

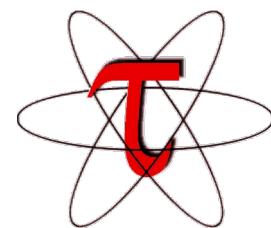
E4S: Extreme-scale Scientific Software Stack

Scalable Tools Workshop

10:30am – 11:00am PDT,
Granlibakken Resort, Lake Tahoe, CA

Sameer Shende
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Performance Research Laboratory, OACISS, University of Oregon
President and Director, ParaTools, Inc.

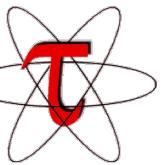
https://e4s.io/talks/E4S_Scalable_Tools23.pdf



Challenges

- As our software gets more complex, it is getting harder to measure the performance of, and install tools and libraries correctly in an integrated and interoperable software stack!
- Can E4S provide a stable platform for tool development?
- What are we missing?

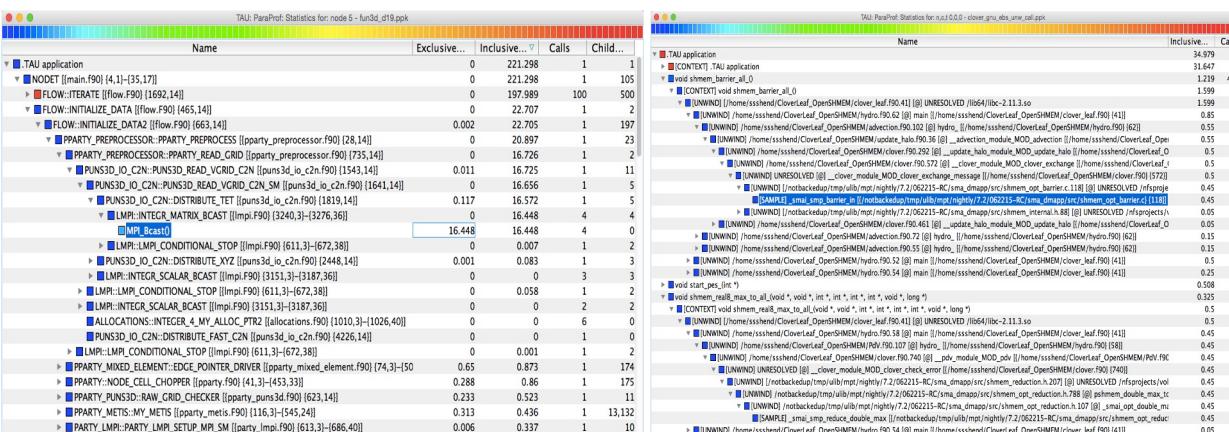
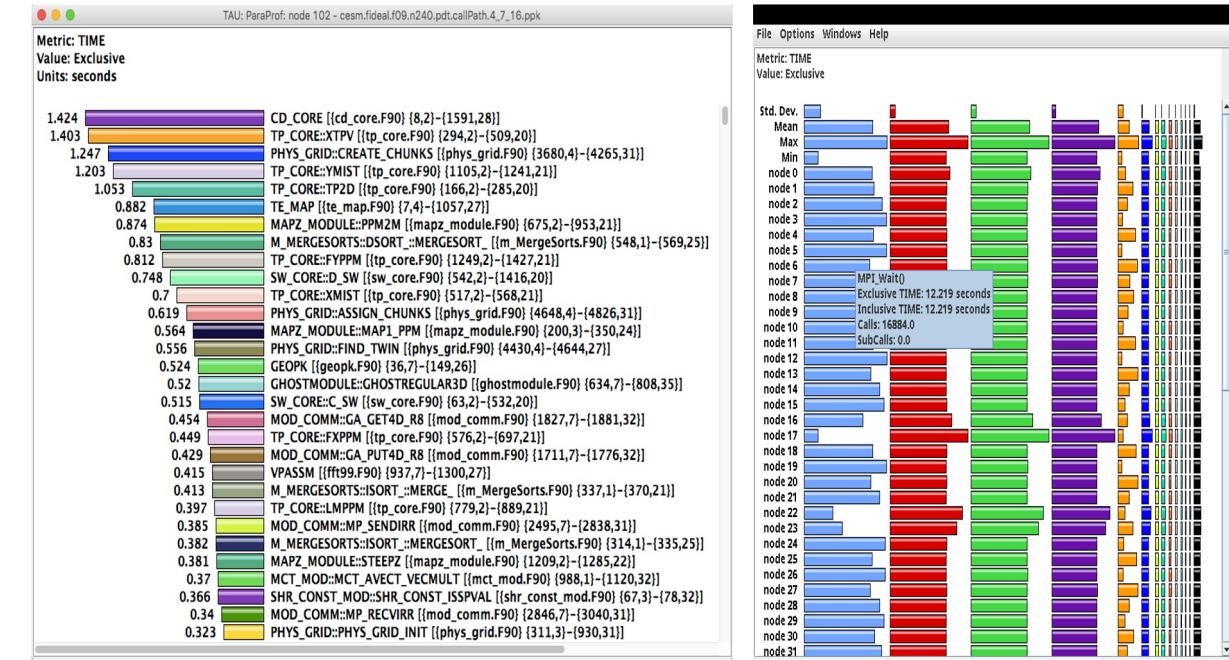
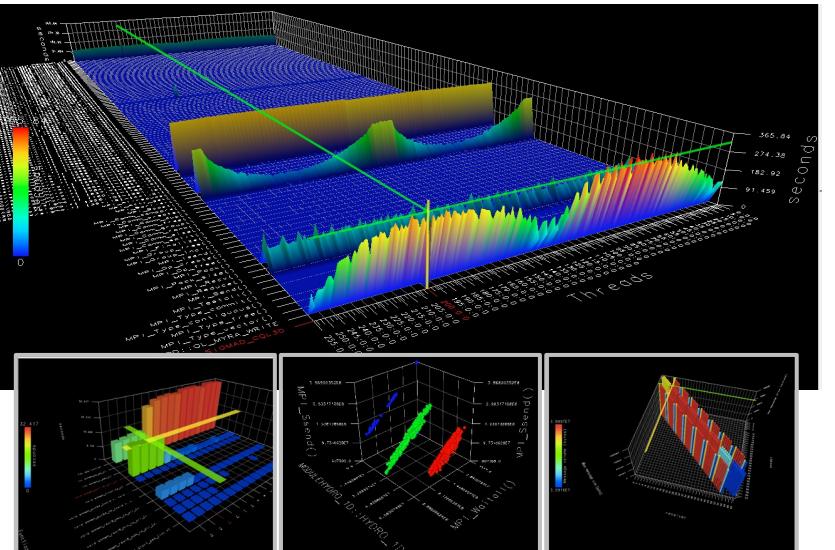
TAU Performance System®



Portable profiling and tracing toolkit for performance analysis of HPC parallel programs

- Supports most parallel execution models
 - Provides instrumentation and measurement
 - Parallel profiling analysis and data mining
 - Open source: <http://tau.uoregon.edu>

TAU runs on most HPC platforms



Our performance evaluation tools are getting complex to install!

- GPU Runtimes: ROCm, CUDA, oneAPI
- Tool interfaces: ROCprofiler V1/ROCtracer V2/Rocprofiler v2, CUPTI, Level Zero, OpenCL, OMPT, Kokkos, Caliper, CAMTimers, PerfStubs, ...
- Tool dependencies:
 - Binutils, libunwind, libdwarf installed just right (-fPIC used to compile .o files that are used in DSOs)
 - GPU runtimes
 - Qt5, Java, Python, perl, bash, sed, awk, cmake...
 - PAPI
 - Compilers: LLVM, GNU, Intel, AMD, NVHPC, PrgEnv-`{cray,amd,nvidia,intel-gnu-amd}` on HPE CPE
 - MPI
 - Intel TBB
 - Boost
 - Other third-party libraries...
- Installing these tools and their dependencies by hand is hard!

DyninstAPI's dependency tree

```
Singularity> spack find -dl -v dyninst
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 --
k3myl3s dyninst@12.3.0~ipo+openmp~stat_dysect~static build_system=cmake build_type=Release generator=make
ukcquzy boost@1.79.0+atomic+chrono~clanglibcpp+container~context~contract~coroutine+date_time~debug+exception~fiber+filesystem+graph~graph_parallel~icu+iostreams~json+locale+log+ma
th+mpi+multithreaded~nowide+numpy~pic+program_options~python+random+regex+serialization+shared+signals~singlethreaded+stacktrace+system~taggedlayout+test+thread+timer~type_erasure~vers
ionedlayout~wave build_system=generic cxxstd=17 patches=a440f96,b8569d7 visibility=global
onsas2b bzip2@1.0.8~debug~pic+shared build_system=generic
j2tltg4 diffutils@3.9 build_system=autotools
4cbi7qh mpich@4.1.1~argobots~cuda+fortran~hwloc+hydra+libxml2+pci~rocm+romio~slurm~two_level_namespace~vci~verbs~wrapperrpath build_system=autotools datatype=engine=auto device
=ech4 netmod=ofi pmi=pmi
bqre6so findutils@4.9.0 build_system=autotools patches=440b954
iv5kj6s libfabric@1.18.0~debug~kdrreg build_system=autotools fabrics=rxm,sockets,tcp,udp
3gsijv7 libpciaccess@0.17 build_system=autotools
kagjghf libtool@2.4.7 build_system=autotools
i5p6x5b util-macros@1.19.3 build_system=autotools
g6lroy7 libxml2@2.10.3~python build_system=autotools
ame4jt7 yaksa@0.2~cuda~rocm build_system=autotools
sqjzqkn autoconf@2.69 build_system=autotools patches=35c4492,7793209,a49dd5b
2qzwzpn automake@1.16.5 build_system=autotools
igzxurr python@3.7.15+bz2+crypt+ctypes+dbm~debug+libxml2+lzma~nis~optimizations+pic+pyexpat+pythoncmd+readline+shared+sqlite3+ssl~tkinter+uuid+zlib build_system=generic
    patches=0d98e93,f2fd060
ewn4mh2 expat@2.5.0+libbsd build_system=autotools
bstssvl libbsd@0.11.7 build_system=autotools
cb26zci libmd@1.0.4 build_system=autotools
rhgoius gettext@0.21.1+bzip2+curses+git~libunistring+libxml2+tar+xz build_system=autotools
qtb2tvv tar@1.34 build_system=autotools zip=pigz
gojmgm4 pigz@2.7 build_system=makefile
d45vpa2 libffi@3.4.4 build_system=autotools
frpj4cl libxcrypt@4.4.33~obsolete_api build_system=autotools
unktq4m readline@8.2 build_system=autotools patches=bbf97f1
3cgnyoh sqlite@3.40.1+column_metadata+dynamic_extensions+fts~functions+rtree build_system=autotools
yeqinad util-linux-uuid@2.38.1 build_system=autotools
tppbn4x xz@5.4.1+pic build_system=autotools libs=shared,static
hi2xsgc zlib@1.2.13+optimize+pic+shared build_system=makefile
so6noth zstd@1.5.5+programs build_system=makefile compression=none libs=shared,static
3w3vs12 cmake@3.26.3~doc+ncurses+ownlibs~qt build_system=generic build_type=Release
3ujhmuv ncurses@6.3~symlinks+termlib abi=none build_system=autotools
u5irkfb openssl@1.1.1t~docs~shared build_system=generic certs mozilla
    ca-certificates-mozilla@2023-01-10 build_system=generic
w233qs7 perl@5.36.0+cpnm+open+shared+threads build_system=generic
swcc5ia berkeley-db@18.1.40+cxx~docs+stl build_system=autotools patches=26090f4,b231fcc
alkzfee gdbm@1.23 build_system=autotools
2ty3ujk elfutils@0.189~debuginfod~nls build_system=autotools
cpp3pz7 libiconv@1.17 build_system=autotools libs=shared,static
5f66p4a m4@1.4.19+sigsegv build_system=autotools patches=9dc5fdb,bfdffa7
e6fw62o libsigsegv@2.14 build_system=autotools
b2tzsv0 pkgconf@1.9.5 build_system=autotools
pkn6xtc gmake@4.4.1~guile build_system=autotools
ac6p20l intel-tbb@2020.3+shared+tm build_system=makefile cxxstd=default patches=62ba015,ce1fb16,d62cb66
owpqkax libiberty@2.40+pic build_system=autotools
```

TAU's dependency tree

```
Singularity> spack find -dl -v tau+rocm
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 --
yc3ekk2 tau@2.32~adios2+binutils~comm~craycnl~cuda+elf+fortran~gasnet+i~level_zero+libdwarf+libunwind~likwid+mpi~ompt~opari~opencl~openmp+otf2+papi+pdt~phase~ppc64le~profileparam+pthr
eads~python+rocm~rocprofiler~roctracer~scorep~shmem~sqlite~x86_64 build_system=generic
dyduxt4 binutils@2.40~gas+gold~gprofng~headers~interwork+ld+libiberty~lto~nls~pgo+plugins build_system=autotools compress_debug_sections=zlib libs=shared,static
j2tlgt4 diffutils@3.9 build_system=autotools
pkn6xtc pkgconf@1.9.5 build_system=autotools
y3bqqtr texinfo@7.0.3 build_system=autotools
rhgoius gettext@0.21.1+bzip2+curses+git~libunistring+libxml2+tar+xz build_system=autotools
qtb2tvv tar@1.34 build_system=autotools zip=pigz
gojgm4 pigz@2.7 build_system=makefile
swcc5ia perl@5.36.0+cpanm+open+shared+threads build_system=generic
alkfee berkeley-db@18.1.40+cxx~docs+stl build_system=autotools patches=26090f4,b231fcc
2ty3ujk gdbm@1.23 build_system=autotools
so6noth zstd@1.5.5+programs build_system=makefile compression=none libs=shared,static
cpp3pz7 elfutils@0.189~debuginfod~nls build_system=autotools
onsas2b bzip2@1.0.8~debug~pic+shared build_system=generic
5f66p4a libiconv@1.17 build_system=autotools libs=shared,static
e6fw62o m4@1.4.19+sigsegv build_system=autotools patches=9dc5fdbd,bfdffa7
b2tzsv0 libsigsegv@2.14 build_system=autotools
tppbn4x xz@5.4.1+pic build_system=autotools libs=shared,static
t2rq3vv hsa-rocr-dev@5.4.3+image+shared build_system=cmake build_type=Release generator=make patches=71e6851
og3ubhr hwloc@2.9.1~cairo~cuda~gl~libudev+libxml2~netloc~nvml~oneapi~level-zero~opencl+pci~rocm build_system=autotools libs=shared,static
3gsijv7 libpciaccess@0.17 build_system=autotools
kagjjhf libtool@2.4.7 build_system=autotools
i5p6x5b util-macros@1.19.3 build_system=autotools
g6lroy7 libxml2@2.10.3~python build_system=autotools
3ujhmuv ncurses@6.3~symlinks+termlib abi=none build_system=autotools
bamxvt7 libdwarf@20180129 build_system=generic
tdegdv2 libunwind@1.6.2~block_signals~conservative_checks~cxx_exceptions~debug~debug_frame+docs+pic+tests+weak_backtrace+xz~zlib build_system=autotools components=none libs=shared,
static
4cbi7qh mpich@4.1.1~argobots~cuda+fortran~hwloc+hydra+libxml2+pci~rocm+romio~slurm~two_level_namespace~vci~verbs~wrapperrpath build_system=autotools datatype=engine=auto device=ch4
netmod=ofi pmi=pmi
bqr6so findutils@4.9.0 build_system=autotools patches=440b954
iv5kj6s libfabric@1.18.0~debug~kdreg build_system=autotools fabrics=rxm,sockets,tcp,udp
ame4jt7 yaksa@0.2~cuda~rocm build_system=autotools
sqjzqkn autoconf@2.69 build_system=autotools patches=35c4492,7793209,a49dd5b
2qzwpnz automake@1.16.5 build_system=autotools
igzxurr python@3.7.15+bz2+crypt+ctypes+dbm~debug+libxml2+lzma~nis~optimizations+pic+pyexpat+pythoncmd+readline+shared+sqlite3+ssl~tkinter+uuid+zlib build_system=generic pat
ches@0d98e93,f2fd060
ewn4mh2 expat@2.5.0+libbsd build_system=autotools
bstssvl libbsd@0.11.7 build_system=autotools
cb26zci libmd@1.0.4 build_system=autotools
d45vpaa libffi@3.4.4 build_system=autotools
frpj4cl libxcrypt@4.4.33~obsolete_api build_system=autotools
u5irkfb openssl@1.1.1t~docs~shared build_system=generic certs mozilla
w233qs7 ca-certificates-mozilla@2023-01-10 build_system=generic
unktq4m readline@8.2 build_system=autotools patches=bbf97f1
3cgnyoh sqlite@3.40.1+column_metadata+dynamic_extensions+fts~functions+rtree build_system=autotools
yeqinad util-linux-uuid@2.38.1 build_system=autotools
viau22p openjdk@11.0.17_8 build_system=generic
e3gh2oa oftf2@2.3 build_system=autotools patches=7e56d93
j5quynt papi@6.0.0.1~cuda+example~infiniband~lmsensors~nvml~powercap~rapl~rocm~rocm_smi~sde+shared~static_tools build_system=autotools
lx67nrs pdt@3.25.1~pic build_system=autotools
hi2xsgc zlib@1.2.13+optimize+pic+shared build_system=makefile
```

HPC Toolkit's dependency tree

```
Singularity> spack find -dl -v hpc toolkit+rocm
-- linux-ubuntu20.04~x86_64 / gcc@11.1.0 --
pqqcfaf hpc toolkit@2023.03.01~cuda~debug~level_zero+mpi+opencl+papi+python+rocm+viewer build_system=autotools
ukcquzy boost@1.79.0+atomic+chrono+clanglibcpp+container+context+contract+coroutine+date_time~debug+exception~fiber+filesystem+graph+graph_parallel~icu+iostreams~json+locale+log+math+mpi+multithreaded~nowide~numpy
~pic+program_options+python+random+regex+serialization+shared+signals~singlethreaded+stacktrace+system~taggedlayout+test+thread+timer~type_erasure~versionedlayout~wave build_system=generic cxxstd=17 patches=a440f96,b8
569d7 visibility=global
so6noth zstd@1.5.5+programs build_system=makefile compression=none libs=shared,static
onbsas2b bzip2@1.0.8~debug~pic+shared build_system=generic
j2tlgt4 diffutils@3.9 build_system=autotools
K3myl3s dyninst@12.3.0~ipo+openmp+stat_dysect~static build_system=cmake build_type=Release generator=make
3w3vsl2 cmake@3.26.3~doc+curses+owllibs+qt build_system=generic build_type=Release
3ujhmuv ncurses@6.3~symlinks+termlib abi=none build_system=autotools
u5irkfb openssl@1.1.1t~docs~shared build_system=generic certs=mozilla
w233qs7 ca-certificates-mozilla@2023-01-10 build_system=generic
ac6p2ol gmake@4.4.1~guile build_system=autotools
cpp3p27 elfutils@0.189~debuginfod~nls build_system=autotools
5f66p4a libiconv@1.17 build_system=autotools libs=shared,static
e6fw62o m4@1.4.19+sigsegv build_system=autotools patches=9dc5fb,bfdf7a
b2tzsv0 libsigsegv@2.14 build_system=autotools
pkn6xtc pkgconf@1.9.5 build_system=autotools
s3u7fv6 hip@5.4.3~cuda~ipo+rocm build_system=cmake build_type=Release generator=make patches=5068750,ca523f1
2diathq hpc viewer@2023.04 build_system=generic
viau22p openjdk@11.0.17_ build_system=generic
ikj6txu hsa-rocr-dev@5.4.3+image~ipo+shared build_system=cmake build_type=Release generator=make patches=71e6851
owpqkax intel-tbb@2020.3+shared+th build_system=makefile cxxstd=default patches=62ba015,ce1fb16,d62cb66
5xnbu3x intel-xed@2022.10.11~debug+pic build_system=generic
igzxurr python@3.7.15+bz2+crypt+ctypes+dbm+debug+libxml2+lzma~nis~optimizations+pic+pyexpat+pythoncmd+readline+shared+sqlite3+ssl~tkinter+uuid+zlib build_system=generic patches=0d98e93,f2fd060
ewn4mh2 expat@2.5.0+libbsd build_system=autotools
bstssvl libbsd@0.11.7 build_system=autotools
cb26zci libmd@0.1.0.4 build_system=autotools
2ty3ujk gdbm@1.23 build_system=autotools
rholouis gettext@0.21.1+bzip2+curses+git~lubunistring+libxml2+tar+xz build_system=autotools
qtb2tvv tar@1.34 build_system=autotools zip=pigz
gojmg4 pigz@2.7 build_system=makefile
d45vp2a libffi@3.4.4 build_system=autotools
frpj4cl libcrypt@4.4.33~obsolete_api build_system=autotools
unktq4m readline@8.2 build_system=autotools patches=bbf97f1
3cgnyoh sqlite@3.40.1~column_metadata+dynamic_extensions+fts~functions+rtree build_system=autotools
yeqinad util-linux-uuid@2.38.1 build_system=autotools
amvc76v libiberty@2.40+pic build_system=autotools
3btazyw libmonitor@2023.03.15~commrank+dlopen+hpc toolkit build_system=autotools
tddegdv2 libunwind@1.6.2~block_signals~conservative_checks~cxx_exceptions~debug~debug_frame+docs+pic+tests+weak_backtrace+xz~zlib build_system=autotools components=none libs=shared,static
2cgjsln memkind@1.13.0 build_system=autotools
sqjzqkn autoconf@2.69 build_system=autotools patches=35c4492,7793209,a49dd5b
swcc5ia perl@5.36.0+cpam+open+shared+threads build_system=generic
alkzee berkeley-db@18.1.40~cxx~docs+stl build_system=autotools patches=26090f4,b231fcc
2qzwpzn automake@1.16.5 build_system=autotools
kagjghf libtool@2.4.7 build_system=autotools
 geg3gor numactl@2.0.14 build_system=autotools patches=4e1d78c,62fc8a8,ff37630
4cbi7qh mpich@4.1.1~argobots+cuda+fortran+hwloc+hydra+libxml2+pci~rocm+romio~slurm~two_level_namespace~vci~verbs~wrapperrpath build_system=autotools datatype=engine=auto device=ch4 netmod=ofi pmi=pmi
bqrre6so findutils@4.9.0 build_system=autotools patches=40b954
iv5kj6s libfabric@1.18.0~debug~kdreg build_system=autotools fabrics=rxe,sockets,tcp,udp
3gsijv7 libpciaccess@0.17 build_system=autotools
i5p6x5b util-macros@1.19.3 build_system=autotools
g6lroy7 libxml2@2.10.3~python build_system=autotools
ame4jt7 yaksa@0.2~cuda+rocm build_system=autotools
j5quynt papi@6.0.0.1~cuda+example+infiniband+lsensors+nvml+powercap+rapl~rocm+rocm_sm1~sde+shared~static_tools build_system=autotools
ftwupzv rocprofiler-dev@5.4.3~ipo build_system=cmake build_type=Release generator=make patches=16754a1,c482eee
lju4qds roctracer-dev@4.5.3~ipo+rocm build_system=cmake build_type=Release generator=make
d2sre54 xerces-c@3.2.4 build_system=autotools cxxstd=default netaccessor(curl transcoder=iconv
curl@8.0.1~gssapi+ldap+libnid2~librtmp+libssh+libssh2~nghttp2 build_system=autotools libs=shared,static tls=openssl
xz@5.4.1+pic build_system=autotools libs=shared,static
mde4ok3 yaml-cpp@0.7.0~ipo+pic+shared~tests build_system=cmake build_type=Release generator=make
hi2xsgc zlib@1.2.13~optimize+pic+shared build_system=makefile
```

Our HPC applications are equally complex!

```
Singularity> spack find -dl -v openfoam
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 -----
zftm6f5 openfoam@22.06~float32~int64~kahip~knl~metis~mggridgen~paraview+scotch+source~spdp~vtk~zoltan build_system=generic
2zb2fugm adios2@2.9.0~blosc+bzip2~cuda~dataspaces~fortran~hdf5~ipo~libpressio+mpi~pic+png~python+ssc+sst+sz+zfp build_system=cmake build_type=Release generator=make
onsas2b bzip2@1.0.8~debug~pic+shared build_system=generic
ii3yqva c-blosc@1.21.2+avx2~ipo build_system=cmake build_type=Release generator=make
pff3ody lz4@1.9.4 build_system=makefile libs=shared,static
pfz5ppi snappy@1.1.10~ipo~pic+shared build_system=cmake build_type=Release generator=make
ac6p2ol gmake@4.4.1~guile build_system=autotools
iv5kj6s libfabric@1.18.0~debug~kdreg build_system=autotools fabrics=rxm,sockets,tcp,udp
d45vp42 libffi@3.4.4 build_system=autotools
n30lmgn libpng@1.6.39~ipo build_system=cmake build_type=Release generator=make libs=shared,static
pkn6xtc pkgconf@1.9.5 build_system=autotools
5m2g6po sz@2.1.12~fortran~hdf5~ipo~netcdf~pastri~python~random_access+shared~stats~time_compression build_system=cmake build_type=Release generator=make
c32srn5 zfp@0.5.5~aligned~c~cuda~fasthash~fortran~ipo~openmp~profile~python+shared~strided~twoWay+utilities bsbs=64 build_system=cmake build_type=Release generator=make
4qiedub boost@1.79.0~atomic+chrono~clanglibcpp+container~context~contract~coroutine~date_time~debug+exception~fiber+filesystem+graph~graph_parallel~icu+iostreams~json+locale+log+math+mpi+multithreaded~owide+numpy~pic+program_options~python+random+regex+serialization+shared+signals~singlethreaded+stacktrace+system~taggedlayout+test+thread+timer~type_erasure~versionedlayout+wave build_system=generic cxxstd
=17 patches=a440f96,b8569d7 visibility=global
tppbn4x xz@5.4.1~pic build_system=autotools libs=shared,static
|so6noth zstd@1.5.5~programs build_system=makefile compression=none libs=shared,static
hd7omtv cgal@4.13~core+demos+eigen~header_only~imageio~ipo+shared build_system=cmake build_type=Release generator=make
xxcjwxz eigen@3.4.0~ipo build_system=cmake build_type=RelWithDebInfo generator=make
r7hokcd gmp@6.2.1~cxx build_system=autotools libs=shared,static patches=69ad2e
vdahj7p mpfr@4.2.0 build_system=autotools libs=shared,static
l3nt23x autoconf-archive@2023.02.20 build_system=autotools
y3bqqrz texinfo@7.0.3 build_system=autotools
3w3vsl2 cmake@3.26.3~doc+nurses+ownlibs~qt build_system=generic build_type=Release
3ujhmuv ncurses@6.3~symlinks+termlib abi=none build_system=autotools
u5irkfb openssl@1.1.1t~docs~shared build_system=generic certs mozilla
w233qs7 ca-certificates-mozilla@2023-01-10 build_system=generic
swcc5ia perl@5.36.0~cpanm+open+shared+threads build_system=generic
alkzfee berkeley-db@18.1.40~cxx~docs+stl build_system=autotools patches=26090f4,b231fcc
2ty3ujk gdbm@1.23 build_system=autotools
xhud4dh fftw@3.3.10~mpi+openmp~pfft_patches build_system=autotools precision=double,float
rvuqshe flex@2.6.4~lex~nls build_system=autotools patches=f8b85a0
sqjzqkn autoconf@2.69 build_system=autotools patches=35c4492,7793209,a49dd5b
2qzwpnz automake@1.16.5 build_system=autotools
5dxfmh2 bison@3.8.2 build_system=autotools
j2tlgt4 diffutils@3.9 build_system=autotools
5f66p4a libiconv@1.17 build_system=autotools libs=shared,static
bqre6so findutils@4.9.0 build_system=autotools patches=440b954
rhgoius gettext@0.21.1~bzip2+curses+git~libunistring+libxml2+tar+xz build_system=autotools
qtb2tvv tar@1.34 build_system=autotools zip=pigz
gojgmg4 pigz@2.7 build_system=makefile
yoasdzo help2man@1.49.3 build_system=autotools
kagijhf libtool@2.4.7 build_system=autotools
e6fw62o m4@1.4.19+sigsegv build_system=autotools patches=9dc5fdb,bfdfa7
b2tzsvo libsigsegv@2.14 build_system=autotools
4cbi7gh mpich@4.1.1~argobots~cuda~fortran~hwloc~hydra+libxml2+pci~rocm+romio~slurm~two_level_namespace~vci~verbs~wrapperrpath build_system=autotools datatype=engine=auto device=ch4 netmod=ofi pmi=pmi
3gsijv7 libpciaccess@0.17 build_system=autotools
i5p6x5b util-macros@1.19.3 build_system=autotools
g6lroy7 libxml2@2.10.3~python build_system=autotools
ame4jt7 yaksa@0.2~cuda~rocm build_system=autotools
igzxutr python@3.7.15~bz2+crypt+ctypes+dbm~debug+libxml2+lzma~nis~optimizations+pic+pyexpat+pythoncmd+readline+shared+sqlite3+ssl~tkinter+uuid+zlib build_system=generic patches=0d98e93,f2fd060
ewn4mh2 expat@2.5.0~libbsd build_system=autotools
bstssvl libbsd@11.7 build_system=autotools
cb26zci libmd@1.0.4 build_system=autotools
frpj4cl libcrypt@4.4.33~obsolete_api build_system=autotools
unktq4m readline@8.2 build_system=autotools patches=bbbf97f1
3cgnyoh sqlite@3.40.1~column_metadata+dynamic_extensions+fts~functions+rtree build_system=autotools
yeqinad util-linux-uuid@2.38.1 build_system=autotools
aogu6qq scotch@0.3~compression~esmumps~int64~ipo~metis+mpi+shared build_system=cmake build_type=Release generator=make
hi2xsgc zlib@1.2.13~optimize+pic+shared build_system=makefile
```

Openfoam

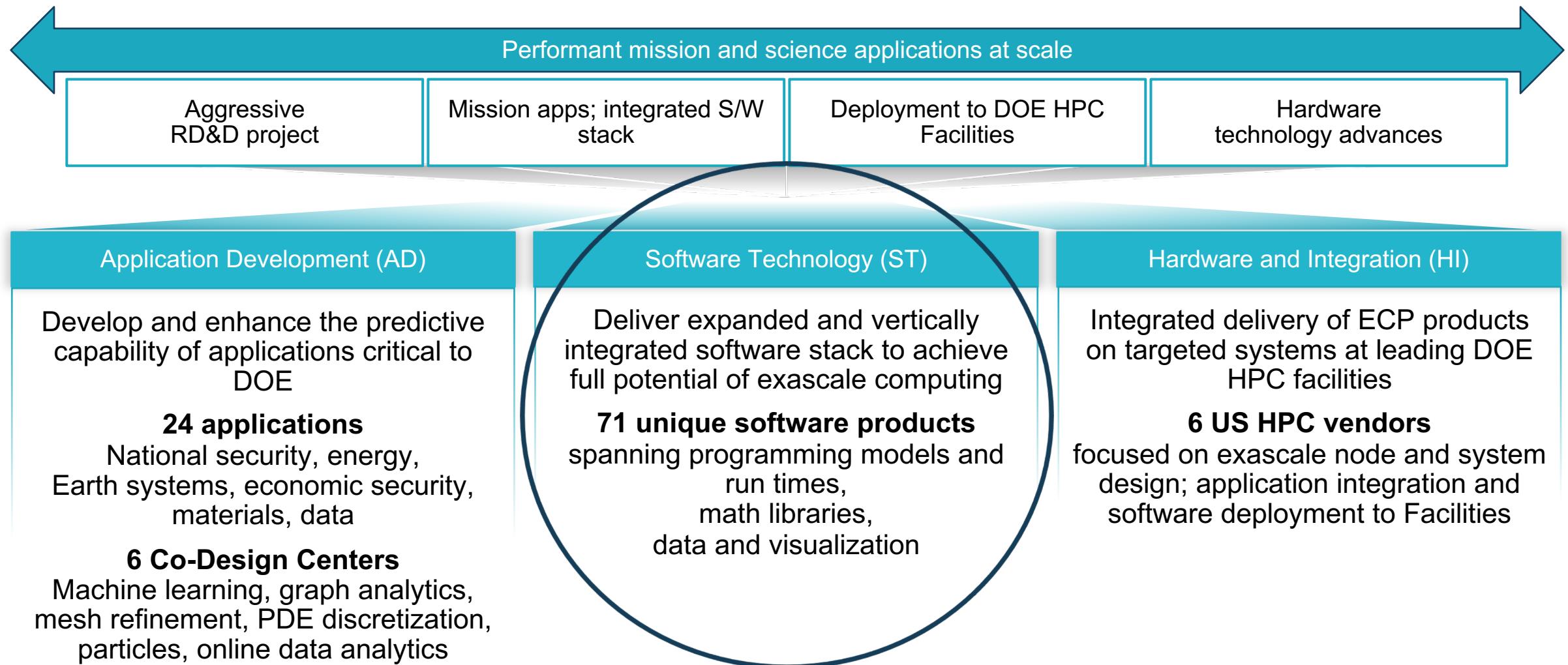
How can we build a software stack to help tool developers?

- Tool dependencies should be pre-installed
- A consistent environment that we can share with other tool developers to report bugs!
- Can containers help here?
- Build your tools with the dependencies inside a container!
 - Same kernel as the host OS
 - Can support a different OS
 - Docker and Singularity/Apttainer are popular container runtimes
- Need a base container that can provide the dependencies!
- E4S provides a rich set of containers with tools and libraries

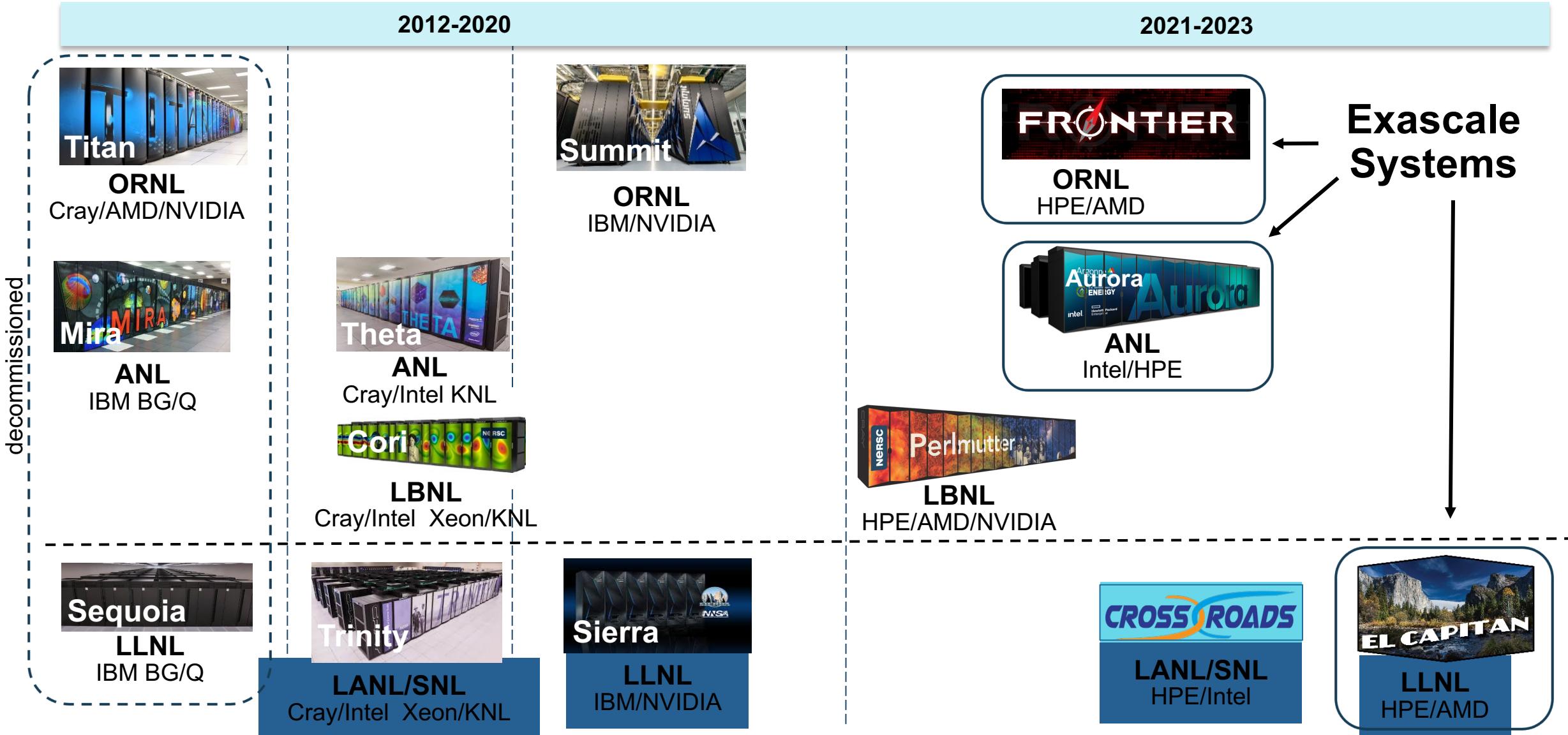
Extreme-scale Scientific Software Stack (E4S)



ECP's holistic approach uses co-design and integration to achieve exascale computing



US DOE HPC Roadmap to Exascale Systems



ECP Software Technology (ST)

Goal

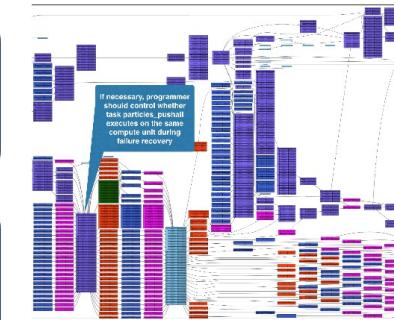
Build a comprehensive, coherent software stack that enables application developers to productively develop highly parallel applications that effectively target diverse exascale architectures

Prepare SW stack for scalability with massive on-node parallelism

Extend existing capabilities when possible, develop new when not

Guide, and complement, and integrate with vendor efforts

Develop and deliver high-quality and robust software products



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 each release
- 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
- May 2023: E4S 23.05 – 109 full release products



<https://e4s.io>

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

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_May23.pdf
- e4s-cl container launch tool allows binary distribution of applications by substituting MPI in the containerized app with the system MPI. e4s-alc is a tool to create custom container images from base images
- Quarterly releases: E4S 23.05 released on May 31, 2023: https://e4s.io/talks/E4S_23.05.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: 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>

e4s-alc: E4S à la carte – a tool to customize container images

The screenshot shows a web browser displaying the README.md file for the e4s-alc project on GitHub. The browser interface includes standard controls like back, forward, and search, and a URL bar showing the address.

The README.md content includes:

- A command-line example: `$ e4s-alc init`
- A section titled "Create image" with two examples:
 - `$ e4s-alc create \
--image centos:8 \
--name my-centos-image \
-p py-numpy \
-p autodiff`
 - `$ e4s-alc create \
--image ubuntu:22.04 \
--name my-ubuntu-image \
--no-spack`
- A section titled "or"
- A command-line example: `$ cat test.json`

```
{  
    "image": "ubuntu:22.04",  
    "name": "test-file-kokkos-raja",  
    "spack": true,  
    "spack-packages": [  
        "kokkos",  
        "raja"  
    ],  
    "os-packages": [  
        "neovim",  
        "valgrind"  
    ]  
}  
$ e4s-alc create -f test.json
```

Add packages to a container image:

- Spack packages
- OS packages (yum/apt/zypper)
- Add a tarball to a location
- Create a new container image
- Works with Docker/podman & Singularity/Apptainer!

Spack

- E4S uses the Spack package manager for software delivery
- Spack provides the ability to specify versions of software packages that are and are not interoperable.
- Spack is a build layer for not only E4S software, but also a large collection of software tools and libraries outside of ECP ST.
- Spack supports achieving and maintaining interoperability between ST software packages.
- <https://spack.io>

Spack is a flexible package manager for HPC

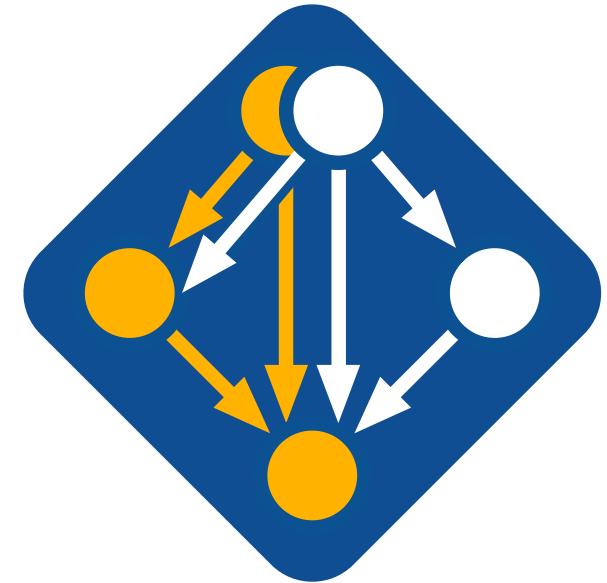
- How to install Spack (works out of the box):

```
$ git clone https://github.com/spack/spack
$ . spack/share/spack/setup-env.sh
```

- How to install a package:

```
$ spack install tau
```

- TAU and its dependencies are installed within the Spack directory.
- Unlike typical package managers, Spack can also install many variants of the same build.
 - Different compilers
 - Different MPI implementations
 - Different build options



Visit spack.io



github.com/spack/spack



@spackpm

Spack provides the *spec* syntax to describe custom configurations

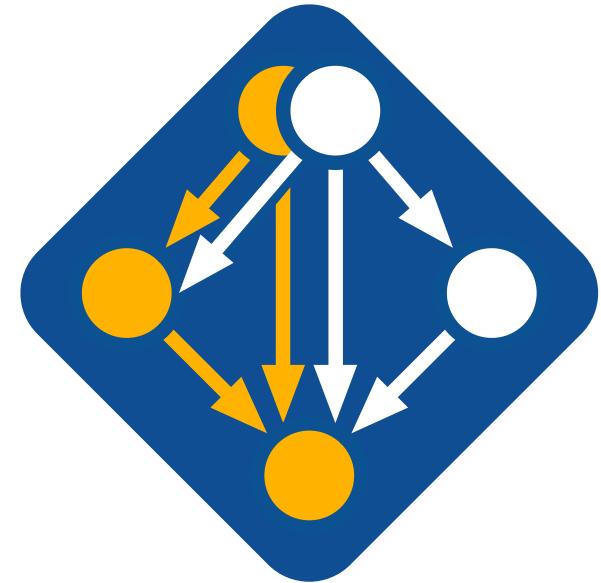
```
$ git clone https://github.com/spack/spack
$ . spack/share/spack/setup-env.sh
$ spack compiler find                                # set up compilers
$ spack external find                               # set up external packages
```

\$ spack install tau	unconstrained
\$ spack install tau@2.32	@ custom version
\$ spack install tau@2.32 %gcc@9.3.0	% custom compiler
\$ spack install tau@2.32 %gcc@9.3.0 +rocm	+/- build option
\$ spack install tau@2.32 %gcc@9.3.0 +mpi ^mvapich2@2.3~wrapperrpath	^ dependency information

- Each expression is a ***spec*** for a particular configuration
 - Each clause adds a constraint to the spec
 - Constraints are optional – specify only what you need.
 - Customize install on the command line!
- Spec syntax is recursive
 - Full control over the combinatorial build space

The Spack community is growing rapidly

- **Spack simplifies HPC software for:**
 - Users
 - Developers
 - Cluster installations
 - The largest HPC facilities
- **Spack is central to ECP's software strategy**
 - Enable software reuse for developers and users
 - Allow the facilities to consume the entire ECP stack
- **The roadmap is packed with new features:**
 - Building the ECP software distribution
 - Better workflows for building containers
 - Stacks for facilities
 - Chains for rapid dev workflow
 - Optimized binaries
 - Better dependency resolution



Visit spack.io



github.com/spack/spack



@spackpm

E4S Download from <https://e4s.io>

The screenshot shows a web browser window displaying the E4S Project website at <https://e4s.id>. The page has a dark green and black abstract background graphic. At the top, there is a navigation bar with links: HOME, EVENTS, ABOUT, E4S-CL, PRODUCT DOCPORTAL, DEPLOYMENTS, COMMUNITY POLICIES, CONTACT, JOIN, FAQ, DOCUMENTATION, and DOWNLOAD. The DOWNLOAD button is highlighted with an orange background. Below the navigation bar, the text "E4S Project" is visible. The main title "The Extreme-scale Scientific Software Stack" is prominently displayed in large white font. A message in the center states: "E4S 23.05 container images now available! See [Downloads](#) for more information on E4S 23.05." Below this, a section titled "What is E4S?" is introduced with a dashed line separator. The text describes E4S as a community effort to provide open source software packages for HPC platforms, mentioning from-source builds and containers of a broad collection of HPC software packages.

E4S Project

The Extreme-scale Scientific Software Stack

E4S 23.05 container images now available!
See [Downloads](#) for more information on E4S 23.05.

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 Container Download from <https://e4s.io>



The screenshot shows a web browser window with the URL <https://e4s-project.github.io/download.html> in the address bar. The page has a dark green and black header with the E4S logo. The navigation menu includes links for HOME, EVENTS, ABOUT, E4S-CL, PRODUCT DOCPORTAL, DEPLOYMENTS, COMMUNITY POLICIES, CONTACT, JOIN, FAQ, DOCUMENTATION, and DOWNLOAD. The DOWNLOAD button is highlighted in orange. Below the header, the main content area features a large title "Acquiring E4S Containers". A detailed paragraph explains the container offerings, mentioning Docker and Singularity images for X86_64, PPC64LE, and AARCH64 architectures, based on Ubuntu 20.04. It also notes the availability of full E4S Release images and minimal base images for CI pipelines using Spack. At the bottom, links are provided to the E4S Docker Hub and the E4S 23.05 Release Notes.

Acquiring E4S Containers

The current E4S container offerings include Docker and Singularity images capable of running on X86_64, PPC64LE, and AARCH64 architectures. Our full E4S Release images 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 23.05 Release Notes](#).

Download E4S 23.05 GPU Container Images: NVIDIA, AMD, Intel

The screenshot shows a web browser window with the URL <https://e4s-project.github.io/download.html>. The page is divided into two main sections: "Container Releases" and "From source with Spack".

Container Releases (Left):

- Docker Downloads - CUDA (highlighted with a blue border)
- Docker Downloads - ROCm
- Docker Downloads - OneAPI
- Singularity x86_64 Download - CUDA 80
- Singularity x86_64 Download - CUDA 90
- Singularity ppc64le Download - CUDA 70
- Singularity aarch64 Download - CUDA 75
- Singularity aarch64 Download - CUDA 80
- Singularity x86_64 Download - ROCm gfx90a
- Singularity x86_64 Download - ROCm gfx908
- Singularity x86_64 Download - OneAPI
- OVA Download

From source with Spack (Right):

- Visit the Spack Project

Spack contains packages for all of the products listed in the E4S 23.05 Full Release category (see above Release Notes). General instructions for building software with Spack can be found at the Spack website. Questions concerning building those packages are deferred to the associated package development team.

- 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

Download E4S 23.05 GPU Container Images: AMD, Intel, and NVIDIA

Note on Container Images

Container images contain binary versions of the Full Release packages listed above. Full-featured GPU-enabled container images are available from Dockerhub:

```
# docker pull ecpe4s/e4s-cuda:23.05
# docker pull ecpe4s/e4s-rocm:23.05
# docker pull ecpe4s/e4s-oneapi:23.05
```

E4S Full GPU Images

These images contain a full Spack-based deployment of E4S, including GPU-enabled packages for NVIDIA, AMD, or Intel GPUs.

These images also contain TensorFlow, PyTorch, and TAU.

AMD ROCm (x86_64)	NVIDIA CUDA (X86_64, PPC64LE, AARCH64)	Intel OneAPI (x86_64)
ecpe4s/e4s-rocm:23.05 mirror 1	ecpe4s/e4s-cuda:23.05 mirror 1	ecpe4s/e4s-oneapi:23.05 mirror 1
e4s-rocm90a-x86_64-23.05.sif mirror 1	e4s-cuda80-x86_64-23.05.sif mirror 1	e4s-oneapi-x86_64-23.05.sif mirror 1
e4s-rocm908-x86_64-23.05.sif mirror 1	e4s-cuda90-x86_64-23.05.sif mirror 1	
	e4s-cuda70-ppc64le-23.05.sif mirror 1	
	e4s-cuda75-aarch64-23.05.sif mirror 1	
	e4s-cuda80-aarch64-23.05.sif mirror 1	

Intel Compilers and MPI Libraries Now Accessible in E4S Containers: A Breakthrough Collaboration Driving Productivity and Sustainability

- Background:
 - E4S provides a unified software stack of libraries and tools for portable performance on HPC systems, especially GPU-based systems.
 - E4S promises seamless portability for onsite and cloud-based workflows through its container-based approach.
 - Intel compilers and libraries available in E4S accelerates preparations for Aurora and future Intel-based GPU systems.
 - E4S eliminates the need for separate management of access to Intel compilers and libraries, benefiting users
 - Many important workflows, especially regression testing and turnkey usage for Intel platforms become feasible and easier
- The E4S-Intel agreement makes Intel compilers and MPI libraries available via E4S containers:
 - Enables full testing and execution of HPC libraries and tools on Intel platforms via E4S, including Aurora early access systems
 - Represents a win-win for DOE, Intel, and the broader E4S user community that is developing at other US agencies and industry
- The Intel agreement brings Intel in line with E4S builds that include AMD and NVIDIA tools.
- The E4S-Intel agreement is possible through the partnership of ECP and the E4S commercial provider, ParaTools, Inc.

E4S base container images allow users to customize their containers

The screenshot shows a web browser window with the URL <https://e4s-project.github.io/download.html>. The page title is "GPU Base Images". It contains two main sections: "GPU Base Images" and "Minimal Spack".

GPU Base Images

These images come with MPICH, CMake, and the relevant GPU SDK – either AMD ROCm, NVIDIA CUDA Toolkit and NVHPC, or Intel OneAPI.

AMD ROCM (X86_64)

- ecpe4s/e4s-base-rocm:23.05
- e4s-base-rocm-x86_64-23.05.sif

NVIDIA Multi-Arch (X86_64, PPC64LE, AARCH64)

- ecpe4s/e4s-base-cuda:23.05
- e4s-base-cuda-x86_64-23.05.sif
- e4s-base-cuda-aarch64-23.05.sif
- e4s-base-cuda-ppc64le-23.05.sif

Intel OneAPI (X86_64)

- ecpe4s/e4s-base-oneapi:23.05
- e4s-base-oneapi-23.05.sif

Minimal Spack

This image contains a minimal setup for using Spack 0.18.0 w/ GNU compilers

X86_64, PPC64LE, AARCH64

- ecpe4s/ubuntu20.04
- ecpe4s-ubuntu20.04-x86_64-23.05.sif
- ecpe4s-ubuntu20.04-ppc64le-23.05.sif
- ecpe4s-ubuntu20.04-aarch64-23.05.sif

e4s-alc: a new tool to customize container images

The screenshot shows the GitHub repository page for 'e4s-alc'. The repository has 6 branches and 0 tags. The main branch has 94 commits. Key commits include updating the README to show singularity support with svg to main, merging 'main' into 'development', and adding a Makefile to download a python interpreter. The README.md file lists supported operating systems (Ubuntu, Red Hat, SUSE) and backends (Docker, Podman, Singularity). The repository has 2 stars, 4 watching, and 1 fork. It includes sections for About, Releases, Packages, and Contributors.

About

E4S à la carte is a tool that allows a user to customize a container image by adding packages to it. These can be system packages and Spack packages.

Code

main 6 branches 0 tags

Commits

File	Description	Time
README	Merge branch 'main' into development	last month
.gitignore	commented why a test is commented out	2 months ago
LICENSE	Added Makefile to download python interpreter	last month
Makefile	Initial commit	3 months ago
README.md	Added Makefile to download python interpreter	last month
pyproject.toml	updated README to show singularity support with svg to main	last week
tox.ini	Slight correction of the description of alc in pyproject + update...	last month
	barebones tox testing implemented	2 months ago

README.md

Operating Systems supported:

- Ubuntu ✓
- Red Hat ✓
- SUSE ✓

Backends supported:

- Docker ✓
- Podman ✓
- Singularity ✓

About

E4S à la carte is a tool that allows a user to customize a container image by adding packages to it. These can be system packages and Spack packages.

Readme

MIT license

2 stars

4 watching

1 fork

Report repository

Releases

No releases published

Packages

No packages published

Contributors 4

Contributor	Name
FrederickDeny	FrederickDeny
PlatinumCD	Cameron Durbin
spoutn1k	Jean-Baptiste Skutnik
sameershende	Sameer Shende

Add to a base image:

- Spack packages
- OS packages
- Tarballs

E4S 23.05 DOE LLVM and CI images

The screenshot shows a web browser window with the URL <https://e4s-project.github.io/download.html>. The page title is "DOE LLVM E4S Image". A sub-section titled "Multi-Arch (X86_64, PPC64LE, AARCH64)" lists several Docker images:

- ecpe4s/e4s-doe-llvm:23.05
- e4s-doe-llvm-x86_64-23.05.sif
- e4s-doe-llvm-aarch64-23.05.sif
- e4s-doe-llvm-ppc64le-23.05.sif

Continuous Integration Images

These are barebones operating system images which contain only essential build tools and python packages needed by Spack.

These images are intended to be used in continuous integration workflows where Spack is first cloned and then used to build and test software.

X86_64	PPC64LE	AARCH64
ecpe4s/ubuntu22.04-runner-x86_64 GitHub	ecpe4s/ubuntu22.04-runner-ppc64le GitHub	ecpe4s/ubuntu22.04-runner-aarch64 GitHub
ecpe4s/ubuntu20.04-runner-x86_64 GitHub	ecpe4s/ubuntu20.04-runner-ppc64le GitHub	ecpe4s/ubuntu20.04-runner-aarch64 GitHub
ecpe4s/ubuntu18.04-runner-x86_64 GitHub	ecpe4s/ubuntu18.04-runner-ppc64le GitHub	ecpe4s/rhel8-runner-aarch64 GitHub
ecpe4s/rhel8-runner-x86_64 GitHub	ecpe4s/rhel8-runner-ppc64le GitHub	ecpe4s/rhel7-runner-ppc64le GitHub

E4S 23.05 Detailed Documentation for Bare-metal Installation



Extreme-scale Scientific Software Stack (E4S) version 23.05

Exascale Computing Project (ECP) Software Technologies (ST) software, Extreme-scale Scientific Software Stack (E4S) v23.05, includes a subset of ECP ST software products, and demonstrates the target approach for future delivery of the full ECP ST software stack. Also available are a number of ECP ST software products that support a Spack package, but are not yet fully interoperable. As the primary purpose of the v23.05 is demonstrating the ST software stack release approach, not all ECP ST software products were targeted for this release. Software products were targeted primarily based on existing Spack package maturity, location within the scientific software stack, and ECP SDK developer experience with the software. Each release will include additional software products, with the ultimate goal of including all ECP ST software products.

[E4S ReadTheDocs: Full Documentation.](#)

[E4S ReadTheDocs: Support Guide.](#)

[E4S Deployment Dashboard.](#)

[E4S v23.05 Release Notes PDF.](#)

[E4S v23.05 Spack Environment Notes.](#)

[E4S Manual Installation Instructions.](#)

[E4S Container Installation Instructions.](#)

[Recipes for building E4S images from scratch.](#)

Prebuilt binaries used in E4S images are stored in the E4S Build Cache.

E4S 23.05 full featured container release on Dockerhub

The screenshot shows the Docker Hub interface for the repository `ecpe4s/e4s-cuda`. The repository has 769 pulls. It displays two tags: `latest` and `23.05-cuda90`.

Tags:

- latest**: Last pushed 12 hours ago by [esw123](#).

DIGEST	OS/ARCH	SCANNED	LAST PULL	COMPRESSED SIZE
b6669ad1d694	linux/amd64	---	12 hours ago	31.05 GB
dc802e90e1a8	linux/arm64/v8	---	---	27.68 GB
2aa237bf4a04	linux/ppc64le	---	5 hours ago	23.75 GB
- 23.05-cuda90**: Last pushed 11 hours ago by [esw123](#).

DIGEST	OS/ARCH	SCANNED	LAST PULL	COMPRESSED SIZE
0c63e404042c	linux/amd64	---	---	30.48 GB

docker pull commands:

- `docker pull ecpe4s/e4s-cuda:latest`
- `docker pull ecpe4s/e4s-cuda:23.05... [link]`

Architectures:

- x86_64
- aarch64
- ppc64le

Software:

- CUDA 12.0
- NVHPC 23.3
- oneAPI 2023.1

E4S 23.05 base container release on DockerHub

The screenshot shows the Docker Hub interface for the repository `ecpe4s/e4s-base-cuda`. The 'Tags' tab is selected, displaying two entries: 'latest' and '23.05'. Each entry shows three available digests: `5ebe7f77a321`, `68b8a131065a`, and `9e19967783fa`. The 'latest' entry also features a 'Manage Repository' button and a 'Pulls 165' badge.

TAG	DIGEST	OS/ARCH	SCANNED	LAST PULL	COMPRESSED SIZE
latest	5ebe7f77a321	linux/amd64	---	---	18.7 GB
	68b8a131065a	linux/arm64/v8	---	---	15.7 GB
	9e19967783fa	linux/ppc64le	---	---	14.37 GB

TAG	DIGEST	OS/ARCH	SCANNED	LAST PULL	COMPRESSED SIZE
23.05	5ebe7f77a321	linux/amd64	---	---	18.7 GB
	68b8a131065a	linux/arm64/v8	---	---	15.7 GB
	9e19967783fa	linux/ppc64le	---	---	14.37 GB

`docker pull ecpe4s/e4s-base-cuda`

Architectures:

- `x86_64`
- `aarch64`
- `ppc64le`

Software:

- CUDA 12.0
- NVHPC 23.3
- oneAPI 2023.1

Minimal Spack base image on Dockerhub

Search for great content (e.g.,)

Explore Repositories Organizations Help ▾ Upgrade exascaleproject

ecpe4s/ubuntu18.04-spack

Manage Repository

Pulls 1M+

Container

Overview Tags

Advanced Image Management

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TAG	DIGEST	OS/ARCH	LAST PULL	COMPRESSED SIZE
latest	95fb8df7019b 47903be536c0	linux/amd64 linux/ppc64le	a day ago a month ago	382 MB 371.9 MB

TAG	DIGEST	OS/ARCH	LAST PULL	COMPRESSED SIZE
0.17.1	95fb8df7019b 47903be536c0	linux/amd64 linux/ppc64le	a day ago a month ago	382 MB 371.9 MB

- Create custom container images
- 1M+ downloads!

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

```
1: adios2           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/adios2-2.9.0-wr34ihoz2sk6iarctnuyxfhsctxwkvq4
2: alquimia        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/alquimia-1.0.10-gba5ayv4ps6ilmh5hc7krkoah3ksbvz
3: aml             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/aml-0.2.0-goqtywxw2lwciznqkc44paexlucn33v
4: amrex           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/amrex-23.05-2syxxbx3xwppc4ut7mbrmlev4ycty4ep
5: arborx          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/arborx-1.3-cvlmzk4kzetidsscc4nd4oprdyvcsp31
6: archer          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/archer-2.0.0-v15rv2ygrh4znug7rdk6jhh6t4nemk51
7: argobots        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/argobots-1.1-f6b6was4pd7d2u2fwvpxdoqffdbate2o
8: axom            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/axom-0.7.0-epaxouqc4ul2kppgnhtvnjl6fr3goik
9: bolt             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/bolt-2.0-zb4pgmqyozhf3ofvhdo26gpj2hibbc2t
10: bricks           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/bricks-r0.1-ymuymne4nwfwytzckstwl6macyp6kkk2
11: butterflypack   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/butterflypack-2.2.2-kzdbd4fvzqfjn575hojafxlen2gzwx2n
12: cabana           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/cabana-0.5.0-hit7qxj2pwnvgmd5kkaeglbnvqsdgf7n
13: caliper          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/caliper-2.9.0-cthblsk6ogn43qnufgbxczjvcrawqzab
14: chai              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/chai-2022.03.0-6gi2vpoxdv25sat6cdubunutp24i5sk
15: charliecloud     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/charliecloud-0.32-bmfm6chwp4g6mgnhjgcrh356gusbrzes
16: conduit           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/conduit-0.8.7-mfdfactk6xuqmyfqdwtiwszivxtrwho2
17: darshan-runtime   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/darshan-runtime-3.4.2-nfblomjg6ejmigmhmh3dux6v7iojxnpf
18: datatransferkit   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/datatransferkit-3.1-rc3-enk32naiegjk42bex5mvuk3y3mefdef6
19: dyninst           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/dyninst-12.3.0-k3myl13szf7v3e2jcqoqwglwyig44440
20: ecp-data-vis-sdk  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/ecp-data-vis-sdk-1.0-s4ya3uqeb2ecyextvb42yprv5zy512qk
21: exaworks          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/exaworks-0.1.0-lxqgwv3cswo6pqlbycqcacwatuhf6iln2
22: faodel            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/faodel-1.2108.1-gxc7m6ajdyb2jupcvx5qrvppe4jlcqt6
23: flecsi             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/flecsi-2.1.0-msfszzew3v1kejgw43xuakoftuxrqnhm
24: flit               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/flit-2.1.0-3ptdgvs22o5ng3euhs6eci5nhaq4jctb
25: flux-sched         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/flux-sched-0.27.0-snqo4rzjtvrjmjkdv1kcxuw4vyt4ypie
26: fortrilinos       /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/fortrilinos-2.2.0-dlxz63fh2tljmw2rje5srgfdbx64adv
27: gasnet             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/gasnet-2023.3.0-aupps4j5ilwaosagcfyhwe4anrv6uknz
28: ginkgo             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/ginkgo-1.5.0-4gsh6pioh6qab3d67j7wtfk5qbfz7lnb
29: globalarrays       /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/globalarrays-5.8.2-nzag4ztsjddm67gdurpwfirprgb3rkz
30: gotcha            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/gotcha-1.0.4-3rwc6g46qxsit3vswvzi6icv67li57wi
31: gptune             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/gptune-4.0.0-dyxc7tkwnenjgl2edjqhvyg7eld643xx
32: h5bench            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/h5bench-1.3-34odudjnljbfxl7a44e32gwmuo6wn6
33: hdf5               /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hdf5-1.14.1-2-naucnnhf57lxmb3dcfls42m4hwdkeg
34: hdf5-vol-async    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hdf5-vol-async-1.5-nwt25ouh2i5vtwvwsaijpnlgowag7ku
35: heffte             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/heffte-2.3.0-rib3o742d45ng7ukq4qq4vh3lst5dcc
36: hpctoolkit         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hpctoolkit-2023.03.01-sbctldelht4ntvzahpd6q5rj23fs25ar
37: hpx                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hpx-1.9.0-374gqtjzm47p6ea3xsuahpagrq2ogwvy
```

GPU runtimes

- AMD (ROCm)
 - 5.4.3
- NVIDIA (CUDA)
 - 12.0
- NVHPC
 - 23.3
- Intel oneAPI
 - 2023.1

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

```
38: hypre          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/hypre-2.28.0-mozopbseodwvy7r7xklin7jnsuh5s7yi
39: kokkos         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/kokkos-4.0.01-tgv5irdj4skczex6c2rvfty274vwuyk7
40: kokkos-kernels /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/kokkos-kernels-3.7.00-2whrnzbzjyni42dytgehkubhke2zgaj5u
41: lammps         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/lammps-20220623.3-cs07xzua5jyld3n6seug2cexxbfnpc
42: lbann          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/lbann-0.102-hf442maq5bbf5nnr4fqlyhxakdndm23
43: legion         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/legion-23.03.0-ksb4tvrgo6sfcfjiicnszr5appehqxn
44: libnrm          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/libnrm-0.1.0-h5ggd2cgai43porp2s2berqrnski2j6c
45: libpressio      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/libpressio-0.95.1-h54uerfc7gttwaokywa5cwntylnklen
46: libquo          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/libquo-1.3.1-e6ulmqqbtppfcjjypvdqrbpkb4brzkgpf
47: loki            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/loki-0.1.7-a4etdi45t2fbweddhjur5t5p56tiu2ca
48: magma           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/magma-2.7.1-dapbrjq25hsqg2cztteusqkismcpnbu
49: mercury         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mercury-2.2.0-iap2sil3mo6g6aljjvg34vtnxh2sglof
50: metall          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/metall-0.25-2xic6pnhpbohlaknalu2qpjnkw4bkvemi
51: mfem             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mfem-4.5.2-2f3kkx62ogbv6bw6sdcybkawubvcyg2n
52: mgard            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mgard-2023-03-31-4maqkp6n3e2xshtu2y3tnve5ch7jdb43
53: mpark-variant   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mpark-variant-1.4.0-6f25xadnfdzmpweuit4yvp134katnt4s
54: mpich            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mpich-4.1.1-4cbi7qhusseuuuh6bccs6lokwgwh6s3itl
55: mpifileutils    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/mpifileutils-0.11.1-tuy2ycdld67kuv3ppp3diqy4o2bmvhok
56: nccmp            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/nccmp-1.9.0.1-qmoiwfcpcnknojwspffuvgrw3n3mphzb
57: nco              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/nco-5.1.5-wwe7fm6df3zhc6d6qckvbcyx05dqawpf
58: netlib-scalapack /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/netlib-scalapack-2.2.0-3zhwrwxw6f2ohmbnpeec34ksb4h7svs65
59: nrm              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/nrm-0.1.0-47ydygda2r3njdpkxyj4wrfpgfdt2zzl
60: omega-h          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/omega-h-9.34.13-m2wmv5mmoxpoy622e6tbk7jzey2ufdvi
61: openfoam         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/openfoam-2206-zftm6f5mhvnxben2nzeqantgg41115d
62: openmpi          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/openmpi-4.1.5-ed5u3cdcbks6dcve6ftb336v5uhwj4by
63: openpmd-api      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/openpmd-api-0.15.1-uzamcamznyauzeem5j72gx2ascjpmju
64: papi             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/papi-6.0.0.1-j7dmzprteci2ifgjyk7rmkb3gydfk7
65: papyrus          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/papyrus-1.0.2-kuro7vtc7kh6fot5xmah6awfwgi5chm2
66: parallel-netcdf  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/parallel-netcdf-1.12.3-mldyjp1nyhw7qiljd327wda7exvpcvtf
67: paraview         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/paraview-5.11.1-x4aqroj67nfq7gpk7w3pw1xhpfhjyrno
68: parsec           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/parsec-3.0.2209-wvchc4psqj3uotxff24xyc24xqwprzdg
69: pdt              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/pdt-3.25.1-lx67nrs24pkbnmnj7am3t75swtowtfc5
70: petsc             /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/petsc-3.19.1-bonrfxf3arijw7ulzcc4xqyd3ceik63
71: phist            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/phist-1.11.2-qz36u6cuvuupj3gj5v7hmm4sdbrzdljv
72: plasma            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/plasma-22.9.29-2qwdll5vjs74mymdiugdhd32iiibm2v3
73: plumed            /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/plumed-2.8.2-oq5243vtzgcl6ex6zookbxqgaeofkzxh
74: precice           /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/precice-2.5.0-b7eniikqkee5veujb5xnuukfnz7wiwm2
75: pumi              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/pumi-2.2.7-57q5bidz4mzlldkfpwaoebwqhvxgps3
76: py-cinemasci     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-cinemasci-1.3-5tnt5kqnzrin5j5dmse6gdq77mteiiyz
77: py-jupyterhub     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-jupyterhub-1.4.1-awj3cwf2d3irsm24dmr37gbhd5xniju
```

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

```
78: py-libensemble          /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-libensemble-0.9.3-3d3tb25q2s3pa7uqscw7wlpz5rqmapa5
79: py-parsl                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-parsl-1.2.0-f7tbq4nmfecdu3nh5fw5zyddwj77zis5
80: py-radical-saga         /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/py-radical-saga-1.20.0-wffrzdrbdd4cpst42gtqonbjni7m5pqe
81: qthreads                 /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/qthreads-1.16-r4ai62sxg3os22n2xfntik7xbvijgst
82: quantum-espresso        /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/quantum-espresso-7.1-2hw2nzkjwtc4xi3hopd2oesn2ikmcbe5e
83: raja                     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/raja-2022.10.4-fffdno3g4c4wm6f2d5rbrehnjgv3ytw4
84: rempi                    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/rempi-1.1.0-bsppoijvc4e4bf7re6u36f75dwo6wnuv
85: scr                      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/scr-3.0.1-4twvdurdxeiv3ipees4y3nk64pmvtrbl
86: slate                   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/slate-2022.07.00-5xkozs6eabgn45t7uttghekb4lanbwk
87: slepc                    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/slepc-3.19.0-vqy6iy24c5wkpfdsejjgql2bx32vjfbq
88: stc                      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/stc-0.9.0-ocmzaflc6rls12dop3poqjbnlyyk7vs2
89: strumpack                /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/strumpack-7.1.1-7feghsapq3qe7stmbfodzcytm7tm41t
90: sundials                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/sundials-6.5.1-f23kbyw7bsam3cpka2mshks36d236yr3
91: superlu-dist              /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/superlu-dist-8.1.2-ibmrgavx57kcy3fc7wdbcneuhk6axgxv
92: swig                     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/swig-4.1.1-cm45hunq4nk7x4ml756gur5wlakaidha
93: sz                       /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/sz-2.1.12.2-bbc3ru73fa67nmr7j4jbv53f6ji5e4xe
94: tasmanian                 /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/tasmanian-7.9-4skuz4cxghjjhlhad776xbixk3jvienk
95: tau                      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/tau-2.32-qxwqmtdsjoaxnrqed5mvlolax5ip27z
96: trilinos                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/trilinos-14.0.0-alm3rf45sel6ahz7ecfs5odq3eziqcah
97: turbine                   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/turbine-1.3.0-sla74mxwn5michnj12aqmrf3gbphfqco
98: umap                     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/umap-2.1.0-de4ftza63dmgjgvv5uhceeuunn2dvkqjg
99: umpire                   /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/umpire-2022.03.1-sprrgtmz5vvvsxxhwngyu7dxbghmdpj
100: unifyfs                  /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/unifyfs-1.0.1-q4bmwojbzaa2npnbcp2q4f1ba5u5oshd
101: upcxx                    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/upcxx-2023.3.0-ideeur7hshezm4ahe2col65tiryjfng
102: variorum                 /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/variorum-0.6.0-h3oif6j2nvqg4qzxjx773bjnef5owexx
103: veloc                    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/veloc-1.6-5g5n244a6mo3i3dlcjxxlq7e315tv426
104: visit                     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/visit-3.3.3-nt4yv7ecffq2onv5xzngja42uzt6tqlb
105: vtk-m                    /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/vtk-m-2.0.0-7rjk76kmxbf4bmyvepvfj5qsclkfz3uw
106: wannier90                 /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/wannier90-3.1.0-dbfs2qlo2yvdxj tcb5mn5d2x1nvplnzc
107: warpx                     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/warpx-23.03-f2nbmfppld7xntj2lpwy552upvwj6bq2
108: xyce                     /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/xyce-7.6.0-vt3rht5enpk1qck7m7d2z7ji64memqzw
109: zfp                      /spack/opt/spack/linux-ubuntu20.04-x86_64/gcc-11.1.0/zfp-1.0.0-ibmowr23apbprdgjrrp4eyblmibwd2w
```

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 23.05 adds support for NVIDIA A100 (sm80), V100 (sm70), and H100 (sm90) GPUs

E4S Support for AI/ML frameworks with V100, 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__
'2.12.0'
>>> import torch
>>> torch.__version__
'2.0.0'
>>> torch.cuda.get_device_name(torch.cuda.current_device())
'NVIDIA H100 PCIe'
>>> █
```

E4S 23.05 supports NVIDIA H100 GPUs with TensorFlow 2.12.0 and PyTorch 2.0.0

E4S 23.05 container with ROCm: Top level specs

```
[Singularity> spack find -x
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 --
adios@1.13.1           darshan-util@3.4.2      heffte@2.3.0          mpark-variant@1.4.0    py-h5py@3.7.0        sz@2.1.12.2
adios2@2.9.0            datatransferkit@3.1-rc3  heffte@2.3.0          mpich@4.1.1         py-jupyterhub@1.4.1  sz3@3.1.7
alquimia@1.0.10        dyninst@12.3.0       hpctoolkit@2023.03.01 mpfileutils@0.11.1   py-libensemble@0.9.3 tasmanian@7.9
aml@0.2.0               ecp-data-vis-sdk@1.0     hpx@1.9.0             nccmp@1.9.0.1       py-petsc4py@3.19.1  tasmanian@7.9
amrex@23.05            ecp-data-vis-sdk@1.0     hpx@1.9.0             nco@5.1.5          py-warpx@23.03      tau@2.32
amrex@23.05            exaworks@0.1.0       hpx@1.9.0             netlib-scalapack@2.2.0 py-warpx@23.03      tau@2.32
arborx@1.3              faodel@1.2108.1      hypre@2.28.0          nrm@0.1.0          py-warpx@23.03      trilinos@13.0.1
arborx@1.3              flecsi@2.1.0        hypre@2.28.0          omega-h@9.34.13    qthreads@1.16       trilinos@14.0.0
archer@2.0.0            flit@2.1.0         kokkos@4.0.01        openfoam@2206       quantum-espresso@7.1 turbine@1.3.0
argobots@1.1            flux-core@0.49.0     kokkos-kernels@3.7.00 lammps@20220623.3   raja@2022.10.4      umap@2.1.0
ascent@0.9.1            fortrilinos@2.2.0    lammps@20220623.3   kokkos@4.0.01       raja@2022.10.4      umpire@2022.03.1
axom@0.7.0              gasnet@2023.3.0     lbann@0.102          openmpi@4.1.5       rempi@1.1.0         umpire@2022.03.1
bolt@2.0                gasnet@2023.3.0     legion@23.03.0      openpmd-api@0.15.1 scr@3.0.1
boost@1.79.0             ginkgo@1.5.0        libcatalyst@2.0.0-rc3 parallel-netcdf@1.12.3 slate@2022.07.00
bricks@r0.1              ginkgo@1.5.0        libnrm@0.1.0         paraview@5.11.1     slate@2022.07.00
butterflypack@2.2.2     globalarrays@5.8.2   libpressio@0.95.1    paraview@5.11.1     slepc@3.19.0
cabana@0.5.0             gmp@6.2.1          libquo@1.3.1         parsec@3.0.2209    slepc@3.19.0
cabana@0.5.0             gotcha@1.0.4       libunwind@1.6.2     pdt@3.25.1          stc@0.9.0
cabana@0.5.0             gptune@4.0.0       loki@0.1.7          petsc@3.19.1       strumpack@7.1.1
caliper@2.9.0            h5bench@1.3        magma@2.7.1          petsc@3.19.1       strumpack@7.1.1
caliper@2.9.0            hdf5@1.12.2       mercury@2.2.0       phist@1.11.2       sundials@6.5.1
chai@2022.03.0            hdf5@1.14.1-2     metall@0.25         plasma@22.9.29    sundials@6.5.1
chai@2022.03.0            hdf5-vol-async@1.5  mfem@4.5.2          plumed@2.8.2       superlu@5.3.0
charliecloud@0.32         hdf5-vol-cache@v1.1  mfem@4.5.2          precice@2.5.0      superlu-dist@8.1.2
conduit@0.8.7             hdf5-vol-log@1.4.0   mgard@2023-03-31    pumi@2.2.7         superlu-dist@8.1.2
darshan-runtime@3.4.2     hdf5-vol-log@1.4.0   py-cinemasci@1.3    py-warpx@23.03    swig@4.0.2-fortran
==> 153 installed packages
Singularity>
```

E4S 23.05 : All Spack packages including dependencies!

726 packages!



E4S 23.05 Intel oneAPI 2023.1: Packages built with Intel compilers

```
Singularity> spack find -x
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 -----
papi@6.0.0.1

-- linux-ubuntu20.04-x86_64 / oneapi@2023.1.0 -----
adios@1.13.1          cabana@0.5.0           gmp@6.2.1
aml@0.2.0              cabana@0.5.0           gotcha@1.0.4
aml@0.2.0              caliper@2.9.0         h5bench@1.3
amrex@22.12             chai@2022.03.0       hdf5-vol-async@1.5
amrex@23.05             charliecloud@0.32    hdf5-vol-log@1.4.0
arborx@1.3               conduit@0.8.7        heffte@2.3.0
arborx@1.3               datatransferkit@3.1-rc3 hpx@1.9.0
archer@2.0.0              exaworks@0.1.0      hypre@2.28.0
argobots@1.1              flecsi@2.2.0        kokkos@4.0.01
axom@0.7.0                flit@2.1.0         kokkos@4.0.01
bolt@2.0                 flux-core@0.49.0     kokkos-kernels@3.7.00
boost@1.82.0              fortrilinos@2.2.0   kokkos-kernels@3.7.00
bricks@r.0.1              gasnet@2023.3.0    lammps@20220623.3
butterflypack@2.2.2       globalarrays@5.8.2   lbann@0.102
                                         legion@23.03.0
                                         libnrm@0.1.0
                                         libquo@1.3.1
                                         libunwind@1.6.2
                                         loki@0.1.7
                                         mercury@2.2.0
                                         metall@0.25
                                         mfem@4.5.2
                                         mgard@2023-03-31
                                         mpark-variant@1.4.0
                                         mpich@4.1.1
                                         mpifileutils@0.11.1
                                         nccmp@1.9.0.1
                                         nco@5.1.5
                                         netlib-scalapack@2.2.0
                                         omega-h@9.34.13
                                         openmpi@4.1.5
                                         openpmd-api@0.15.1
                                         papyrus@1.0.2
                                         parsec@3.0.2209
                                         pdt@3.25.1
                                         petsc@3.19.1
                                         phist@1.11.2
                                         plasma@22.9.29
                                         plumed@2.8.2
                                         precice@2.5.0
                                         pumi@2.2.7
                                         py-h5py@3.7.0
                                         strumpack@7.1.1
                                         sundials@6.5.1
                                         superlu@5.3.0
                                         superlu-dist@8.1.2
                                         swig@4.0.2-fortran
                                         sz3@3.1.7
                                         tasmanian@7.9
                                         tau@2.32
                                         tau@2.32
                                         raja@2022.10.4
                                         rempi@1.1.0
                                         slate@2022.07.00
                                         slepc@3.19.0
                                         stc@0.9.0
                                         strumpack@7.1.1
                                         sundials@6.5.1
                                         superlu@5.3.0
                                         superlu-dist@8.1.2
                                         swig@4.0.2-fortran
```

Use of Intel oneAPI BaseKit and HPCToolkit is subject to acceptance of Intel EULA by the user

E4S 23.05 Intel oneAPI 2023.1: Packages built with Intel compilers

```
Singularity> module avail
```

----- /opt/intel/oneapi/modulefiles -----						
advisor/latest		compiler32/latest	dnnl-cpu-tbb/latest	inspector/latest		mpi/latest
advisor/2023.1.0	(D)	compiler32/2023.1.0	dnnl-cpu-tbb/2023.1.0	inspector/2023.1.0	(D)	mpi/2021.9.0 (D)
ccl/latest		dal/latest	dnnl/latest	intel_ipp_intel64/latest		oclpga/latest
ccl/2021.9.0	(D)	dal/2023.1.0	dnnl/2023.1.0	intel_ipp_intel64/2021.8.0	(D)	oclpga/2023.1.0 (D)
clck/latest		debugger/latest	dpl/latest	intel_ipppc_intel64/latest		tbb/latest
clck/2021.7.3	(D)	debugger/2023.1.0	dpl/2022.1.0	intel_ipppc_intel64/2021.7.0	(D)	tbb/2021.9.0 (D)
compiler-rt/latest		dev-utilities/latest	icc/latest	itac/latest		vtune/latest
compiler-rt/2023.1.0	(D)	dev-utilities/2021.9.0	icc/2023.1.0	itac/2021.9.0	(D)	vtune/2023.1.0 (D)
compiler-rt32/latest		dnnl-cpu-gomp/latest	icc32/latest	mk1/latest		
compiler-rt32/2023.1.0	(D)	dnnl-cpu-gomp/2023.1.0	icc32/2023.1.0	mk1/2023.1.0	(D)	
compiler/latest		dnnl-cpu-iomp/latest	init_opencl/latest	mk132/latest		
compiler/2023.1.0	(D)	dnnl-cpu-iomp/2023.1.0	init_opencl/2023.1.0	mk132/2023.1.0	(D)	
----- /spack/share/spack/lmod/linux-ubuntu20.04-x86_64/mpich/4.1.1/Core -----						
adios/1.13.1		datatransferkit/3.1-rc3	libnrm/0.1.0	petsc/3.19.1		strumpack/7.1.1-openmp
amrex/22.12-sycl		exaworks/0.1.0	libquo/1.3.1	phist/1.11.2-openmp		sundials/6.5.1
amrex/23.05	(D)	flecsi/2.2.0	mercury/2.2.0	plumed/2.8.2		superlu-dist/8.1.2
arborx/1.3-sycl		fortrilinos/2.2.0	metall/0.25	precice/2.5.0		tasmanian/7.9
arborx/1.3	(D)	globalarrays/5.8.2	mfem/4.5.2	pumi/2.2.7		tau/2.32-level-zero (L)
axom/0.7.0-openmp		h5bench/1.3	mpfileutils/0.11.1	py-h5py/3.7.0		tau/2.32 (D)
boost/1.82.0		hdf5-vol-async/1.5	nccmp/1.9.0.1	py-libensemble/0.9.3		trilinos/13.0.1
bricks/r0.1		hdf5-vol-log/1.4.0	nco/5.1.5	py-petsc4py/3.19.1		turbine/1.3.0
butterflypack/2.2.2-openmp		heffte/2.3.0	netlib-scalapack/2.2.0	quantum-espresso/7.1-openmp		wannier90/3.1.0
cabana/0.5.0-sycl		hpx/1.9.0	omega-h/9.34.13	rempi/1.1.0		
cabana/0.5.0	(D)	hypre/2.28.0	openpmd-api/0.15.1	slate/2022.07.00-openmp		
caliper/2.9.0		lammps/20220623.3-openmp	papyrus/1.0.2	slepc/3.19.0		
conduit/0.8.7		lbann/0.102	parsec/3.0.2209	stc/0.9.0		
----- /spack/share/spack/lmod/linux-ubuntu20.04-x86_64/Core -----						
aml/0.2.0-level-zero		flit/2.1.0	kokkos/4.0.01-openmp	mpich/4.1.1	(L)	superlu/5.3.0
aml/0.2.0	(D)	flux-core/0.49.0	kokkos/4.0.01-sycl-openmp	openmpi/4.1.5		swig/4.0.2-fortran
archer/2.0.0		gasnet/2023.3.0	legion/23.03.0	papi/6.0.0.1	(L)	sz3/3.1.7
argobots/1.1		gmp/6.2.1	libunwind/1.6.2	pdt/3.25.1		umap/2.1.0
bolt/2.0		gotcha/1.0.4	loki/0.1.7	plasma/22.9.29		umpire/2022.03.1
chai/2022.03.0		kokkos-kernels/3.7.00-openmp	mgard/2023-03-31-openmp	qthreads/1.16		variorum/0.6.0
charliecloud/0.32		kokkos-kernels/3.7.00-sycl	(D) mpark-variant/1.4.0	raja/2022.10.4-openmp		

Use of Intel oneAPI BaseKit and HPCToolkit is subject to acceptance of Intel EULA by the user

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

```
Singularity> spack find -x
-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 --
adios@1.13.1          chai@2022.03.0      gptune@4.0.0      libcatalyst@2.0.0-rc3    openpmd-api@0.15.1    py-warpx@23.03      tasmanian@7.9
adios2@2.9.0           charliecloud@0.32   h5bench@1.3      libnrm@0.1.0          papi@6.0.0.1        qthreads@1.16       tasmanian@7.9
alquimia@1.0.10       conduit@0.8.7      hdf5@1.12.2     libpressio@0.95.1     papyrus@1.0.2       quantum-espresso@7.1 tau@2.32
aml@0.2.0              darshan-runtime@3.4.2  hdf5@1.14.1-2   libquo@1.3.1         parallel-netcdf@1.12.3 raja@2022.10.4      tau@2.32
amrex@23.05            darshan-util@3.4.2   hdf5-vol-async@1.5 libunwind@1.6.2       paraview@5.11.1      raja@2022.10.4      trilinos@13.0.1
amrex@23.05            datatransferkit@3.1-rc3 hdf5-vol-cache@v1.1 loki@0.1.7          paraview@5.11.1      rempi@1.1.0        trilinos@14.0.0
arbortex@1.3             dyninst@12.3.0     hdf5-vol-log@1.4.0 magma@2.7.1         parsec@3.0.2209    scr@3.0.1         turbine@1.3.0
arbortex@1.3             ecp-data-vis-sdk@1.0   hdf5-vol-log@1.4.0 mercury@2.2.0       pdt@3.25.1        slate@2022.07.00   umap@2.1.0
archer@2.0.0            ecp-data-vis-sdk@1.0   heffte@2.3.0     metall@0.25        petsc@3.19.1       slate@2022.07.00   umpire@2022.03.1
argobots@1.1            exaworks@0.1.0     heffte@2.3.0     mfem@4.5.2          petsc@3.19.1       slepc@3.19.0       umpire@2022.03.1
ascent@0.9.1            faodel@1.2108.1   hpctoolkit@2023.03.01 mgard@2023-03-31    phist@1.11.2       slepc@3.19.0       unifyfs@1.0.1
axom@0.7.0              flecsi@2.1.0      hpctoolkit@2023.03.01 mpark-variant@1.4.0 plasma@22.9.29    stc@0.9.0         upcxx@2023.3.0
bolt@2.0                flit@2.1.0       hpx@1.9.0        mpich@4.1.1        plumed@2.8.2       strumpack@7.1.1    upcxx@2023.3.0
boost@1.79.0            flux-core@0.49.0   hpx@1.9.0        mpifileutils@0.11.1 precice@2.5.0       strumpack@7.1.1    variorum@0.6.0
bricks@r0.1              fortrilinos@2.2.0   hypre@2.28.0     nccmp@1.9.0.1      pumi@2.2.7         sundials@6.5.1     veloc@1.6
butterflypack@2.2.2     gasnet@2023.3.0   hypre@2.28.0     nco@5.1.5          py-cinemasci@1.3   sundials@6.5.1     visit@03.3.3
cabana@0.5.0            gasnet@2023.3.0   kokkos@4.0.01    netlib-scalapack@2.2.0 py-h5py@3.7.0       superlu@5.3.0     vtk-m@1.9.0
cabana@0.5.0            ginkgo@1.5.0      kokkos@4.0.01    nrm@0.1.0          py-jupyterhub@1.4.1 superlu-dist@8.1.2  vtk-m@2.0.0
cabana@0.5.0            ginkgo@1.5.0      kokkos-kernels@3.7.00 omega-h@9.34.13    py-libensembl@0.9.3 superlu-dist@8.1.2  wannier90@3.1.0
caliper@2.9.0           globalarrays@5.8.2   lammps@20220623.3 lbann@0.102        openfoam@2206      py-petsc4py@3.19.1 swig@4.0.2-fortran xyce@7.6.0
caliper@2.9.0           gmp@6.2.1        legion@23.03.0   legate@0.1.5       openmpi@4.1.5       py-warpx@23.03     sz@2.1.12.2
chai@2022.03.0          gotcha@1.0.4      legate@0.1.5       py-warpx@23.03     py-warpx@23.03     sz3@3.1.7
==> 153 installed packages
```

E4S 23.05 supports AMD MI100 (gfx908) as well as MI250X (gfx90a) GPUs

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

Singularity> module avail

/spack/share/spack/lmod/linux-ubuntu20.04-x86_64/mpich/4.1.1/Core					
adios/1.13.1	ginkgo/1.5.0-openmp	(D)	nccmp/1.9.0.1	slate/2022.07.00-openmp	(D)
adios2/2.9.0	globalarrays/5.8.2		nco/5.1.5	slepc/3.19.0-gfx908	
alquimia/1.0.10	gptune/4.0.0		netlib-scalapack/2.2.0	slepc/3.19.0	(D)
amrex/23.05-gfx908	h5bench/1.3		omega-h/9.34.13	stc/0.9.0	
amrex/23.05	(D) hdf5-vol-async/1.5		openfoam/2206	strumpack/7.1.1-gfx908-openmp	
arbortex/1.3-gfx908	hdf5-vol-cache/v1.1		openpmd-api/0.15.1	strumpack/7.1.1-openmp	(D)
arbortex/1.3	(D) hdf5-vol-log/1.4.0		papyrus/1.0.2	sundials/6.5.1-gfx908	
ascent/0.9.1-openmp	hdf5/1.12.2		parallel-netcdf/1.12.3	sundials/6.5.1	(D)
axom/0.7.0-openmp	hdf5/1.14.1-2	(D)	paraview/5.11.1-gfx908	superlu-dist/8.1.2-gfx908	
boost/1.79.0	heffte/2.3.0-gfx908		paraview/5.11.1	superlu-dist/8.1.2	(D)
bricks/r0.1	heffte/2.3.0	(D)	parsec/3.0.2209	sz/2.1.12.2	
butterflypack/2.2.2-openmp	hpctoolkit/2023.03.01-rocm		petsc/3.19.1-gfx908	tasmanian/7.9-gfx908	
cabana/0.5.0-rocm-gfx90a	hpctoolkit/2023.03.01	(D)	petsc/3.19.1	tasmanian/7.9	(D)
cabana/0.5.0-rocm-gfx908	hpx/1.9.0-gfx908		phist/1.11.2-openmp	tau/2.32-rocm	(L)
cabana/0.5.0	(D) hpx/1.9.0	(D)	plumed/2.8.2	tau/2.32	(D)
caliper/2.9.0-gfx908	hypre/2.28.0-gfx908		precice/2.5.0	trilinos/13.0.1	
caliper/2.9.0	(D) hypre/2.28.0	(D)	pumi/2.2.7	trilinos/14.0.0-gfx908	(D)
conduit/0.8.7	lammps/20220623.3-openmp		py-cinemasci/1.3	turbine/1.3.0	
darshan-runtime/3.4.2	lbann/0.102		py-h5py/3.7.0	unifyfs/1.0.1	
datatransferkit/3.1-rc3	libcatalyst/2.0.0-rc3		py-libensemble/0.9.3	upcxx/2023.3.0-gfx908	
dyninst/12.3.0-openmp	libnrm/0.1.0		py-petsc4py/3.19.1	upcxx/2023.3.0	(D)
ecp-data-vis-sdk/1.0-gfx908	libpressio/0.95.1-openmp		py-warpix/23.03-dims2	veloc/1.6	
ecp-data-vis-sdk/1.0	(D) libquo/1.3.1		py-warpix/23.03-dims3	visit/3.3.3	
exaworks/0.1.0	mercury/2.2.0		py-warpix/23.03-dimsRZ	(D) vtk-m/1.9.0-openmp	
faodel/1.2108.1	metall/0.25		quantum-espresso/7.1-openmp	vtk-m/2.0.0-gfx908	(D)
flecsi/2.1.0	mfem/4.5.2-gfx908		rempi/1.1.0	wannier90/3.1.0	
fortrilinos/2.2.0	mfem/4.5.2	(D)	scr/3.0.1	xyce/7.6.0	
ginkgo/1.5.0-gfx908-openmp	mpfileutils/0.11.1		slate/2022.07.00-gfx908-openmp		
/spack/share/spack/lmod/linux-ubuntu20.04-x86_64/Core					
aml/0.2.0	flux-core/0.49.0		libunwind/1.6.2	(L) pdt/3.25.1	(L) umap/2.1.0
archer/2.0.0	gasnet/2023.3.0-gfx908		loki/0.1.7	plasma/22.9.29	umpire/2022.03.1-gfx908
argobots/1.1	gasnet/2023.3.0	(D)	magma/2.7.1-gfx908	py-jupyterhub/1.4.1	umpire/2022.03.1
bolt/2.0	gmp/6.2.1		mgard/2023-03-31-openmp	qthreads/1.16	(D) variorum/0.6.0
chai/2022.03.0-gfx908	gotcha/1.0.4		mpark-variant/1.4.0	raja/2022.10.4-gfx908	zfp/0.5.5
chai/2022.03.0	(D) kokkos-kernels/3.7.00-openmp		mpich/4.1.1	(L) raja/2022.10.4-openmp	(D)
charliecloud/0.32	kokkos/4.0.01-gfx908		nrm/0.1.0	superlu/5.3.0	
darshan-util/3.4.2	kokkos/4.0.01-openmp	(D)	openmpi/4.1.5	swig/4.0.2-fortran	
flit/2.1.0	legion/23.03.0		papi/6.0.0.1	(L) sz3/3.1.7	

E4S 23.05 DOE LLVM Release: x86_64, ppc64le, and aarch64

```
Singularity> spack find -x
-- linux-ubuntu20.04-x86_64 / clang@16.0.2 -----
adios@1.13.1 cabana@0.5.0 globalarrays@5.8.2 heffte@2.3.0 mfem@4.5.2 parsec@3.0.2209 sundials@6.5.1 umpire@2022.03.1
aml@0.2.0 chai@2022.03.0 gmp@6.2.1 hypre@2.28.0 mpark-variant@1.4.0 pdt@3.25.1 superlu@5.3.0 upcxx@2023.3.0
amrex@23.05 charliecloud@0.32 gotcha@1.0.4 legion@23.03.0 mpich@4.1.1 plumed@2.8.2 swig@4.0.2-fortran
arbortex@1.3 flit@2.1.0 h5bench@1.3 libnrm@0.1.0 nccmp@1.9.0.1 pumi@2.2.7 tasmanian@7.9
argobots@1.1 flux-core@0.49.0 hdf5-vol-async@1.5 libquo@1.3.1 nco@5.1.5 qthreads@1.16 turbine@1.3.0
bolt@2.0 gasnet@2023.3.0 hdf5-vol-log@1.4.0 libunwind@1.6.2 papyrus@1.0.2 stc@0.9.0 umap@2.1.0

-- linux-ubuntu20.04-x86_64 / gcc@11.1.0 -----
cmake@3.26.3 llvm-doe@16.0.2

|Singularity> spack find -x
-- linux-ubuntu20.04-ppc64le / clang@16.0.2 -----
adios@1.13.1 cabana@0.5.0 globalarrays@5.8.2 heffte@2.3.0 mfem@4.5.2 parsec@3.0.2209 sundials@6.5.1 umpire@2022.03.1
aml@0.2.0 chai@2022.03.0 gmp@6.2.1 hypre@2.28.0 mpark-variant@1.4.0 pdt@3.25.1 superlu@5.3.0 upcxx@2023.3.0
amrex@23.05 charliecloud@0.32 gotcha@1.0.4 legion@23.03.0 mpich@4.1.1 plumed@2.8.2 swig@4.0.2-fortran
arbortex@1.3 flit@2.1.0 h5bench@1.3 libnrm@0.1.0 nccmp@1.9.0.1 pumi@2.2.7 tasmanian@7.9
argobots@1.1 flux-core@0.49.0 hdf5-vol-async@1.5 libquo@1.3.1 nco@5.1.5 qthreads@1.16 turbine@1.3.0
bolt@2.0 gasnet@2023.3.0 hdf5-vol-log@1.4.0 libunwind@1.6.2 papyrus@1.0.2 stc@0.9.0 umap@2.1.0

-- linux-ubuntu20.04-ppc64le / gcc@11.1.0 -----
cmake@3.26.3 llvm-doe@16.0.2

|Singularity> spack find -x
-- linux-ubuntu20.04-aarch64 / clang@16.0.2 -----
adios@1.13.1 cabana@0.5.0 globalarrays@5.8.2 heffte@2.3.0 mfem@4.5.2 parsec@3.0.2209 sundials@6.5.1 umpire@2022.03.1
aml@0.2.0 chai@2022.03.0 gmp@6.2.1 hypre@2.28.0 mpark-variant@1.4.0 pdt@3.25.1 superlu@5.3.0 upcxx@2023.3.0
amrex@23.05 charliecloud@0.32 gotcha@1.0.4 legion@23.03.0 mpich@4.1.1 plumed@2.8.2 swig@4.0.2-fortran
arbortex@1.3 flit@2.1.0 h5bench@1.3 libnrm@0.1.0 nccmp@1.9.0.1 pumi@2.2.7 tasmanian@7.9
argobots@1.1 flux-core@0.49.0 hdf5-vol-async@1.5 libquo@1.3.1 nco@5.1.5 qthreads@1.16 turbine@1.3.0
bolt@2.0 gasnet@2023.3.0 hdf5-vol-log@1.4.0 libunwind@1.6.2 papyrus@1.0.2 stc@0.9.0 umap@2.1.0

-- linux-ubuntu20.04-aarch64 / gcc@11.1.0 -----
cmake@3.26.3 llvm-doe@16.0.2
```

E4S Build Cache for Spack 0.19.1 hosted at U. Oregon

The screenshot shows a web browser window with the URL <https://oaciss.uoregon.edu/e4s/inventory.html> in the address bar. The page title is "E4S Build Cache for Spack 0.20.0". Below the title, there is a section titled "To add this mirror to your Spack:" with two command-line instructions:

```
$> spack mirror add E4S https://cache.e4s.io  
$> spack buildcache keys -it
```

Below these instructions, a box highlights the text "102,289 total packages". Further down, it says "Last updated 2023-05-31 16:38 PST". There are two sets of filter buttons:

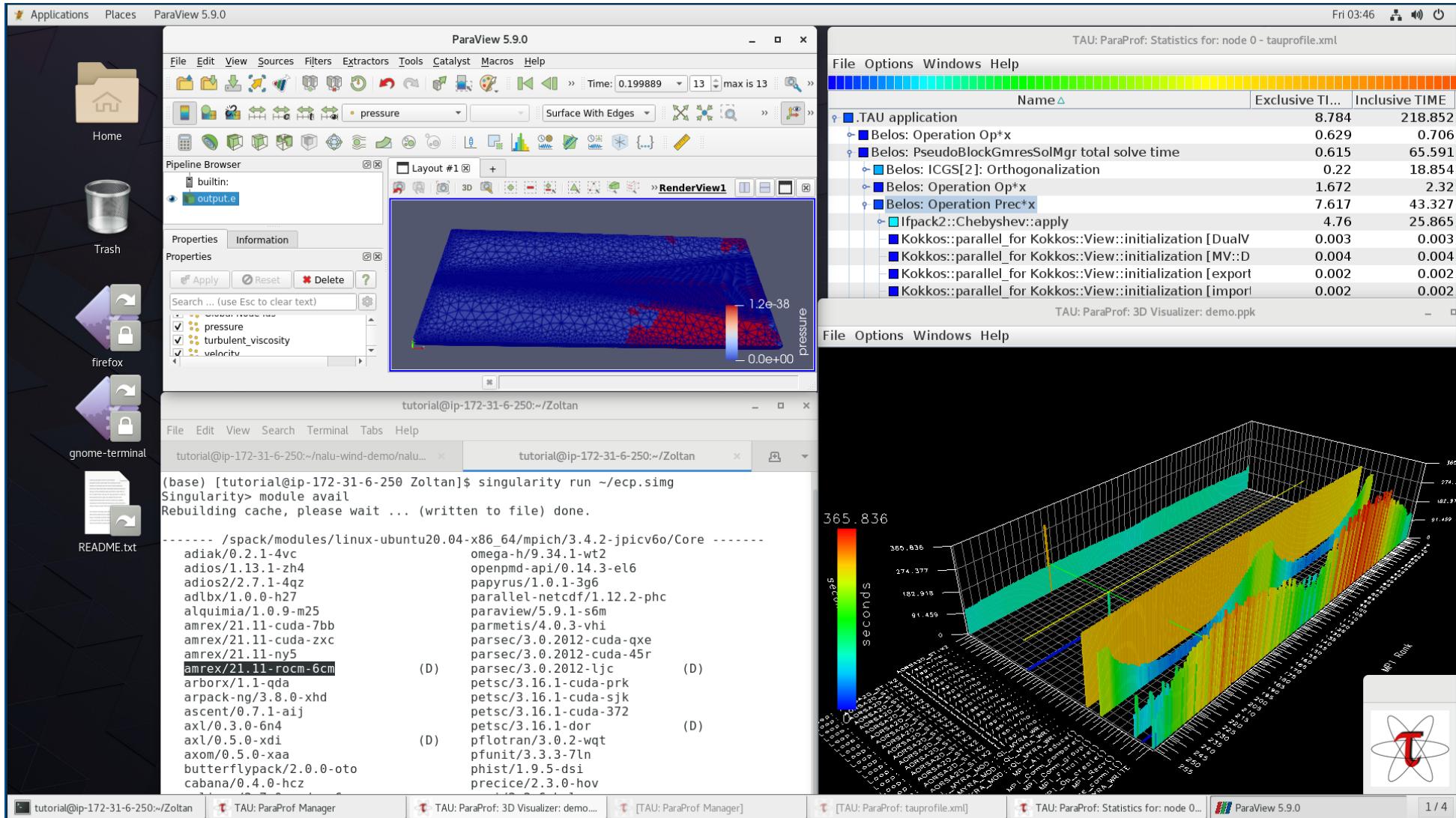
- Processor architecture filters: All Arch, PPC64LE, X86_64, AARCH64
- Operating System filters: All OS, Centos 7, Centos 8, RHEL 7, RHEL 8, Ubuntu 18.04, Ubuntu 20.04

A search bar is located below the filters. At the bottom of the page, there is a row of links:

[adiak@0.1.1](#) [adiak@0.2.1](#) [adiak@0.2.2](#) [adios2@2.5.0](#) [adios2@2.6.0](#) [adios2@2.7.0](#)

- Over 100K binaries!
- No need to recompile from source code.

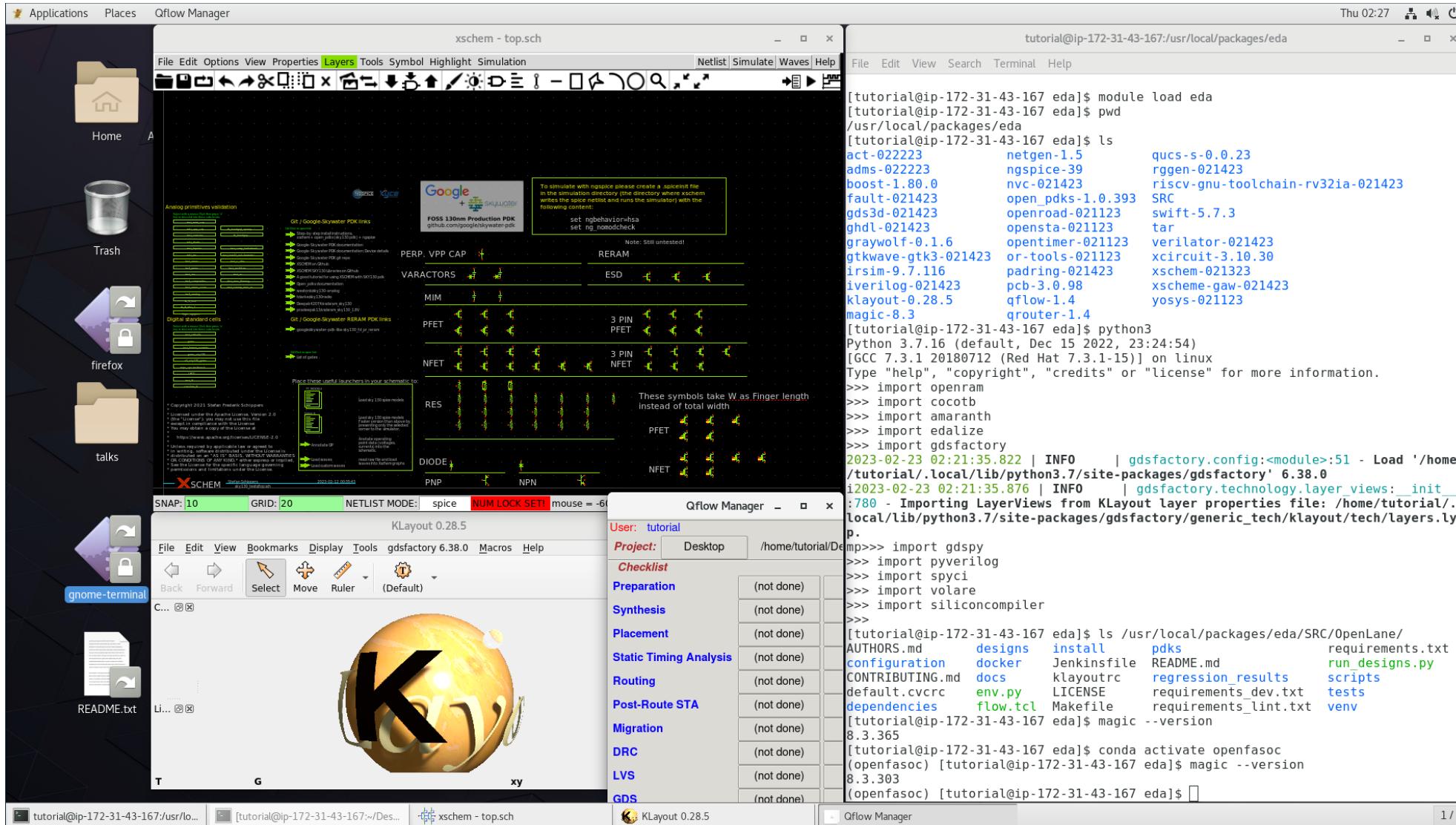
E4S 23.02 AWS image: US-West2 (OR)



- 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



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
 - Gdsp
 - 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

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#	Packages currently in E4S	URL	#	Packages currently in E4S	URL
25	Covered	https://github.com/hpretl/verilog-covered	37	Padring	https://github.com/donn/padring
26	Edalize	https://github.com/olofk/edalize	38	Pyverilog	https://github.com/PyHDI/Pyverilog
27	Gaw3-xschem	https://github.com/StefanSchippers/xschem-gaw.git	39	OpenRAM	https://github.com/VLSIDA/OpenRAM
28	GDSFactory	https://github.com/gdsfactory/gdsfactory	40	Rggen	https://github.com/rggen/rggen
29	GDSPy	https://github.com/heitzmann/gdspy	41	Spyci	https://github.com/gmagni/spyci
30	GDS3D	https://github.com/trilomix/GDS3D	42	Volare	https://github.com/efabless/volare
31	Ghdl	https://github.com/ghdl/ghdl	43	Siliconcompiler	https://github.com/siliconcompiler/siliconcompiler
32	Gtkwave	https://github.com/gtkwave/gtkwave	44	Verilator	https://github.com/verilator/verilator
33	iic-osic	https://github.com/hpretl/iic-osic.git	45	Sky130	SkyWater Technologies 130nm CMOS PDK
34	Iverilog	https://github.com/steveicarus/iverilog.git	46	Actflow	https://github.com/asyncvlsi/actflow.git
35	Netlistsvg	https://github.com/nturley/netlistsvg	47	Qucs-s	https://github.com/Qucs
36	Ngspice	https://github.com/ignamv/ngspice	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>

Can E4S help provide a stable platform for tool development?

- Bare-metal installation as well as containers built with Spack
- Base containers that can be customized with e4s-alc
- Replace MPI in containerized E4S application with system MPI using e4s-cl
- What are we missing?

Thank you

<https://www.exascaleproject.org>

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