1.3-qsmnqjoforx6ixbjiw64vwhavr3gvqvl
6:	archer	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/archer-2.0.0-rr27rmq6zlgxfulep5wgzeocngt3shvv
7:	argobots	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/argobots-main-jd3kjxsmgfenqothza55bbnqlie7njkj
8:	ascent	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/ascent-0.8.0-o7bfe5w3sfauxli6ieouzt3wchdwkgaq
9:	axom	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/axom-0.7.0-hkcsw75sgfx6pmzj4qztunxmq7pfhbgs
10:	bolt	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/bolt-2.0-2thdzkc3vtqofvdmocxsohpwdfmuwcqa
11:	butterflypack	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/butterflypack-2.2.2-z5h2oovx6gqkgeajncn3wbogat74njyb
12:	cabana	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/cabana-0.5.0-oaq5hkzzasd2635mvdfuhgxiuptzqgxp
13:	caliper	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/caliper-2.9.0-bs3oajtfnhkyz4c7qdh7fgizqvnxwxhm
14:	chai	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/chai-2022.03.0-2g4vadbrrihxmopdidiz7afyde6hhmjz
15:	charliecloud	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/charliecloud-0.30-zapmcbpmws4o3sh7x4xgaukgbsabyciu
16:	conduit	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/conduit-0.8.6-gxoays5dlf52yfon7quguneofibivs52
17:	darshan-runtime	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/darshan-runtime-3.4.2-cbnodic6dcant7ydmxmtck32acp5tstd
18:	datatransferkit	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/datatransferkit-3.1-rc3-jz5cu7llzem5gdszzrhzc55z5lcm5da5
19:	dyninst	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/dyninst-12.2.1-nl5cijb4qlqzo5rev47pyxsg6rksulct
20:	ecp-data-vis-sdk	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/ecp-data-vis-sdk-1.0-uul24ntg6vwtfxukghnm2j4cloqbkro2
21:	exaworks	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/exaworks-0.1.0-5d7iztblfyqsw6ogmrfbdhzftcg2ldv6
22:	faodel	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/faodel-1.2108.1-zjbhsr7pfzlzbrfxkuzbjyhhwhbkcta7
23:	flecsi	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/flecsi-2.1.0-jt4zixen2qtpbls33gs3hcnsrbbjyw2w
24:	flit	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/flit-2.1.0-lwoh6mb5quvk3z3xhi2eok5i4dgqdw2z
25:	flux-sched	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/flux-sched-0.26.0-scwzowmjfqdgstyyv4g6nqpxccfqmyyf
26:	fortrilinos	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/fortrilinos-2.2.0-s3vsdt5r25qbhfmw4gqj4g6cjnvcap46
27:	gasnet	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/gasnet-2022.9.2-cdddcblbrdivk2umogveyszcyggsv432
28:	ginkgo	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/ginkgo-1.5.0-eddbyedjjexhspm3ukfh7dedydfcbrj7
29:	globalarrays	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/globalarrays-5.8-xq2kqc775qab5s5tw4umszvrwjudpyv4
30:	gotcha	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/gotcha-1.0.4-2iikt3dito7pazr2euixcfqkssv52t2c
31:	gptune	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/gptune-3.0.0-ypp6vwbfdk2g5cdzsgvzuomciaszx42i
32:	h5bench	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/h5bench-1.3-il35zrekj6x3v3ui24obfzvkqayuqzp4
33:	hdf5	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/hdf5-1.14.0-ae3kowljjfrgg2sz6zchk5g3i6rfxa6c
34:	hdf5-vol-async	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/hdf5-vol-async-1.4-ehehrb6tuy77smjyf5zs47fiypnaccs3
35:	heffte	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/heffte-2.3.0-g4fscfuikh5kpslrnugmk3u7j4nmnzre
36:	hpctoolkit	/spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/hpctoolkit-2022.10.01-rk6vi5k7rrcufy6stgsgzo5s55upmirh

GPU runtimes for IBM Power
- CUDA 12
- NVHPC 23.1

Languages
- Julia with MPI and CUDA
- Python

EDA Tools
- Xyce

AI packages for NVIDIA GPU
- TensorFlow
- PyTorch

23.02 Release: 100+ Official Products + dependencies (gcc, ppc64le)

```
  37:  hpx                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/hpx-1.8.1-sz5gykq7azz2b2hmkliflgirlfl6rbce
  38:  hypre              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/hypre-2.27.0-jkkhvok4mb477yuh4yuh5llwg63g6uqx
  39:  kokkos             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/kokkos-3.7.01-ov4nnz7d57gs3ijp5obk2rjvw4vsp6gn
  40:  kokkos-kernels     /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/kokkos-kernels-3.7.00-nwmj4dcs4zgf3ul3fzvpwi7wekn6uhlf
  41:  lammps             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/lammps-20221103-jr3rds5tfvh7k5c3f3nslokqmpqhqdt6
  42:  legion             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/legion-21.03.0-pa4x27plz72z3yf54xykjhl4mb7htoyo
  43:  libnrm             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/libnrm-0.1.0-scw77754mhcsfn7oxhkpgylcra5fteep
  44:  libpressio         /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/libpressio-0.90.2-k52y2rkalqdx45gyf3owrv4k2ov73dsn
  45:  libquo             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/libquo-1.3.1-aw45a7s3mfldzcr5i6dtnwrzv2l3mlpb
  46:  magma              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/magma-2.7.0-qcnxaj3lfvvr35jpuolzwhv65a7k3mji
  47:  mercury            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/mercury-2.2.0-5pfvrkk3uqumew5eqzsbsgexzbxkjwez
  48:  metall             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/metall-0.23.1-fs55t7vqb32e32lileploiz5re76qr2k
  49:  mfem               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/mfem-4.5.0-hqmotggjln3zv5gybzvz7qltqhdy6dtr
  50:  mpark-variant      /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/mpark-variant-1.4.0-unlxd5bslawng2rgg7mzeqailm7jxyzy
  51:  mpich              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/mpich-4.1-caz2jxqxui6dwkllcut7pyuubzim7o76
  52:  mpifileutils       /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/mpifileutils-0.11.1-jjhhhdmud4ls6wuq76o53mxxujbp7tk7
  53:  nccmp              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/nccmp-1.9.0.1-yltquk3dtylmmrzgc64asquncffp2igm
  54:  nco                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/nco-5.0.6-s6h5qufwh2ndmqrjkdhnweak6pyg7bmw
  55:  netcdf-c           /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/netcdf-c-4.9.0-e74drxychna74hzibbgmovoulgdqil4c
  56:  netlib-scalapack   /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/netlib-scalapack-2.2.0-2m7hru44xky4kdgpphckhfkyxp4jfmnq
  57:  nrm                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/nrm-0.1.0-e6smi65b3bs4tjpjjykn4ukmenzunloo
  58:  omega-h            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/omega-h-9.34.13-t6shxc3rmbyafrsdiojzvrm4q632cqem
  59:  openmpi            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/openmpi-4.1.4-ih7bzoel7lxbu4oknuksooocmncvx64v
  60:  openpmd-api        /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/openpmd-api-0.14.5-oxa2uqzvwwaydmuwwm7p573iudyxwvqa
  61:  papi               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/papi-6.0.0.1-xjug5fip2x5geakdjitmc4h5gzf2hqn5
  62:  papyrus            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/papyrus-1.0.2-s4mpt3scmvyktakat3obhsieme6at5m5
  63:  parallel-netcdf    /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/parallel-netcdf-1.12.3-yuy3atnhffb2mjxlztykljfubvnzrjtp
  64:  paraview           /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/paraview-5.11.0-v3yxtfqxg5ujkqvhrbydmua4rqdlncr7
  65:  parsec             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/parsec-3.0.2209-5vym6yqnvasymbbcmfhzhakvwj77c2mp
  66:  pdt                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/pdt-3.25.1-rsjchybcj2rqz3g7qmb2kwvf6pxfwjql
  67:  petsc              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/petsc-3.18.3-kw3ondyb53m6yrtokhhlufhxpewts4sh
  68:  phist              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/phist-1.11.2-yq7aum2d5yz6z23t3gawbnjh6ertybky
  69:  plasma             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/plasma-22.9.29-c74s5wv4x72as2tcwpzyfd4s7s7nn4dm
  70:  plumed             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/plumed-2.8.1-mggpvmb6wwkqoajxqf6nyykecwaufka4
  71:  precice            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/precice-2.5.0-5eizyzu7jphkssqnll6525judl7suf4t
  72:  pumi               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/pumi-2.2.7-x3kitqacxhtpioi2qjkkps4ydw33arnj
```

23.02 Release: 100+ Official Products + dependencies (gcc, ppc64le)

```
 73:  py-cinemasci       /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/py-cinemasci-1.3-l5s6teix3s33rptf3mug3piaoqafkyky
 74:  py-jupyterhub      /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/py-jupyterhub-1.4.1-5ushkvcpkith22jh3e2ogpqgl4omzf64
 75:  py-libensemble     /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/py-libensemble-0.9.3-zoct4wabl6jjkcetritrjvfojft6s2vi
 76:  py-parsl           /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/py-parsl-1.1.0-j22rtxkucwqtcajjo6rlqsy7xbe52ti2
 77:  py-radical-pilot   /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/py-radical-pilot-1.20.0-b34p7wqwbwm23sajdfx2aqjilrugu6lv
 78:  py-radical-saga    /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/py-radical-saga-1.20.0-6wridazyrbmi3v22cbflkeq653bc6rka
 79:  qthreads           /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/qthreads-1.16-zgu6khhmxaasaqgcpp4qxs3h63xzzunt
 80:  quantum-espresso   /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/quantum-espresso-7.1-4htsxebxal6ngbjhhinh6jyatjkcrosf
 81:  raja               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/raja-2022.03.0-zk7g22mqzpnfcptnobvfwhlig64szzl5
 82:  scr                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/scr-3.0.1-u5noc6h3fjfxkur7j2iihmvicvaibhqg
 83:  slate              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/slate-2022.07.00-uyd6luj2ltjdnw6qukoqdalsqmyiccdm
 84:  slepc              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/slepc-3.18.2-7z2hv4fayyfxkxrzovixnrxdk4s5ivbc
 85:  stc                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/stc-0.9.0-i56537xhsswksxix64pybky2mstjmatk
 86:  strumpack          /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/strumpack-7.0.1-c4rzvqbgu7mqaodpfjgz72ayw45ldfa6
 87:  sundials           /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/sundials-6.4.1-u7posdrvom6jpywkoenhxianxyhsnc6p
 88:  superlu-dist       /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/superlu-dist-8.1.2-w4atelx6t4vo37cdlybi2eh2a6s775x2
 89:  swig               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/swig-4.1.1-vd2e67zxddsmpowdmqzifaruhiwezogj
 90:  sz                 /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/sz-2.1.12.2-jmz7jngtwmoui5rkqcv7tlzsphk3baq3
 91:  tasmanian          /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/tasmanian-7.9-b4byfebe2irfqjpvxcu5nq5sqqlfyo25
 92:  tau                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/tau-2.32-weovuw675deq564qe3zpz2irc6z6u3su
 93:  trilinos           /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/trilinos-13.4.1-pzejfobejmkcnsb355lv7ovsrvw6ujan
 94:  turbine            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/turbine-1.3.0-rvdipz5nq2hqk2mp7rd6kt7jmj3k3c7w
 95:  umap               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/umap-2.1.0-dfplzphuupkwyhg4zb6w7nsftqyfsi2p
 96:  umpire             /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/umpire-2022.03.1-p5mkmidm7dgfts2akgbmmez3gyp4mlac
 97:  unifyfs            /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/unifyfs-1.0.1-mgbxxi6pq2p5qmchoxswbrbmfwvk6ve3
 98:  upcxx              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/upcxx-2022.9.0-7kshcsvu563qj7akt7haqerekpfij7b5
 99:  veloc              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/veloc-1.6-b2vuxi2nnjawmvodnmcduxzi5k6mtiug
100:  visit              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/visit-3.2.2-kpkmu3znmo2dmfkqx2lqc5nkoqbw7tbq
101:  vtk-m              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/vtk-m-1.7.1-l3zdka6zgyvncdck6jl36t5py5emywzx
102:  wannier90          /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/wannier90-3.1.0-rsz7cpirm7u6yyy2642jfref2b3j54hd
103:  warpx              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/warpx-23.01-soztf67qv5ze5ny3xkslex7idkn3jr2y
104:  xyce               /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/xyce-7.5.0-472hw4wjpsihxrnvcqr2wn2ce72uxtv5
105:  yaksa              /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/yaksa-0.2-rw7d43p72iyswnbanfpdkmfou6rhipvg
106:  zfp                /spack/opt/spack/linux-ubuntu20.04-ppc64le/gcc-9.4.0/zfp-1.0.0-c4yjifwg5bs7u54tuhq2y56zshr2zrfv
```

E4S Support for CUDA variants on ppc64le

```
Singularity> uname -m
ppc64le
Singularity> spack find +cuda
-- linux-ubuntu20.04-ppc64le / gcc@9.4.0 ------------------------
adios2@2.8.3       camp@0.2.3            flux-core@0.47.0       kokkos@3.7.00          papi@6.0.0.1       slepc@3.18.2        umpire@6.0.0
amrex@23.02        camp@2022.03.2        ginkgo@1.5.0           kokkos@3.7.01          paraview@5.11.0    strumpack@7.0.1     umpire@2022.03.1
arborx@1.3         camp@2022.03.2        heffte@2.3.0           kokkos@3.7.01          petsc@3.18.3       sundials@6.4.1      vtk-h@0.8.1
ascent@0.8.0       chai@2022.03.0        hpctoolkit@2022.10.01  kokkos-kernels@3.7.00  petsc@3.18.3       superlu-dist@8.1.2  vtk-m@1.7.1
blaspp@2022.07.00  dray@0.1.8            hpx@1.8.1              lapackpp@2022.07.00    raja@0.14.0        tasmanian@7.9       zfp@0.5.5
cabana@0.5.0       ecp-data-vis-sdk@1.0  hwloc@2.9.0            magma@2.7.0            raja@2022.03.0     tau@2.32
caliper@2.9.0      flecsi@2.1.0          hypre@2.27.0           mfem@4.5.0             slate@2022.07.00   trilinos@13.4.1
==> 47 installed packages
Singularity>
```

23.02 Release: 100+ Official Products + dependencies (gcc, aarch64)

1:	adios2	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/adios2-2.8.3-b3wi6yrke722ok66o6chrv5dgrxonl3p
2:	alquimia	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/alquimia-1.0.10-4qqzxozokivdnfkjv7o7knodpe2amzl4
3:	aml	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/aml-0.2.0-hack5wdz26i34jk2swt4333cp2iwg5wp
4:	amrex	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/amrex-23.02-6os4ef7k4g3ry6zxelbc3dqdrkrxk3cj
5:	arborx	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/arborx-1.3-d7bhot5l6u4h7aurclmi5a7b6a6cgbtc
6:	archer	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/archer-2.0.0-pamgyel3f6xmabil4bbp3ncfjwong3jd
7:	argobots	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/argobots-main-abqjumv667mqhc54lpr73grixuofusv7
8:	ascent	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/ascent-0.8.0-xlohuk7lno776lfofgv7fh4bpysiqpt5
9:	axom	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/axom-0.7.0-msx23eyqdxfntztnzjcvg7kc44242l6b
10:	bolt	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/bolt-2.0-udcposo7ucvsvaq24serdaeiumzdos3l
11:	butterflypack	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/butterflypack-2.2.2-psvoz2sz67rafmlutdmvuaydbx3w3f6y
12:	cabana	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/cabana-0.5.0-4vmt5gzhvqzaxtmgymuvajby75cnaan4
13:	caliper	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/caliper-2.9.0-uenbcmkylivpfqsuygulga5cv4rjiew4
14:	chai	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/chai-2022.03.0-jaf3uldqcfybtjcuzaev27pvqqvqkd7m
15:	charliecloud	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/charliecloud-0.30-rpwzolax4x4cngntqnxtxireos3tqgf2
16:	conduit	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/conduit-0.8.6-fqso6neyt6u47nft5sfjfrjyupzcx25s
17:	dealii	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/dealii-9.4.0-yj77ozerqy7jbkhjynjvstl3zvjldqbj
18:	datatransferkit	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/datatransferkit-3.1-rc3-yn5euj5brulevhut4hcrtdrwfovponni
19:	dyninst	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/dyninst-12.2.1-ww2xihmxrajhqr2tcz6utvj4siypg3rm
20:	ecp-data-vis-sdk	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/ecp-data-vis-sdk-1.0-6qmpsam7voxwuvhhjpxuuhxijibgku2i
21:	exaworks	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/exaworks-0.1.0-ha5qbdohz3wj5o2ok3qro5jpl6sf57n6
22:	flecsi	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/flecsi-2.1.0-2iuntcpxijaiotxxn5gqp2prpwy4cr67
23:	flit	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/flit-2.1.0-c6utquhr4fgprozvtchknhee3mpum6xk
24:	flux-sched	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/flux-sched-0.26.0-wqaxuw3f6f4ocvth5hq4ftqeg5gtqatu
25:	fortrilinos	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/fortrilinos-2.2.0-6eqti4z5nqhfnglf6fcjiq4ug254ojyx
26:	gasnet	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/gasnet-2022.9.2-4dhin3frk4fxzwqpfgvv3ncwrvtwanss
27:	ginkgo	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/ginkgo-1.5.0-l3jpt55cjncfybxzkgaa6ls4zjlwmaxi
28:	globalarrays	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/globalarrays-5.8-5ehzt3mwejtn543qpyat7hkzbcbtcz6j
29:	gotcha	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/gotcha-1.0.4-gtc2ufwj76xwfvmhcvjktivhry6zxstd
30:	gptune	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/gptune-3.0.0-mlg2mo6t6wxgg4rkuxvn5kp4rzfcw2fd
31:	h5bench	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/h5bench-1.3-a7reymvmochkmyih7f6e2dyyz3yg3i7b
32:	hdf5	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/hdf5-1.14.0-ixpcnwtl6dr7yzfnd2fkziltooomtlmr
33:	hdf5-vol-async	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/hdf5-vol-async-1.4-tuoqj65y3cwe5swjtjfaumdzhnz2zstq
34:	heffte	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/heffte-2.3.0-yq4vkhg4fseecfggmrmtevb53pcc5osw
35:	hpctoolkit	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/hpctoolkit-2022.10.01-tgpsn2xgghaygcpfquozmfft6nmxwyjw
36:	hypre	/spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/hypre-2.27.0-ltt4gizloowjs65jyajl6ezgw3gbmmrg

GPU runtimes for aarch64
- CUDA 12
- NVHPC 23.1

Languages
- Julia with MPI and CUDA
- Python

EDA
- Xyce

AI packages for NVIDIA GPU
- TensorFlow
- PyTorch

23.02 Release: 100+ Official Products + dependencies (gcc, aarch64)

```
 37:  kokkos              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/kokkos-3.7.01-z3tvvgq5hwlvlpayftudtb4z3flkqjcx
 38:  kokkos-kernels      /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/kokkos-kernels-3.7.00-kn6bccwg2c7smicbv46sypz3swwzif52
 39:  lammps              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/lammps-20221103-wntmfs4svb7iasdwlwk7c4u5lhhneim3
 40:  legion              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/legion-21.03.0-4kwezfpevc5yyza23gtjob3cjjvuktcs
 41:  libnrm              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/libnrm-0.1.0-m7pxu4j4yhd4tlscn3hystvsfxfli44m
 42:  libpressio          /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/libpressio-0.90.2-3pkxaohfsmf6vtobzhbt35irh4xkb5fc
 43:  libquo              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/libquo-1.3.1-yvg5s2gngbjlfulavqjnr6qsyoek3rcb
 44:  magma               /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/magma-2.7.0-6o2jvneqf3ffgmohuzwp3gdnhaingrp5
 45:  mercury             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/mercury-2.2.0-6ta6g36gr7gl5dook6g6mg7ml63wrete
 46:  metall              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/metall-0.23.1-f5dwezw2n42gf3yefxd7hpl3ohqdr4jd
 47:  metis               /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/metis-5.1.0-pdd4332qyb2e5i3ykjaaqdgdz74aoemx
 48:  mfem                /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/mfem-4.5.0-7f4dcxn2l3kvtx4wizwuddkpr7amunxl
 49:  mpark-variant       /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/mpark-variant-1.4.0-nzcxqyjtds7jzmtwd2f5dnvhvwplbdew
 50:  mpich               /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/mpich-4.0.2-ngiippuljfh3hj52gkxt562rencw73c3
 51:  mpifileutils        /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/mpifileutils-0.11.1-3unm24kzow35sihhmmgr5bjtdhpp24rz
 52:  netcdf-c            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/netcdf-c-4.9.0-ou26lpbtcwtbhcqzhluqksrp547qpvvr
 53:  netlib-scalapack    /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/netlib-scalapack-2.2.0-d5zvuhd774da6ruukbafj62pwq2fp4x7
 54:  nccmp               /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/nccmp-1.9.0.1-kzi6wbh4vhrs4lpuv6e7fapkra3m4hnb
 55:  nco                 /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/nco-5.0.6-3lbuixsdtexbnhc6mgs6figocefhnknk
 56:  nrm                 /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/nrm-0.1.0-oromof4iip4yev5japxvjmk3zly3npl7
 57:  omega-h             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/omega-h-9.34.13-qntld6tbe4qr5566spqriz255qy2dwlh
 58:  openmpi             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/openmpi-4.1.4-r2b7nvfabf6ydkpxhhzi5gatf6annbus
 59:  openpmd-api         /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/openpmd-api-0.14.5-nv4cdtotkqd5u5ty4f3hjbbdr7aendr3
 60:  papi                /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/papi-6.0.0.1-c44hqtkqrtyxqgfwq2yseqzajdktnrdf
 61:  papyrus             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/papyrus-1.0.2-sxan3pvrvy6evbtwbqwa3dfo75o67gjs
 62:  parallel-netcdf     /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/parallel-netcdf-1.12.3-l7f5w6dffcq2np6jx6lmtqk74uipol7r
 63:  parmetis            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/parmetis-4.0.3-gv3yp7atilwiw5y2z7hj2hw3sdzymirb
 64:  parsec              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/parsec-3.0.2209-n7jakbico7n3nrz4orxyskuiietsurat
 65:  pdt                 /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/pdt-3.25.1-dtetja2hxykx45ysshw7ng6w6nzb4jlw
 66:  petsc               /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/petsc-3.18.3-tv5to4w7o2oq4ah3ilvy62gjxmlewyar
 67:  plasma              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/plasma-22.9.29-pybvtwqfasonxgfhit7heuu6nlpq3dhh
 68:  plumed              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/plumed-2.8.1-eq5wh6sj4exbbwudi5prashfge2pgg2i
 69:  precice             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/precice-2.5.0-l44g4cg6vl2miadne23ucq2rwncw5ynj
 70:  pumi                /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/pumi-2.2.7-72gjhfnp2mtlamkkebih3zrbo3bahy4t
 71:  py-cinemasci        /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-cinemasci-1.3-wpnanippv2wthubf7obcpf4kasckei6e
 72:  py-jupyterhub       /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-jupyterhub-1.4.1-rgzvmjszhb7ptgtdxuz2fxhez4w5utn7
```

23.02 Release: 100+ Official Products + dependencies (gcc, aarch64)

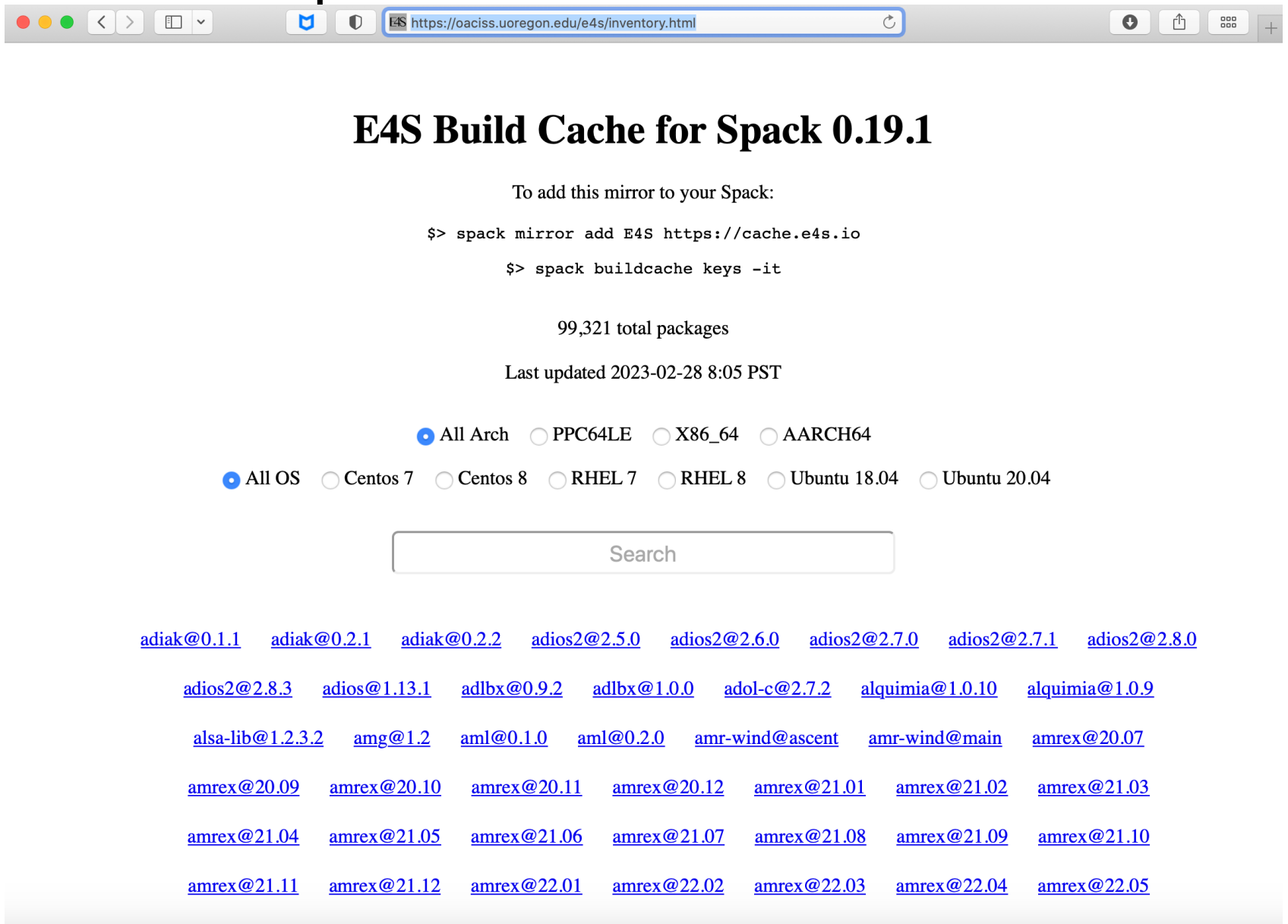
```
 73:  py-libensemble   /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-libensemble-0.9.3-a67zo4rhwqlcmvvugp4rvbxrvbnqlojz
 74:  py-opentuner     /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-opentuner-0.8.7-4pn4msp7qqcu5by53aaozqf7dhan6mmw
 75:  py-parsl         /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-parsl-1.1.0-ad3wsflhbb3g64stederau7htqr22gsn
 76:  py-radical-entk  /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-radical-entk-1.20.0-mtxp7zwfafkenwgncffncdfaadpzyzcc
 77:  py-radical-pilot /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-radical-pilot-1.20.0-tntigqbn5bs7e7vfxnawzg75fsrn2vo3
 78:  py-radical-saga  /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/py-radical-saga-1.20.0-46ofmjooprydzbnsuvamjr7i6b6ul4n7
 79:  qthreads         /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/qthreads-1.16-zj6pplftxpkotg4x7cqnj5xq5dyaxrg2
 80:  quantum-espresso /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/quantum-espresso-7.1-mcxmod2mi2khe2kkrtwfw3zqps32hanz
 81:  raja             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/raja-2022.03.0-pfgblltnrsfmp3ivgtomqzyk34h7fpp7
 82:  scr              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/scr-3.0.1-onzrdmbx5c434vvvzvi5g225pdqcdigq
 83:  slate            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/slate-2022.07.00-3oy3p6nyy4wc47ckwhb6qtirp6b2am2b
 84:  slepc            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/slepc-3.18.2-fvafaiknbmttshvb2sdqfv7lid2t5gal
 85:  stc              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/stc-0.9.0-ofdm2dqxbdkidfbq4i3dlpjo5ucww5of
 86:  strumpack        /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/strumpack-7.0.1-a5lbqwrhgtymlg7i6qfmp3us76fdljri
 87:  sundials         /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/sundials-6.4.1-oi4cweugfunvohluzegxrcnetkbziscv
 88:  superlu-dist     /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/superlu-dist-8.1.2-olduld4eshsagzxgvnrx73q3nwktxm64
 89:  swig             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/swig-4.1.1-o74mzbcdvg3ae3n4mzokifhbaoncywqc
 90:  sz               /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/sz-2.1.12.2-qndzzh24zhpqwhgmf5ux6pzvteyjdckn
 91:  tasmanian        /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/tasmanian-7.9-mjry4xvuh2vsvdrsgzzftcu2duozun4p
 92:  tau              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/tau-2.32-l2slygu2bm67qk6twtyvcerdflr3ztfm
 93:  trilinos         /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/trilinos-13.4.1-lokkji3fvnjrkqqk73ylkbuve3aczoih
 94:  turbine          /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/turbine-1.3.0-hh5sxeft47sns5itjka6sulmvrtl2wfl
 95:  umap             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/umap-2.1.0-c4do6mpg7q3dgjabiahffi5vmajaj6aq
 96:  umpire           /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/umpire-2022.03.1-ltqdwkoiep3fjgb47v7f7igv7y6s6sum
 97:  unifyfs          /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/unifyfs-1.0.1-4imx7l4ggzwm7pw7st2aegt3jw3spzhk
 98:  upcxx            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/upcxx-2022.9.0-znmbjuqfqroyvu4w3gqofs2vekmqqbgz
 99:  veloc            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/veloc-1.6-efunnoqduzkxskjqoi5wo7uclcf5p7vo
100:  visit            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/visit-3.2.2-6m6met233ynb2rahcqgobmlnnkt6luzy
101:  vtk-m            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/vtk-m-1.7.1-zc5oxpmxlsarwj7sjqddlxkjvdv7q25o
102:  wannier90        /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/wannier90-3.1.0-j2clku3qrzbndlgfk4imqwcx6lju56ju
103:  warpx            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/warpx-23.01-emjk3fcz42hwpjohybik7figxu2fhmxu
104:  xyce             /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/xyce-7.5.0-a6gp5etburyjhqs2gv74xubl23aicav4
105:  yaksa            /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/yaksa-0.2-3a4aik2vgllpn6xvm7do6rfiekyjmqg7
106:  zfp              /spack/opt/spack/linux-ubuntu20.04-aarch64/gcc-11.1.0/zfp-1.0.0-xrx3l7rmv64ct3laje2xhz2hjk2gyqad
```

E4S Support for CUDA variants on aarch64

```
Singularity> uname -m
aarch64
Singularity> spack find +cuda cuda_arch=80
-- linux-ubuntu20.04-aarch64 / gcc@11.1.0 ----------------------
amrex@23.02         camp@2022.03.2  ginkgo@1.5.0   kokkos@3.7.01          omega-h@9.34.13   strumpack@7.0.1     umpire@2022.03.1
arborx@1.3          camp@2022.03.2  heffte@2.3.0   kokkos-kernels@3.7.00  petsc@3.18.3      sundials@6.4.1      vtk-h@0.8.1
ascent@0.8.0        chai@2022.03.0  hypre@2.27.0   lapackpp@2022.07.00    raja@2022.03.0    superlu-dist@8.1.2  vtk-m@1.7.1
blaspp@2022.07.00   dealii@9.4.0    kokkos@3.7.00  magma@2.7.0            slate@2022.07.00  tasmanian@7.9
caliper@2.9.0       flecsi@2.1.0    kokkos@3.7.01  mfem@4.5.0             slepc@3.18.2      trilinos@13.4.1
==> 33 installed packages
Singularity> spack find +cuda cuda_arch=75
-- linux-ubuntu20.04-aarch64 / gcc@11.1.0 ----------------------
amrex@23.02         camp@2022.03.2  ginkgo@1.5.0   kokkos@3.7.01          omega-h@9.34.13   strumpack@7.0.1     umpire@2022.03.1
arborx@1.3          camp@2022.03.2  heffte@2.3.0   kokkos-kernels@3.7.00  petsc@3.18.3      sundials@6.4.1      vtk-h@0.8.1
ascent@0.8.0        chai@2022.03.0  hypre@2.27.0   lapackpp@2022.07.00    raja@2022.03.0    superlu-dist@8.1.2  vtk-m@1.7.1
blaspp@2022.07.00   dealii@9.4.0    kokkos@3.7.00  magma@2.7.0            slate@2022.07.00  tasmanian@7.9
caliper@2.9.0       flecsi@2.1.0    kokkos@3.7.01  mfem@4.5.0             slepc@3.18.2      trilinos@13.4.1
==> 33 installed packages
Singularity>
```

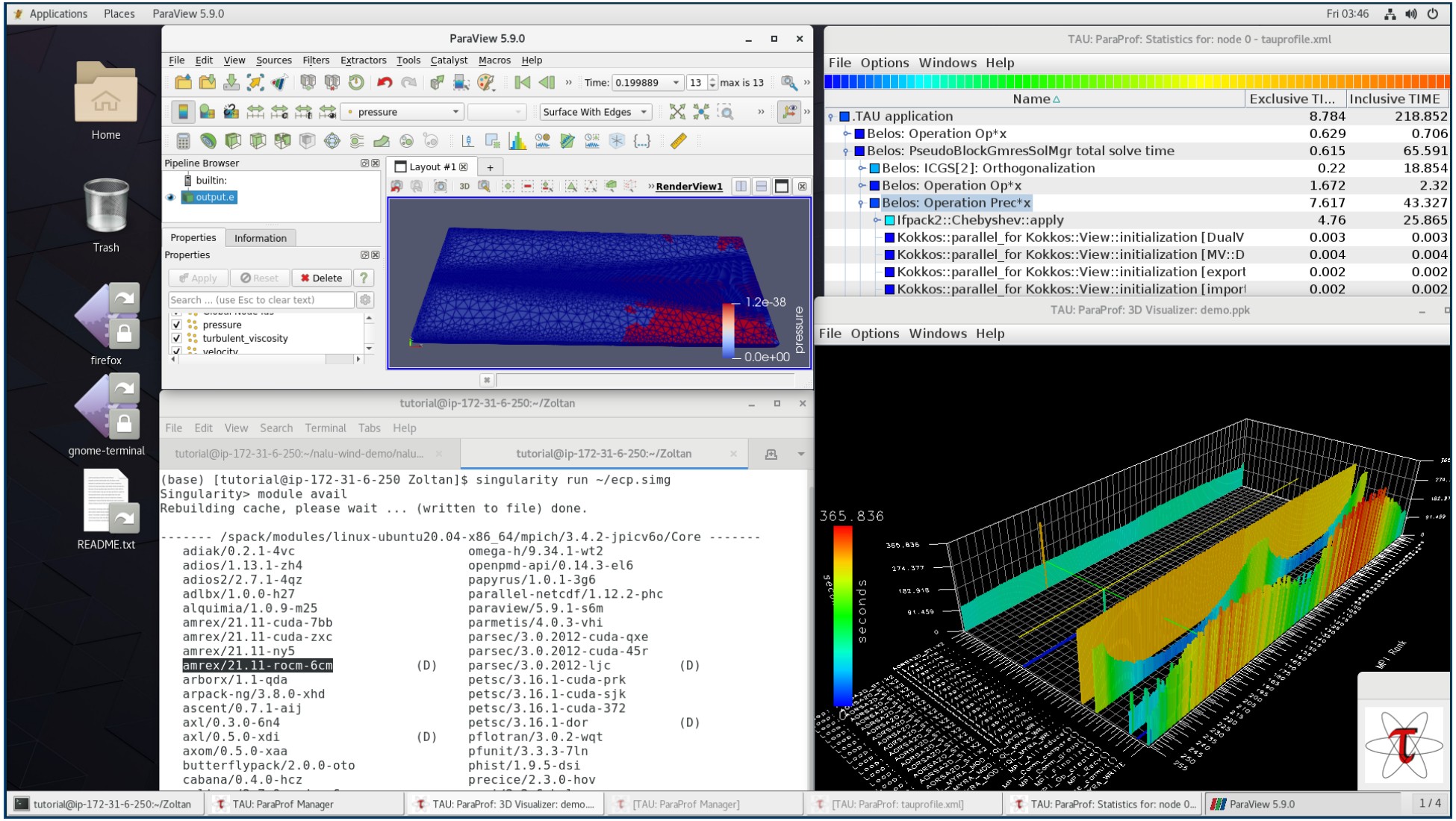
Support for A100 and T4 GPUs under aarch64

E4S Build Cache for Spack 0.19.0



- Over 99,000 binaries!
- No need to recompile from source code.

E4S 23.02 AWS image: US-West2 (OR)

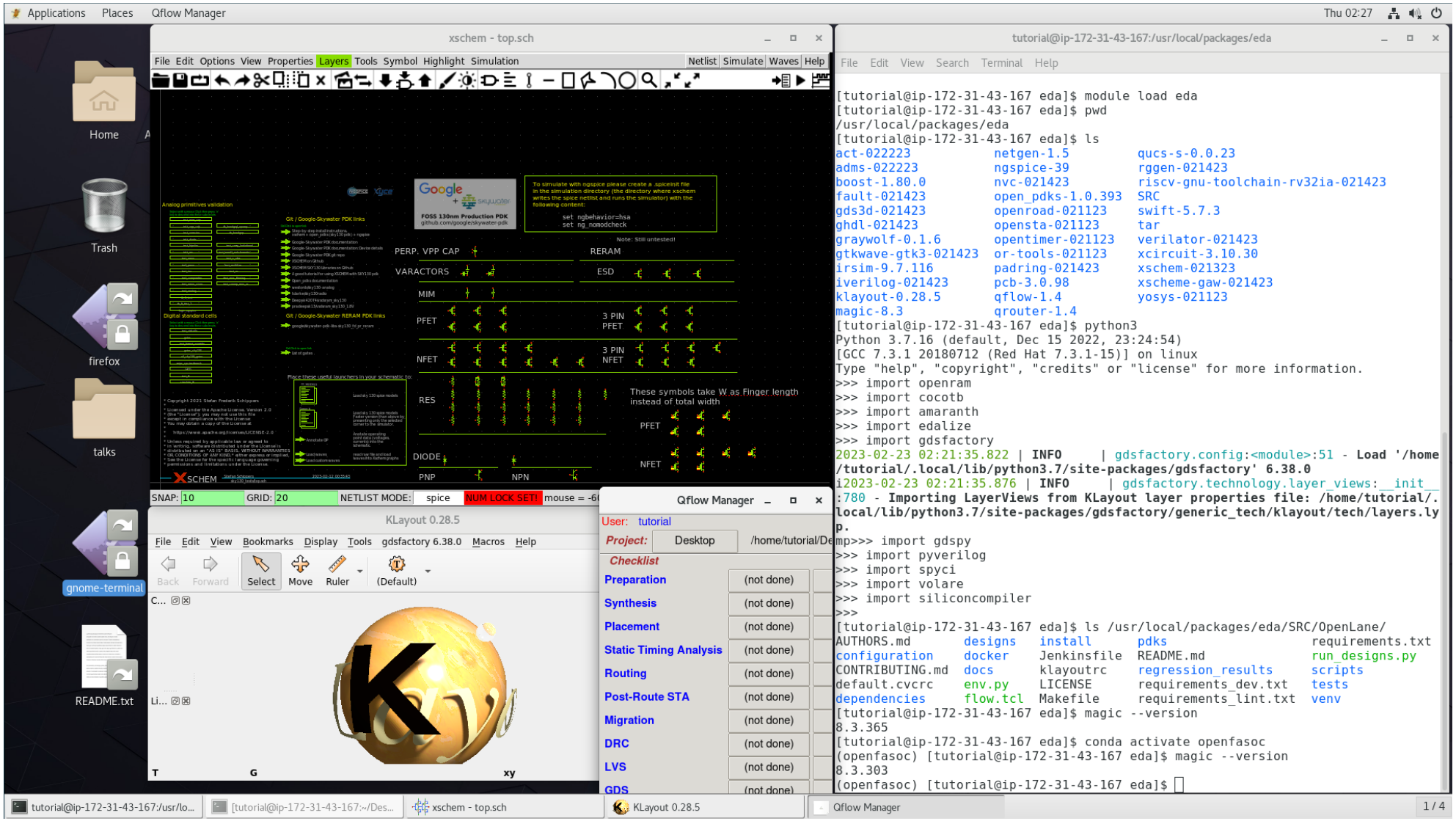


E4S 23.02 AWS

- Intel oneAPI
- CUDA
- NVHPC
- ROCm
- AWS DCV
- Spack Build Cache
- ECP: Nalu-Wind
- Trilinos 13.4.0
- OpenFOAM
- ParaView
- TAU
- Docker
- Shifter
- Charliecloud
- E4S Singularity…

E4S for Commercial Cloud Platforms for EDA on AWS

- E4S: HPC Software Ecosystem – a curated software portfolio for Electronic Design Automation



https://e4s.io/eda

E4S EDA on AWS

- Magic
- ACT
- Klayout
- Qflow
- Xschem
- Xcircuit
- Yosys
- Volator
- OpenROAD
- OpenLane
- iVerilog
- Gtkwave
- Irsim
- Qrouter
- Fault
- GDS3D
- Rggen
- Python tools
  - Cocotb
  - Amaranth
  - Edalize
  - Gdsfactory
  - Gdspy
  - OpenRAM
  - Gdstk
  - Silicon compiler
  - Volare …
- PDKs
  - GF
  - Skywater

E4S for Commercial Cloud Platforms for EDA on AWS

- E4S: HPC Software Ecosystem – a curated software portfolio for Electronic Design Automation

#	Packages currently in E4S	URL
1	Magic	http://opencircuitdesign.com/magic/
2	Xyce	https://xyce.sandia.gov
3	NGSPICE	https://ngspice.sourceforge.io
4	KLayout	https://www.klayout.de
5	Qflow	http://opencircuitdesign.com/qflow
6	OR-Tools	https://developers.google.com/optimization
7	IRSIM	http://opencircuitdesign.com/irsim/
8	OpenROAD	https://github.com/The-OpenROAD-Project/OpenROAD
9	OpenLane	https://openlane.readthedocs.io/
10	OpenFASOC	https://openfasoc.readthedocs.io/
11	Open_PDKs	http://opencircuitdesign.com/open_pdks/
12	Netgen	http://opencircuitdesign.com/netgen/

#	Packages currently in E4S	URL
13	Yosys	https://github.com/YosysHQ/yosys
14	Xcircuit	http://opencircuitdesign.com/xcircuit/
15	Graywolf	https://github.com/rubund/graywolf
16	OpenSTA	https://github.com/The-OpenROAD-Project/OpenSTA
17	OpenTimer	https://github.com/OpenTimer/OpenTimer
18	Qrouter	http://opencircuitdesign.com/qrouter/
19	Xscheme	https://github.com/silicon-vlsi-org/eda-xschem
20	RISC-V GNU Toolchain	https://github.com/riscv-collab/riscv-gnu-toolchain
21	Fault: Design for Test	https://github.com/AUCOHL/Fault
22	NVC	https://github.com/nickg/nvc
23	Amaranth	https://github.com/amaranth-lang/amaranth
24	Cocotb	https://github.com/cocotb/cocotb

https://e4s.io/eda

E4S for Commercial Cloud Platforms for EDA on AWS

- E4S: HPC Software Ecosystem – a curated software portfolio for Electronic Design Automation

#	Packages currently in E4S	URL
25	Covered	https://github.com/hpretl/verilog-covered
26	Edalize	https://github.com/olofk/edalize
27	Gaw3-xschem	https://github.com/StefanSchippers/xschem-gaw.git
28	GDSFactory	https://github.com/gdsfactory/gdsfactory
29	GDSPy	https://github.com/heitzmann/gdspy
30	GDS3D	https://github.com/trilomix/GDS3D
31	Ghdl	https://github.com/ghdl/ghdl
32	Gtkwave	https://github.com/gtkwave/gtkwave
33	iic-osic	https://github.com/hpretl/iic-osic.git
34	Iverilog	https://github.com/steveicarus/iverilog.git
35	Netlistsvg	https://github.com/nturley/netlistsvg
36	Ngspyce	https://github.com/ignamv/ngspyce

#	Packages currently in E4S	URL
37	Padring	https://github.com/donn/padring
38	Pyverilog	https://github.com/PyHDI/Pyverilog
39	OpenRAM	https://github.com/VLSIDA/OpenRAM
40	Rggen	https://github.com/rggen/rggen
41	Spyci	https://github.com/gmagno/spyci
42	Volare	https://github.com/efabless/volare
43	Siliconcompiler	https://github.com/siliconcompiler/siliconcompiler
44	Verilator	https://github.com/verilator/verilator
45	Sky130	SkyWater Technologies 130nm CMOS PDK
46	Actflow	https://github.com/asyncvlsi/actflow.git
47	Qucs-s	https://github.com/Qucs
48	ADMS	https://github.com/Qucs/ADMS.git
49	Gdstk	https://heitzmann.github.io/gdstk/
50	xcell	https://github.com/asyncvlsi/xcell.git

https://e4s.io/eda

e4s-cl: A tool to simplify the launch of MPI jobs in E4S containers

- E4S containers support replacement of MPI libraries using MPICH ABI compatibility layer and Wi4MPI [CEA] for OpenMPI replacement.
- Applications binaries built using E4S can be launched with Singularity using MPI library substitution for efficient inter-node communications.
- e4s-cl is a new tool that simplifies the launch and MPI replacement.
  - e4s-cl init --backend [singularity|shifter|docker] --image <file> --source <startup_cmds.sh>
  - e4s-cl mpirun -np <N> <command>
- Usage:

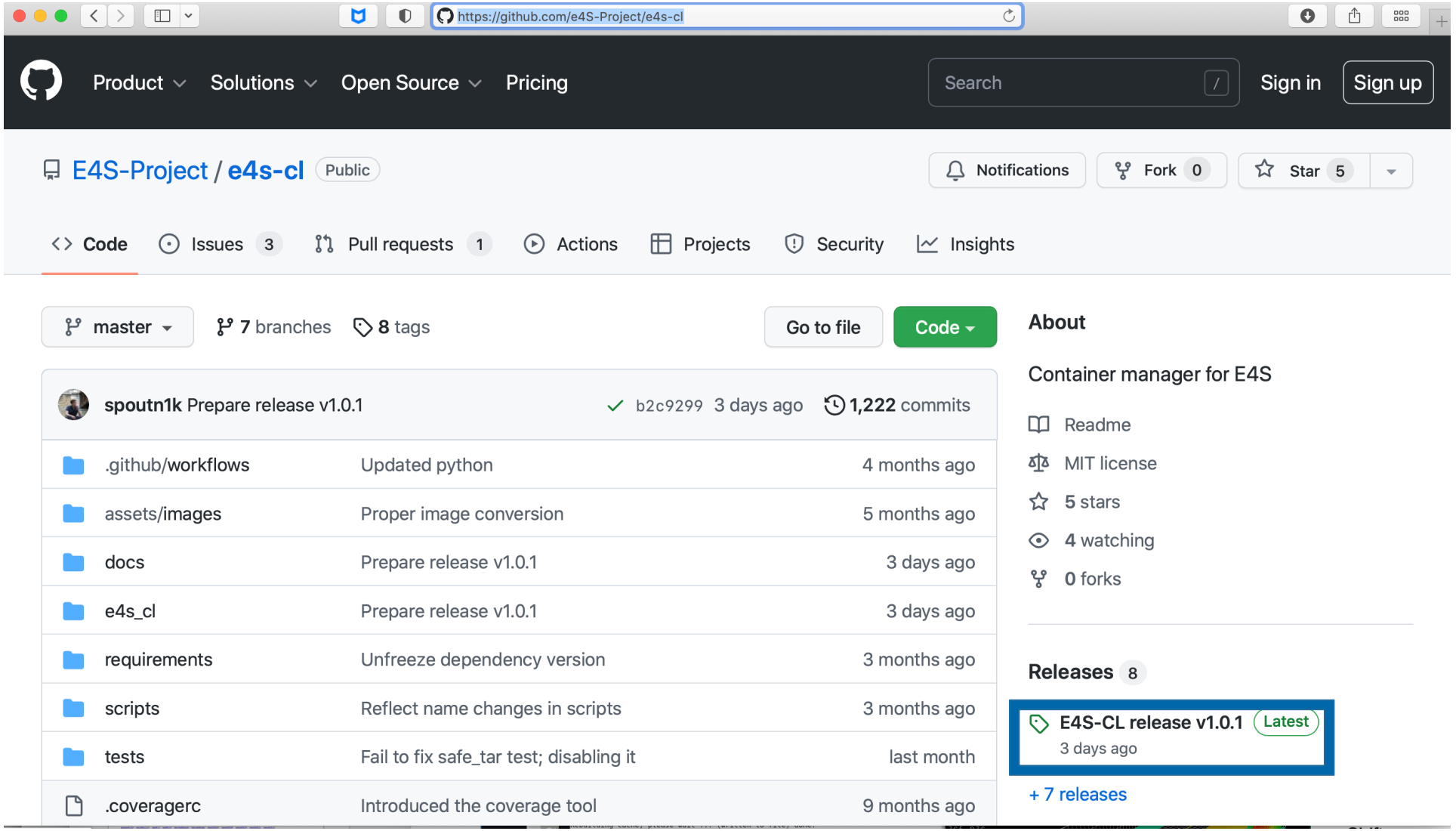
```
e4s-cl init --backend singularity --image ~/images/e4s-gpu-x86.sif --source ~/source.sh

cat ~/source.sh
   . /spack/share/spack/setup-env.sh
   spack load trilinos+cuda cuda_arch=80

e4s-cl mpirun -np 4 ./a.out
```

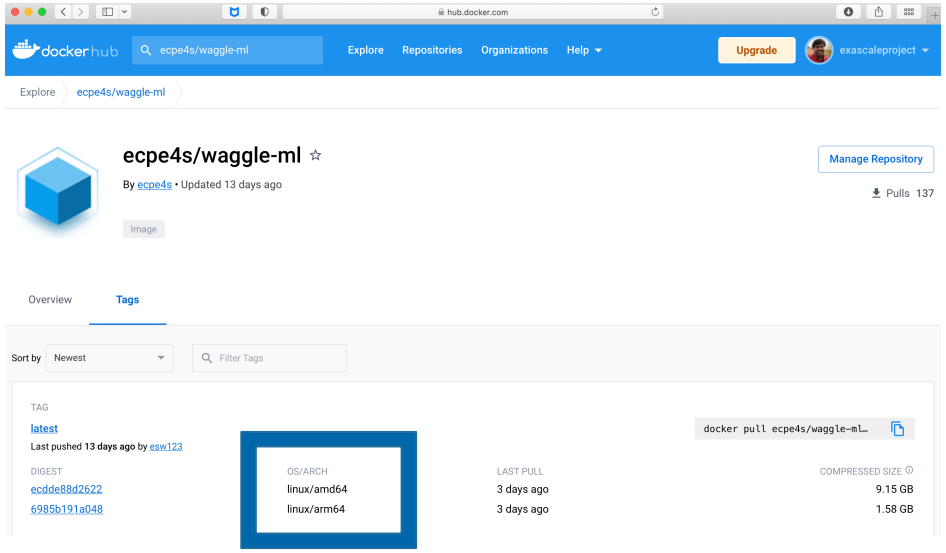
https://github.com/E4S-Project/e4s-cl

New release of e4s-cl on GitHub

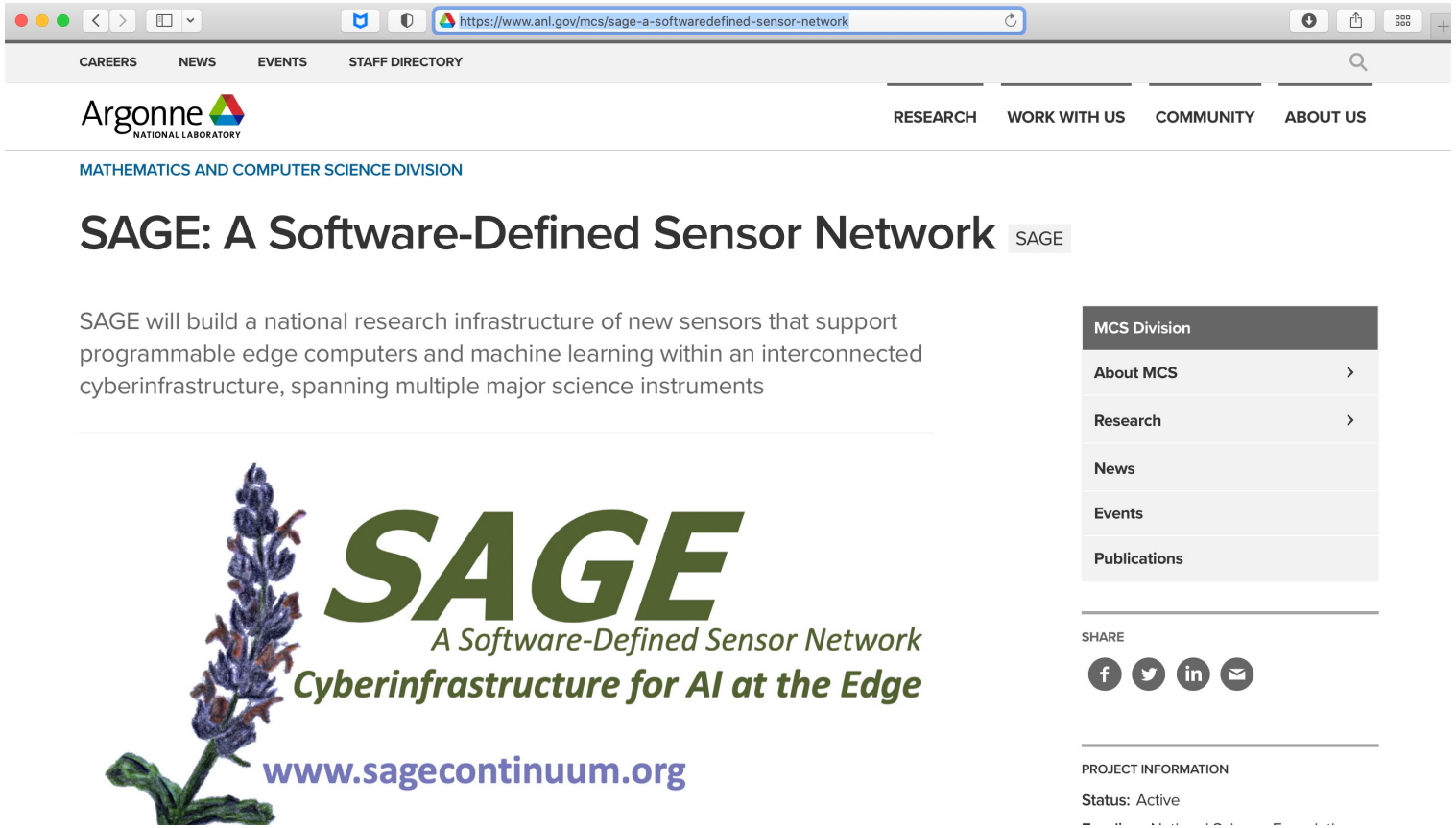


https://github.com/E4S-Project/e4s-cl

Release of custom E4S images: Waggle and SAGE projects



% docker pull ecpe4s/waggle-ml



Thank you

https://www.exascaleproject.org

This research was supported by the Exascale Computing Project (17-SC-20-SC), a joint project of the U.S. Department of Energy's Office of Science and National Nuclear Security Administration, responsible for delivering a capable exascale ecosystem, including software, applications, and hardware technology, to support the nation's exascale computing imperative.

Thank you to all collaborators in the ECP and broader computational science communities. The work discussed in this presentation represents creative contributions of many people who are passionately working toward next-generation computational science.