



# Release Notes

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## SUSE Linux Enterprise for High-Performance Computing 15 SP2

SUSE Linux Enterprise for High-Performance Computing is a highly scalable, high performance open-source operating system designed to utilize the power of parallel computing. This document provides an overview of high-level general features, capabilities, and limitations of SUSE Linux Enterprise for High-Performance Computing 15 SP2 and important product updates.

These release notes are updated periodically. The latest version is always available at <https://www.suse.com/releasesnotes> .


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# 1 About the Release Notes

The most recent version of the Release Notes is available online at <https://www.suse.com/releasesnotes> .

Entries can be listed multiple times if they are important and belong to multiple sections.

Release notes only list changes that happened between two subsequent releases. Always review all release notes documents that apply in your upgrade scenario.

## 2 SUSE Linux Enterprise for High-Performance Computing

SUSE Linux Enterprise for High-Performance Computing is a highly scalable, high performance open-source operating system designed to utilize the power of parallel computing for modeling, simulation and advanced analytics workloads.

SUSE Linux Enterprise for High-Performance Computing 15 SP2 provides tools and libraries related to High Performance Computing. This includes:

- Workload manager
- Remote and parallel shells
- Performance monitoring and measuring tools
- Serial console monitoring tool
- Cluster power management tool
- A tool for discovering the machine hardware topology
- System monitoring
- A tool for monitoring memory errors
- A tool for determining the CPU model and its capabilities (x86-64 only)
- User-extensible heap manager capable of distinguishing between different kinds of memory (x86-64 only)
- Serial and parallel computational libraries providing the common standards BLAS, LAPACK, ...

- Various MPI implementations
- Serial and parallel libraries for the HDF5 file format

## 2.1 Hardware Platform Support

SUSE Linux Enterprise for High-Performance Computing 15 SP2 is available for the Intel 64/AMD64 (x86-64) and AArch64 platforms.

## 2.2 Important Sections of This Document

If you are upgrading from a previous SUSE Linux Enterprise for High-Performance Computing release, you should review at least the following sections:

- *Section 2.4, “Support Statement for SUSE Linux Enterprise for High-Performance Computing”*
- *Section 6.3, “Upgrade-Related Notes”*


## 2.3 Support and Life Cycle

SUSE Linux Enterprise for High-Performance Computing is backed by award-winning support from SUSE, an established technology leader with a proven history of delivering enterprise-quality support services.

SUSE Linux Enterprise for High-Performance Computing 15 has a 13-year life cycle, with 10 years of General Support and 3 years of Extended Support. The current version (SP2) will be fully maintained and supported until 6 months after the release of SUSE Linux Enterprise for High-Performance Computing 15 SP3.

Any release package is fully maintained and supported until the availability of the next release. Extended Service Pack Overlay Support (ESPOS) and Long Term Service Pack Support (LTSS) are also available for this product. If you need additional time to design, validate and test your upgrade plans, Long Term Service Pack Support (LTSS) can extend the support you get by an additional 12 to 36 months in 12-month increments, providing a total of 3 to 5 years of support on any given Service Pack.

For more information, see:

- The support policy at <https://www.suse.com/support/policy.html> 
- Long Term Service Pack Support page at <https://www.suse.com/support/programs/long-term-service-pack-support.html> 

## 2.4 Support Statement for SUSE Linux Enterprise for High-Performance Computing

To receive support, you need an appropriate subscription with SUSE. For more information, see <https://www.suse.com/support/programs/subscriptions/> .

The following definitions apply:

### L1

Problem determination, which means technical support designed to provide compatibility information, usage support, ongoing maintenance, information gathering and basic troubleshooting using available documentation.

### L2

Problem isolation, which means technical support designed to analyze data, reproduce customer problems, isolate problem area and provide a resolution for problems not resolved by Level 1 or prepare for Level 3.

### L3

Problem resolution, which means technical support designed to resolve problems by engaging engineering to resolve product defects which have been identified by Level 2 Support.

For contracted customers and partners, SUSE Linux Enterprise for High-Performance Computing 15 SP2 is delivered with L3 support for all packages, except for the following:

- Technology Previews, see [Section 4, "Technology Previews"](#)
- Sound, graphics, fonts and artwork
- Packages that require an additional customer contract

SUSE will only support the usage of original packages. That is, packages that are unchanged and not recompiled.

## 2.5 Documentation and Other Information

### 2.5.1 On the Product Medium

- For general product information, see the file README in the top level of the product medium.
- For a chronological log of all changes made to updated packages, see the file ChangeLog in the top level of the product medium.
- Detailed change log information about a particular package is available using RPM:

```
rpm --changelog -qp FILE_NAME.rpm
```

(Replace *FILE\_NAME.rpm* with the name of the RPM.)

- For more information, see the directory docu of the product medium of SUSE Linux Enterprise for High-Performance Computing 15 SP2.

### 2.5.2 Online Documentation


- Find a collection of White Papers in the SUSE Linux Enterprise for High-Performance Computing Resource Library at <https://www.suse.com/products/server/hpc#resources> .

## 3 Modules, Extensions, and Related Products


This section comprises information about modules and extensions for SUSE Linux Enterprise for High-Performance Computing 15 SP2. Modules and extensions add functionality to the system.

### 3.1 Modules in the SLE 15 SP2 Product Line


The SLE 15 SP2 product line is made up of modules that contain software packages. Each module has a clearly defined scope. Modules differ in their life cycles and update timelines.

The modules available within the product line based on SUSE Linux Enterprise 15 SP2 at the release of SUSE Linux Enterprise for High-Performance Computing 15 SP2 are listed in the *Modules and Extensions Quick Start* at <https://documentation.suse.com/html/SLES-modulesquick/> .

Not all SLE modules are available with a subscription for SUSE Linux Enterprise for High-Performance Computing 15 SP2 itself (see the column *Available for*).

For information about the availability of individual packages within modules, see <https://scc.suse.com/packages> .

## 3.2 Available Extensions

The following extension is not covered by SUSE support agreements, available at no additional cost and without an extra registration key: SUSE Package Hub, see <https://packagehub.suse.com/> .

## 3.3 Related Products

This section lists related products. Usually, these products have their own release notes documents that are available from <https://www.suse.com/releasesnotes>.

- SUSE Linux Enterprise JeOS: <https://www.suse.com/products/server/jeos>
- SUSE Enterprise Storage: <https://www.suse.com/products/suse-enterprise-storage>
- SUSE Linux Enterprise Desktop: <https://www.suse.com/products/desktop>
- SUSE Linux Enterprise Server for SAP Applications: <https://www.suse.com/products/sles-for-sap>
- SUSE Linux Enterprise for High-Performance Computing: <https://www.suse.com/products/server/hpc>
- SUSE Linux Enterprise Real Time: <https://www.suse.com/products/realtime>
- SUSE Manager: <https://www.suse.com/products/suse-manager>

# 4 Technology Previews

Technology previews are packages, stacks, or features delivered by SUSE which are not supported. They may be functionally incomplete, unstable or in other ways not suitable for production use. They are included for your convenience and give you a chance to test new technologies within an enterprise environment.

Whether a technology preview becomes a fully supported technology later depends on customer and market feedback. Technology previews can be dropped at any time and SUSE does not commit to providing a supported version of such technologies in the future.

Give your SUSE representative feedback about technology previews, including your experience and use case.

## 5 Packages

### 5.1 New Packages

#### 5.1.1 Adaptable IO System (ADIOS) 1.13.1 Has Been Added

The Adaptable IO System (ADIOS) provides a simple, flexible way for scientists to describe the data in their code that may need to be written, read, or processed outside of the running simulation. For more information, see <https://www.olcf.ornl.gov/center-projects/adios/>.

#### 5.1.2 libfabric 1.9.0 Has Been Added

The package `Libfabric` provides a user-space API to access high-performance fabric services, such as RDMA. For more information, see <https://www.github.com/ofiwg/libfabric>.

#### 5.1.3 rdma-core 27.0 Has Been Added

The package `rdma-core` contains the userspace components for the Linux kernel's Infiniband subsystem. For more information, see <https://github.com/linux-rdma/rdma-core>.

#### 5.1.4 slurm-webdoc Has Been Added

`slurm-webdoc` installs a web server and the `slurm-doc` package, so you can view Slurm documentation. It also contains a tool to help you generate a `slurm.conf`.



## 5.2 Updated Packages

### 5.2.1 `cpuid` Has Been Updated to Version 20180519

`cpuid` 20180519 adds support for various new CPUs and makes available a number of new bit fields.

### 5.2.2 Support for EFA in AWS

Amazon Web Services (AWS) has introduced the EFA driver to support HPC workloads. The Linux kernel of SUSE Linux Enterprise for High-Performance Computing now supports this driver.

### 5.2.3 `fftw3` Has Been Updated to Version 3.3.8

`fftw3` 3.3.8 includes official support for the AArch64 architecture.

### 5.2.4 `genders` Has Been Updated to Version 1.27.3

This version of `genders` can parse faster. For project information, see <https://github.com/chaos/genders>.

### 5.2.5 `gsl` Has Been Updated to Version 2.6

For more information about the updates in `gsl` 2.6, see <http://git.savannah.gnu.org/cgit/gsl.git/tree/NEWS>.

### 5.2.6 `hdf5` Has Been Updated to Version 1.10.5

For more information about the updates in `hdf5` 1.10.5, see <https://support.hdfgroup.org/ftp/HDF5/releases/hdf5-1.10/hdf5-1.10.5/src/hdf5-1.10.5-RELEASE.txt>.

### 5.2.7 hwloc Has Been Updated to Version 2.1.0

Version 2.1.0 of hwloc brings many improvements:

- There are two new object types: "Die" for Xeon 9200 processors, and "MemorySideCache" (used when DDR is a cache in front of NVDIMMs).
- There is better support for discovering the locality of memory.
- `lstopo` received a range of improvements: better graphical output, factorization of identical objects, and many keyboard shortcuts to configure interactive outputs.
- There are now Bash completions that ease command-line invocations.

For more information, see <https://www.mail-archive.com/hwloc-announce@lists.open-mpi.org/msg00127.html>.

### 5.2.8 hydre Has Been Updated to Version 2.18.2

hydre 2.18.2 includes bug fixes and some improvements, such as GPU optimizations. For more information, see <https://github.com/hydre-space/hydre/blob/master/CHANGELOG>.

### 5.2.9 memkind Has Been Updated to Version 1.9.0

memkind 1.9.0 includes a large number of fixes and improvements over the 1.6.x version. For more information, see <https://memkind.github.io/memkind/>.

### 5.2.10 MPICH Has Been Updated to Version 3.3.2

MPICH 3.3.2 adds a number of improvements and bug fixes, highlights are:

- Support for the struct `sockaddr` in MPICH, Hydra, and PMI socket code.
- A new CH4 device layer implementation designed for low software overhead.
- Support for the PMIx client library in CH4 netmods. See also [Section 5.2.17, "Added Support for PMIx in Slurm and MPI libraries"](#) and <https://pmix.github.io/pmix/>.

For more information, see the [README](#) file in the package `mpich`.

### 5.2.11 MUMPS Has Been Updated to Version 5.2.1

MULTifrontal Massively Parallel sparse direct Solver (MUMPS) 5.2.1 includes bug fixes, improved distributed memory usage and MPI granularity, and reduced memory usage due to low-rank factorization. For more information, see <http://mumps.enseeiht.fr/index.php?page=dwnld#cl>.

### 5.2.12 mvapich2 Has Been Updated to Version 2.3.3

For more information about the updates in mvapich2 2.3.3, see <http://mvapich.cse.ohio-state.edu/overview/>.

### 5.2.13 netcdf-cxx4 Has Been Updated to Version 4.3.1

The netcdf-cxx4 4.3.1 adds ncFile::create() and a new open function and constructor to allow for more flexibility when opening a file. For more information, see <https://www.unidata.ucar.edu/blogs/news/entry/netcdf-c-4-3-1>.

### 5.2.14 netcdf-fortran Has Been Updated to Version 4.5.2

For more about updates in netcdf-fortran 4.5.2, see the change logs at:

- <https://github.com/Unidata/netcdf-fortran/releases/tag/v4.5.2>
- <https://github.com/Unidata/netcdf-fortran/releases/tag/v4.5.1>
- <https://github.com/Unidata/netcdf-fortran/releases/tag/v4.5.0>

### 5.2.15 OpenBLAS Has Been Updated to Version 0.3.7

For more information about the updates in OpenBLAS 0.3.7, see <https://www.openblas.net/Changelog.txt>.

### 5.2.16 PAPI Has Been Updated to Version 5.7.0

PAPI 5.7.0 includes a new component, called pcp which interfaces to the Performance Co-Pilot (PCP). This release also upgrades the PAPI nvml component with write access to the information and controls exposed via the NVIDIA Management Library. For more information, see <https://icl.cs.utk.edu/papi/news/news.html?id=381>.

### 5.2.17 Added Support for PMIx in Slurm and MPI libraries

PMIx abstracts the internals of MPI implementations for workload managers and unifies the way MPI jobs are started by the workload manager: With PMIx, there is no need to utilize the individual MPI launchers on Slurm anymore, `srun` will take care of this. In addition, the workload manager can determine the topology of the cluster. This removes the need for users to specify topologies manually.

### 5.2.18 python3-numpy Has Been Updated to Version 1.16

python3-numpy 1.16 includes several new features and bug fixes, including:

- A new extensible random module along with four selectable random number generators and improved seeding designed for use in parallel processes has been added.
- New radix sort and Timsort sorting methods have been implemented.

For more information, see <https://numpy.org/doc/1.16/release.html> .

### 5.2.19 Slurm Has Been Updated to Version 19.05.5

Slurm is shipped in version 19.05.5, meaning the same version of Slurm is now used across SUSE Linux Enterprise for High-Performance Computing versions.

## 5.3 Removed Packages and Functionality

### 5.3.1 ohpc

The package `ohpc` provided RPM macros for compatibility with the OpenHPC project. It is no longer needed.

## 6 Installation and Upgrade

SUSE Linux Enterprise for High-Performance Computing comes with a number of preconfigured system roles for HPC. These roles provide a set of preselected packages typical for the specific role, as well as an installation workflow that will configure the system to make the best use of system resource based on a typical role use case.

### 6.1 System Roles for SUSE Linux Enterprise for High-Performance Computing 15 SP2

With SUSE Linux Enterprise for High-Performance Computing 15 SP2, it is possible to choose specific roles for the system based on modules selected during the installation process. When the HPC Module is enabled, these three roles are available:

#### HPC Management Server (Head Node)

This role includes the following features:

- Uses XFS as the default root file system
- Includes HPC-enabled libraries
- Disables firewall and Kdump services
- Installs controller for the Slurm Workload Manager
- Mounts a large scratch partition to /var/tmp

#### HPC Compute Node

This role includes the following features:

- Uses XFS as the default root file system
- Includes HPC-enabled libraries
- Disables firewall and Kdump services
- Based from minimal setup configuration
- Installs client for the Slurm Workload Manager
- Does not create a separate home partition
- Mounts a large scratch partition to /var/tmp

## HPC Development Node

This role includes the following features:

- Includes HPC-enabled libraries
- Adds compilers and development toolchain

The scratch partition `/var/tmp/` will only be created if there is sufficient space available on the installation medium (minimum 32 GB).

The Environment Module `Lmod` will be installed for all roles. It is required at build time and run time of the system. For more information, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

All libraries specifically build for HPC will be installed under `/usr/lib/hpc`. They are not part of the standard search path, thus the `Lmod` environment module system is required.

`Munge` authentication is installed for all roles. This requires to copy the same generated munge keys to all nodes of a cluster. For more information, see [Section 7.16, “mrsh/mrlogin — Remote Login Using munge Authentication”](#) and [Section 7.15, “munge Authentication”](#).

From the Ganglia monitoring system, the data collector `ganglia-gmond` is installed for every role, while the data aggregator `ganglia-gmetad` needs to be installed manually on the system which is expected to collect the data. For more information, see [Section 7.3, “Ganglia — System Monitoring”](#).

The system roles are only available for new installations of SUSE Linux Enterprise for High-Performance Computing.

## 6.2 Installation

This section includes information related to the initial installation of the SUSE Linux Enterprise for High-Performance Computing 15 SP2.

## 6.3 Upgrade-Related Notes

This section includes upgrade-related information for the SUSE Linux Enterprise for High-Performance Computing 15 SP2.

You can upgrade to SUSE Linux Enterprise for High-Performance Computing 15 SP2 from SLES 12 SP3 or SUSE Linux Enterprise for High-Performance Computing 12 SP3. When upgrading from SLES 12 SP3, the upgrade will only be performed if the SUSE Linux Enterprise for High-Performance Computing module has been registered prior to upgrading. Otherwise, the system will instead be upgraded to SLES 15.

To upgrade from SLES 12 to SLES 15, make sure to unregister the SUSE Linux Enterprise for High-Performance Computing module prior to upgrading. To do so, open a root shell and execute:

```
SUSEConnect -d -p sle-module-hpc/12/ARCH
```

Replace ARCH with the architecture used (x86\_64, aarch64).

When migrating to SUSE Linux Enterprise for High-Performance Computing 15 SP2, all modules not supported by the migration target need to be deregistered. This can be done by executing:

```
SUSEConnect -d -p sle-module-MODULE_NAME/12/ARCH
```

Replace MODULE\_NAME by the name of the module and ARCH with the architecture used (x86\_64, aarch64).

## 7 Functionality

This section comprises information about packages and their functionality, as well as additions, updates, removals and changes to the package layout of software.

### 7.1 `cpuid` — x86 CPU Identification Tool

`cpuid` executes the x86 CPUID instruction and decodes and prints the results to stdout. Its knowledge of Intel, AMD and Cyrix CPUs is fairly complete. It also supports Intel Knights Mill CPUs (x86-64).

To install `cpuid`, run: `zypper in cpuid`.

For information about runtime options for `cpuid`, see the man page `cpuid(1)`.

Note that this tool is only available for x86-64.

## 7.2 ConMan — The Console Manager

ConMan is a serial console management program designed to support a large number of console devices and simultaneous users. It supports:

- local serial devices
- remote terminal servers (via the telnet protocol)
- IPMI Serial-Over-LAN (via FreeIPMI)
- Unix domain sockets
- external processes (for example, using 'expect' scripts for telnet, ssh, or ipmi-sol connections)

ConMan can be used for monitoring, logging and optionally timestamping console device output. To install ConMan, run `zypper in conman`.

### Important: conmand Sends Unencrypted Data

The daemon `conmand` sends unencrypted data over the network and its connections are not authenticated. Therefore, it should be used locally only: Listening to the port `localhost`. However, the IPMI console does offer encryption. This makes `conman` a good tool for monitoring a large number of such consoles.

Usage:

- ConMan comes with a number of expect-scripts: check `/usr/lib/conman/exec`.
- Input to `conman` is not echoed in interactive mode. This can be changed by entering the escape sequence `&E`.
- When pressing `Enter` in interactive mode, no line feed is generated. To generate a line feed, press `Ctrl-L`.

For more information about options, see the man page of ConMan.

## 7.3 Ganglia — System Monitoring

Ganglia is a scalable distributed monitoring system for high-performance computing systems, such as clusters and grids. It is based on a hierarchical design targeted at federations of clusters.



## Using Ganglia

To use Ganglia, make sure to install ganglia-gmetad on the management server. Then start the Ganglia meta-daemon: rcgmetad start. To make sure the service is started after a reboot, run: systemctl enable gmetad. On each cluster node which you want to monitor, install ganglia-gmond, start the service rcgmond start and make sure it is enabled to be started automatically after a reboot: systemctl enable gmond. To test whether the gmond daemon has connected to the meta-daemon, run gstat -a and check that each node to be monitored is present in the output.

## Ganglia on Btrfs

When using the Btrfs file system, the monitoring data will be lost after a rollback and the service gmetad will not start again. To fix this issue, either install the package ganglia-gmetad-skip-bcheck or create the file /etc/ganglia/no\_btrfs\_check.

## Using the Ganglia Web Interface

To use the Ganglia Web interface, it is required to add the *Web and Scripting Module* first. Which modules are activated and which are available can be checked with SUSEConnect -l. To activate the *Web and Scripting Module*, run: SUSEConnect -p sle-module-web-scripting/15/x86\_64.

Install ganglia-web on the management server. Depending on which PHP version is used (default is PHP 7), enable it in Apache2: a2enmod php7.

Then start Apache2 on this machine: rcapache2 start and make sure it is started automatically after a reboot: systemctl enable apache2. The Ganglia Web interface should be accessible from http://MANAGEMENT\_SERVER/ganglia-web.

## 7.4 Genders — Static Cluster Configuration Database

Support for Genders has been added to the HPC module.

Genders is a static cluster configuration database used for configuration management. It allows grouping and addressing sets of hosts by attributes and is used by a variety of tools. The Genders database is a text file which is usually replicated on each node in a cluster.

Perl, Python, C, and C++ bindings are supplied with Genders, the respective packages provide man pages or other documentation describing the APIs.

To create the Genders database, follow the instructions and examples in [/etc/genders](#) and check [/usr/share/doc/packages/genders-base/TUTORIAL](#). Testing a configuration can be done with [nodeattr](#) (for more information, see [man 1 nodeattr](#)).

List of packages:

- [genders](#)
- [genders-base](#)
- [genders-devel](#)
- [python-genders](#)
- [genders-perl-compat](#)
- [libgenders0](#)
- [libgendersplusplus2](#)

## 7.5 GNU Compiler Collection for HPC

[gnu-compilers-hpc](#) installs the base version of the GNU compiler suite and provides environment files for Lmod to select this compiler suite and provides environment module files for them. This version of the compiler suite is required to enable linking against HPC libraries enabled for environment modules.

This package requires [lua-lmod](#) to supply environment module support.

To install [gnu-compilers-hpc](#), run:

```
zypper in gnu-compilers-hpc
```

To set up the environment appropriately and select the GNU toolchain, run:

```
module load gnu
```

If you have more than one version of this compiler suite installed, add the version number of the compiler suite. For more information, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 7.6 hwloc — Portable Abstraction of Hierarchical Architectures for High-Performance Computing

hwloc provides command-line tools and a C API to obtain the hierarchical map of key computing elements, such as: NUMA memory nodes, shared caches, processor packages, processor cores, processing units (logical processors or "threads") and even I/O devices. hwloc also gathers various attributes such as cache and memory information, and is portable across a variety of different operating systems and platforms. Additionally it may assemble the topologies of multiple machines into a single one, to let applications consult the topology of an entire fabric or cluster at once.

In graphical mode (X11), hwloc can display the topology in a human-readable format. Alternatively, it can export to one of several formats, including plain text, PDF, PNG, and FIG. For more information, see the man pages provided by hwloc.

It also features full support for import and export of XML-formatted topology files via the libxml2 library.

The package hwloc-devel offers a library that can be directly included into external programs. This requires that the libxml2 development library (package libxml2-devel) is available when compiling hwloc.

## 7.7 Lmod — Lua-based Environment Modules

Lmod is an advanced environment module system which allows the installation of multiple versions of a program or shared library, and helps configure the system environment for the use of a specific version. It supports hierarchical library dependencies and makes sure that the correct version of dependent libraries are selected. Environment Modules-enabled library packages supplied with the HPC module support parallel installation of different versions and flavors of the same library or binary and are supplied with appropriate lmod module files.

### Installation and Basic Usage

To install Lmod, run: **zypper in lua-lmod**.

Before Lmod can be used, an init file needs to be sourced from the initialization file of your interactive shell. The following init files are available:

```
/usr/share/lmod/<lmod_version>/init/bash
```

```
/usr/share/lmod/<lmod_version>/init/ksh
/usr/share/lmod/<lmod_version>/init/tcsh
/usr/share/lmod/<lmod_version>/init/zsh
/usr/share/lmod/<lmod_version>/init/sh
```

Pick the one appropriate for your shell. Then add the following to the init file of your shell:

```
. /usr/share/lmod/<LMOD_VERSION>/init/<INIT-FILE>
```

To obtain <lmod\_version>, run:

```
rpm -q lua-lmod | sed "s/.*-([^-]\+)-.*\/\1/"
```

The init script adds the command module.

## Listing Available Modules

To list the available all available modules, run: module spider. To show all modules which can be loaded with the currently loaded modules, run: module avail. A module name consists of a name and a version string separated by a / character. If more than one version is available for a certain module name, the default version (marked by \*) or (if this is not set) the one with the highest version number is loaded. To refer to a specific module version, the full string NAME/VERSION may be used.

## Listing Loaded Modules

module list shows all currently loaded modules. Refer to module help for a short help on the module command and module help MODULE-NAME for a help on the particular module. Note that the module command is available only when you log in after installing lua-lmod.

## Gathering Information About a Module

To get information about a particular module, run: module whatis MODULE-NAME. To load a module, run: module load MODULE-NAME. This will ensure that your environment is modified (that is, the PATH and LD\_LIBRARY\_PATH and other environment variables are prepended) such that binaries and libraries provided by the respective modules are found. To run a program compiled against this library, the appropriate module load commands must be issued beforehand.

## Loading Modules

The `module load MODULE` command needs to be run in the shell from which the module is to be used. Some modules require a compiler toolchain or MPI flavor module to be loaded before they are available for loading.

## Environment Variables

If the respective development packages are installed, build time environment variables like `LIBRARY_PATH`, `CPATH`, `C_INCLUDE_PATH` and `CPLUS_INCLUDE_PATH` will be set up to include the directories containing the appropriate header and library files. However, some compiler and linker commands may not honor these. In this case, use the appropriate options together with the environment variables `-I PACKAGE_NAME_INC` and `-L PACKAGE_NAME_LIB` to add the include and library paths to the command lines of the compiler and linker.

## For More Information

For more information on Lmod, see <https://lmod.readthedocs.org>.

## 7.8 ohpc — OpenHPC Compatibility Macros

`ohpc` contains compatibility macros to build OpenHPC packages on SUSE Linux Enterprise.

To install `ohpc`, run: `zypper in ohpc`.

## 7.9 pdsh — Parallel Remote Shell Program

`pdsh` is a parallel remote shell which can be used with multiple back-ends for remote connections. It can run a command on multiple machines in parallel.

To install `pdsh`, run `zypper in pdsh`.

On SLES 12, the back-ends `ssh`, `mrsh`, and `exec` are supported. The `ssh` back-end is the default. Non-default login methods can be used by either setting the `PDSH_RCMD_TYPE` environment variable or by using the `-R` command argument.

When using the `ssh` back-end, it is important that a non-interactive (that is, passwordless) login method is used.

The `mrsh` back-end requires the `mrshd` to be running on the client. The `mrsh` back-end does not require the use of reserved sockets. Therefore, it does not suffer from port exhaustion when executing commands on many machines in parallel. For information about setting up the system to use this back-end, see [Section 7.16, “mrsh/mrlogin — Remote Login Using munge Authentication”](#).

Remote machines can either be specified on the command line or `pdsh` can use a `machines` file (`/etc/pdsh/machines`), `dsh` (Dancer's shell) style groups or netgroups. Also, it can target nodes based on the currently running Slurm jobs.

The different ways to select target hosts are realized by modules. Some of these modules provide identical options to `pdsh`. The module loaded first will win and consume the option. Therefore, we recommend limiting yourself to a single method and specifying this with the `-M` option.

The `machines` file lists all target hosts one per line. The appropriate netgroup can be selected with the `-g` command line option.

The following host-list plugins for `pdsh` are supported: `machines`, `slurm`, `netgroup` and `dshgroup`. Each host-list plugin is provided in a separate package. This avoids conflicts between command line options for different plugins which happen to be identical and helps to keep installations small and free of unneeded dependencies. Package dependencies have been set to prevent installing plugins with conflicting command options. To install one of the plugins, run:

```
zypper in pdsh-PLUGIN_NAME
```

For more information, see the man page `pdsh`.

## 7.10 PowerMan — Centralized Power Control for Clusters

PowerMan allows manipulating remote power control devices (RPC) from a central location. It can control:

- local devices connected to a serial port
- RPCs listening on a TCP socket
- RPCs which are accessed through an external program

The communication to RPCs is controlled by “expect”-like scripts. For a list of currently supported devices, see the configuration file `/etc/powerman/powerman.conf`.

To install PowerMan, run `zypper in powerman`.

To configure it, include the appropriate device file for your RPC (`/etc/powerman/*.dev`) in `/etc/powerman/powerman.conf` and add devices and nodes. The device “type” needs to match the “specification” name in one of the included device files, the list of “plugs” used for nodes need to match an entry in the “plug name” list.

After configuring PowerMan, start its service by:

```
systemctl start powerman.service
```

To start PowerMan automatically after every boot, do:

```
systemctl enable powerman.service
```

Optionally, PowerMan can connect to a remote PowerMan instance. To enable this, add the option `listen` to `/etc/powerman/powerman.conf`.



## Important: Unencrypted Transfer

Data is transferred unencrypted, therefore this is not recommended unless the network is appropriately secured.

## 7.11 rasdaemon — Utility to Log RAS Error Tracings

`rasdaemon` is a RAS (Reliability, Availability and Serviceability) logging tool. It records memory errors using the EDAC tracing events. EDAC drivers in the Linux kernel handle detection of ECC errors from memory controllers.

`rasdaemon` can be used on large memory systems to track, record and localize memory errors and how they evolve over time to detect hardware degradation. Furthermore, it can be used to localize a faulty DIMM on the board.

To check whether the EDAC drivers are loaded, execute:

```
ras-mc-ctl --status
```

The command should return `ras-mc-ctl: drivers are loaded`. If it indicates that the drivers are not loaded, EDAC may not be supported on your board.

To start `rasdaemon`, run `systemctl start rasdaemon.service`. To start `rasdaemon` automatically at boot time, execute `systemctl enable rasdaemon.service`. The daemon will log information to `/var/log/messages` and to an internal database. A summary of the stored errors can be obtained with:

```
ras-mc-ctl --summary
```

The errors stored in the database can be viewed with

```
ras-mc-ctl --errors
```

Optionally, you can load the DIMM labels silk-screened on the system board to more easily identify the faulty DIMM. To do so, before starting `rasdaemon`, run:

```
systemctl start ras-mc-ctl start
```

For this to work, you need to set up a layout description for the board. There are no descriptions supplied by default. To add a layout description, create a file with an arbitrary name in the directory `/etc/ras/dimm_labels.d/`. The format is:

```
Vendor: VENDOR-NAME
Model: MODEL-NAME
LABEL: MC.TOP.MID.LOW
```

## 7.12 Slurm — Utility for HPC Workload Management

Slurm is an open source, fault-tolerant, and highly scalable cluster management and job scheduling system for Linux clusters containing up to 65,536 nodes. Components include machine status, partition management, job management, scheduling and accounting modules.

For a minimal setup to run Slurm with *munge* support on one compute node and multiple control nodes, follow these instructions:

1. Before installing Slurm, create a user and a group called `slurm`.

### Important: Make Sure of Consistent UIDs and GIDs for Slurm's Accounts

For security reasons, Slurm does not run as the user `root` but under its own user. It is important that the user `slurm` has the same UID/GID across all nodes of the cluster.



If this user/group does not exist, the package `slurm` creates this user and group when it is installed. However, this does not guarantee that the generated UIDs/GIDs will be identical on all systems.

Therefore, we strongly advise you to create the user/group `slurm` before installing `slurm`. If you are using a network directory service such as LDAP for user and group management, you can use it to provide the `slurm` user/group as well.

2. Install `slurm-munge` on the control and compute nodes: **`zypper in slurm-munge`**
3. Configure, enable and start "munge" on the control and compute nodes as described in [Section 7.16, "mrsh/mrlogin — Remote Login Using munge Authentication"](#).
4. On the compute node, edit `/etc/slurm/slurm.conf`:

- a. Configure the parameter `ControlMachine=CONTROL_MACHINE` with the host name of the control node.

To find out the correct host name, run `hostname -s` on the control node.

- b. Additionally add:

```
NodeName=NODE_LIST Sockets=SOCKETS \  
CoresPerSocket=CORES_PER_SOCKET \  
ThreadsPerCore=THREADS_PER_CORE \  
State=UNKNOWN
```

and

```
PartitionName=normal Nodes=NODE_LIST \  
Default=YES MaxTime=24:00:00 State=UP
```

where `NODE_LIST` is the list of compute nodes (that is, the output of `hostname -s` run on each compute node (either comma-separated or as ranges: `foo[1-100]`)). Additionally, `SOCKETS` denotes the number of sockets, `CORES_PER_SOCKET` the number of cores per socket, `THREADS_PER_CORE` the number of threads for CPUs which can execute more than one thread at a time. (Make sure that `SOCKETS * CORES_PER_SOCKET * THREADS_PER_CORE` does not exceed the number of system cores on the compute node).

- c. On the control node, copy `/etc/slurm/slurm.conf` to all compute nodes:

```
scp /etc/slurm/slurm.conf COMPUTE_NODE:/etc/slurm/
```

- d. On the control node, start slurmctld:

```
systemctl start slurmctld.service
```

Also enable it so that it starts on every boot:

```
systemctl enable slurmctld.service
```

- e. On the compute nodes, start and enable slurmd:

```
systemctl start slurmd.service  
systemctl enable slurmd.service
```

The last line causes slurmd to be started on every boot automatically.

For further documentation, see the [Quick Start Administrator Guide \(https://slurm.schedmd.com/quickstart\\_admin.html\)](https://slurm.schedmd.com/quickstart_admin.html) and [Quick Start User Guide \(https://slurm.schedmd.com/quickstart.html\)](https://slurm.schedmd.com/quickstart.html). There is further in-depth documentation on the [Slurm documentation page \(https://slurm.schedmd.com/documentation.html\)](https://slurm.schedmd.com/documentation.html).

## 7.13 Enabling the pam\_slurm\_adopt Module

The pam\_slurm\_adopt module allows restricting access to compute nodes to those users that have jobs running on them. It can also take care of *run-away processes* from user's jobs and end these processes when the job has finished.

pam\_slurm\_adopt works by binding the login process of a user and all its child processes to the cgroup of a running job.

It can be enabled with following steps:

1. In the configuration file slurm.conf, set the option PrologFlags=contain. Make sure the option ProctrackType=proctrack/cgroup is also set.
2. Restart the services slurmctld and slurmd.  
For this change to take effect, it is not sufficient to issue the command scontrol reconfigure.

### 3. Decide whether to limit resources:

- If resources are not limited, user processes can continue running on a node even after the job to which they were bound has finished.
- If resources are limited using a `cgroup`, user processes will be killed when the job finishes, and the controlling `cgroup` is deactivated.

To activate resource limits via a `cgroup`, in the file `/etc/slurm/cgroup.conf`, set the option `ConstrainCores=yes`.

Due to the complexity of accurately determining RAM requirements of jobs, limiting the RAM space is not recommended.

### 4. Install the package `slurm-pam_slurm`:

```
zypper install slurm-pam_slurm
```

### 5. (Optional) You can disallow logins by users who have no running job in the machine:

- **Disabling SSH Logins Only:** In the file `/etc/pam.d/ssh`, add the option:

```
account    required pam_slurm_adopt.so
```

- **Disabling All Types of Logins:** In the file `/etc/pam.d/common-account`, add the option:

```
account    required pam_slurm_adopt.so
```

## 7.14 memkind — Heap Manager for Heterogeneous Memory Platforms and Mixed Memory Policies

The `memkind` library is a user-extensible heap manager built on top of `jemalloc` which enables control of memory characteristics and a partitioning of the heap between kinds of memory. The kinds of memory are defined by operating system memory policies that have been applied to virtual address ranges. Memory characteristics supported by `memkind` without user extension include control of NUMA and page size features.

For more information, see:

- the man pages [memkind](#) and [hbwallow](#)
- <https://github.com/memkind/memkind> 
- <https://memkind.github.io/memkind/> 



This tool is only available for x86-64.

## 7.15 *munge* Authentication

*munge* allows users to connect as the same user from a machine to any other machine which shares the same secret key. This can be used to set up a cluster of machines between which the user can connect and execute commands without any additional authentication.

The *munge* authentication is based on a single shared key. This key is located under `/etc/munge/munge.key`. At the installation time of the *munge* package an individual munge key is created from the random source `/dev/urandom`. This key has to be the same on all systems that should allow login to each other: To set up *munge* authentication on these machines copy the *munge* key from one machine (ideally a head node of the cluster) to the other machines within this cluster:

```
scp /etc/munge/munge.key root@NODE_N:/etc/munge/munge.key
```

Then enable and start the service *munge* on each machine:

```
systemctl enable munge.service
systemctl start munge.service
```

If several nodes are installed, one key must be selected and synchronized to all the other nodes in the cluster. This key file should belong to the *munge* user and must have the access rights `0400`.

## 7.16 *mrsh*/*mrlogin* — Remote Login Using *munge* Authentication

*mrsh* is a set of remote shell programs using the *munge* authentication system instead of reserved ports for security.

It can be used as a drop-in replacement for *rsh* and *rlogin*.

To install *mrsh*, do the following:

- If only the *mrsh* client is required (without allowing remote login to this machine), use: **zypper in mrsh**.
- To allow logging in to a machine, the server needs to be installed: **zypper in mrsh-server**.
- To get a drop-in replacement for **rsh** and **rlogin**, run: **zypper in mrsh-rsh-server-compat** or **zypper in mrsh-rsh-compat**.

To set up a cluster of machines allowing remote login from each other, first follow the instructions for setting up and starting *munge* authentication in [Section 7.15, “munge Authentication”](#). After *munge* has been successfully started, enable and start **mrlogin** on each machine on which the user will log in:

```
systemctl enable mrlogind.socket mrshd.socket
systemctl start mrlogind.socket mrshd.socket
```

To start *mrsh* support at boot, run:

```
systemctl enable munge.service
systemctl enable mrlogin.service
```

We do not recommend using *mrsh* when logged in as the user **root**. This is disabled by default. To enable it anyway, run:

```
echo "mrsh" >> /etc/securetty
echo "mrlogin" >> /etc/securetty
```

## 8 HPC Libraries

Library packages which support environment modules follow a distinctive naming scheme: all packages have the compiler suite and, if built with MPI support, the MPI flavor in their name: **\*-[MPI\_FLAVOR]-COMPILER-hpc\***. To support a parallel installation of multiple versions of a library package, the package name contains the version number (with dots **.** replaced by underscores **\_**). To simplify the installation of a library, **master** -packages are supplied which will ensure that the latest version of a package is installed. When these **master** packages are updated, the latest version of the respective library packages will be installed while leaving

previous versions installed. Library packages are split between runtime and compile time packages. The compile time packages typically supply include files and .so-files for shared libraries. Compile time package names end with `-devel`. For some libraries static (`.a`) libraries are supplied as well, package names for these end with `-devel-static`.

As an example: Package names of the ScaLAPACK library version 2.0.2 built with GCC for Open MPI v1:

- library package: `libscalapack2_2_0_2-gnu-openmpi1-hpc`
- library master package: `libscalapack2-gnu-openmpi1-hpc`
- development package: `libscalapack2_2_0_2-gnu-openmpi1-hpc-devel`
- development master package: `libscalapack2-gnu-openmpi1-hpc-devel`
- static library package: `libscalapack2_2_0_2-gnu-openmpi1-hpc-devel-static`

(Note that the digit `2` appended to the library name denotes the `.so` version of the library).

To install a library packages run `zypper in LIBRARY-MASTER-PACKAGE`. To install a development file, run `zypper in LIBRARY-DEVEL-MASTER-PACKAGE`.

Presently, the GNU compiler collection version 4.8 as provided with SUSE Linux Enterprise 15 and the MPI flavors Open MPI v.2 and MVAPICH2 are supported.

## 8.1 FFTW HPC Library — Discrete Fourier Transforms

`FFTW` is a C subroutine library for computing the Discrete Fourier Transform (DFT) in one or more dimensions, of both real and complex data, and of arbitrary input size.

This library is available as both a serial and an MPI-enabled variant. This module requires a compiler toolchain module loaded. To select an MPI variant, the respective MPI module needs to be loaded beforehand. To load this module, run:

```
module load fftw3
```

List of master packages:

- `libfftw3-gnu-hpc`
- `fftw3-gnu-hpc-devel`
- `libfftw3-gnu-openmpi1-hpc`

- [fftw3-gnu-openmpi1-hpc-devel](#)
- [libfftw3-gnu-mvapich2-hpc](#)
- [fftw3-gnu-mvapich2-hpc-devel](#)

For general information about Lmod and modules, see [\*Section 7.7, “Lmod — Lua-based Environment Modules”\*](#).

## 8.2 HDF5 HPC Library — Model, Library, File Format for Storing and Managing Data

HDF5 is a data model, library, and file format for storing and managing data. It supports an unlimited variety of data types, and is designed for flexible and efficient I/O and for high volume and complex data. HDF5 is portable and extensible, allowing applications to evolve in their use of HDF5.

There are serial and MPI variants of this library available. All flavors require loading a compiler toolchain module beforehand. The MPI variants also require loading the correct MPI flavor module.

To load the highest available serial version of this module run:

```
module load hdf5
```

When an MPI flavor is loaded, the MPI version of this module can be loaded by:

```
module load phpdf5
```

List of master packages:

- [hdf5-examples](#)
- [hdf5-gnu-hpc-devel](#)
- [libhdf5-gnu-hpc](#)
- [libhdf5\\_cpp-gnu-hpc](#)
- [libhdf5\\_fortran-gnu-hpc](#)
- [libhdf5\\_hl\\_cpp-gnu-hpc](#)

- [`libhdf5\_hl\_fortran-gnu-hpc`](#)
- [`hdf5-gnu-openmpi1-hpc-devel`](#)
- [`libhdf5-gnu-openmpi1-hpc`](#)
- [`libhdf5\_fortran-gnu-openmpi1-hpc`](#)
- [`libhdf5\_hl\_fortran-gnu-openmpi1-hpc`](#)
- [`hdf5-gnu-mvapich2-hpc-devel`](#)
- [`libhdf5-gnu-mvapich2-hpc`](#)
- [`libhdf5\_fortran-gnu-mvapich2-hpc`](#)
- [`libhdf5\_hl\_fortran-gnu-mvapich2-hpc`](#)

For general information about Lmod and modules, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 8.3 NetCDF HPC Library — Implementation of Self-Describing Data Formats

The NetCDF software libraries for C, C++, FORTRAN, and Perl are a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.

### [netcdf Packages](#)

The packages with names starting with `netcdf` provide C bindings for the NetCDF API. These are available with and without MPI support.

There are serial and MPI variants of this library available. All flavors require loading a compiler toolchain module beforehand. The MPI variants also require loading the correct MPI flavor module.

The MPI variant becomes available when the MPI module is loaded. Both variants require loading a compiler toolchain module beforehand. To load the highest version of the non-MPI `netcdf` module, run:

```
module load netcdf
```



To load the highest available MPI version of this module, run:

```
module load pnetcdf
```

List of master packages:

- [netcdf-gnu-hpc](#)
- [netcdf-gnu-hpc-devel](#)
- [netcdf-gnu-hpc](#)
- [netcdf-gnu-hpc-devel](#)
- [netcdf-gnu-openmpi1-hpc](#)
- [netcdf-gnu-openmpi1-hpc-devel](#)
- [netcdf-gnu-mvapich2-hpc](#)
- [netcdf-gnu-mvapich2-hpc-devel](#)

### [netcdf-cxx Packages](#)

[netcdf-cxx4](#) provides a C++ binding for the NetCDF API.

This module requires loading a compiler toolchain module beforehand. To load this module, run:

```
module load netcdf-cxx4
```

List of master packages:

- [libnetcdf-cxx4-gnu-hpc](#)
- [libnetcdf-cxx4-gnu-hpc-devel](#)
- [netcdf-cxx4-gnu-hpc-tools](#)

### [netcdf-fortran Packages](#)

The [netcdf-fortran](#) packages provide FORTRAN bindings for the NetCDF API, with and without MPI support.

## For More Information

For general information about Lmod and modules, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 8.4 NumPy Python Library

NumPy is a general-purpose array-processing package designed to efficiently manipulate large multi-dimensional arrays of arbitrary records without sacrificing too much speed for small multi-dimensional arrays.

NumPy is built on the Numeric code base and adds features introduced by numarray as well as an extended C API and the ability to create arrays of arbitrary type which also makes NumPy suitable for interfacing with general-purpose data-base applications.

There are also basic facilities for discrete Fourier transform, basic linear algebra and random number generation.

This package is available both for Python 2 and Python 3. The specific compiler toolchain and MPI library flavor modules must be loaded for this library. The correct library module for the Python version used needs to be specified when loading this module. To load this module, run:

- for Python 2: module load python2-numpy
- for Python 3: module load python3-numpy

List of master packages:

- python2-numpy-gnu-hpc
- python2-numpy-gnu-hpc-devel
- python3-numpy-gnu-hpc
- python3-numpy-gnu-hpc-devel

## 8.5 OpenBLAS Library — Optimized BLAS Library

OpenBLAS is an optimized BLAS (Basic Linear Algebra Subprograms) library based on GotoBLAS2 1.3, BSD version. It provides the BLAS API. It is shipped as a package enabled for environment modules and thus requires using Lmod to select a version. There are two variants of this library, an OpenMP-enabled variant and a pthreads variant.

## OpenMP-Enabled Variant

The OpenMP variant covers all use cases:

- **Programs using OpenMP.** This requires the OpenMP-enabled library version to function correctly.
- **Programs using pthreads.** This requires an OpenBLAS library without pthread support. This can be achieved with the OpenMP-version. We recommend limiting the number of threads that are used to 1 by setting the environment variable `OMP_NUM_THREADS=1`.
- **Programs without pthreads and without OpenMP.** Such programs can still take advantage of the OpenMP optimization in the library by linking against the OpenMP variant of the library.

When linking statically, ensure that `libgomp.a` is included by adding the linker flag `-lgomp`.

## pthreads Variant

The pthreads variant of the OpenBLAS library can improve the performance of single-threaded programs. The number of threads used can be controlled with the environment variable `OPENBLAS_NUM_THREADS`.

## Installation and Usage

This module requires loading a compiler toolchain beforehand. To select the latest version of this module provided, run:

- OpenMP version:

```
module load openblas-pthreads
```

- pthreads version:

```
module load openblas
```

List of master package for:

- `libopenblas-gnu-hpc`
- `libopenblas-gnu-hpc-devel`

- [libopenblas-pthreads-gnu-hpc](#)
- [libopenblas-pthreads-gnu-hpc-devel](#)

For general information about Lmod and modules, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 8.6 PAPI HPC Library — Consistent Interface for Hardware Performance Counters

PAPI (package [papi](#)) provides a tool with a consistent interface and methodology for use of the performance counter hardware found in most major microprocessors.

This package serves all compiler toolchains and does not require a compiler toolchain to be selected. The latest version provided can be selected by running:

```
module load papi
```

List of master packages:

- [papi-hpc](#)
- [papi-hpc-devel](#)

For general information about Lmod and modules, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 8.7 PETSc HPC Library — Solver for Partial Differential Equations

PETSc is a suite of data structures and routines for the scalable (parallel) solution of scientific applications modeled by partial differential equations.

This module requires loading a compiler toolchain as well as an MPI library flavor beforehand. To load this module, run:

```
module load petsc
```

List of master packages:

- [libpetsc-gnu-openmpi1-hpc](#)
- [petsc-gnu-openmpi1-hpc-devel](#)

- [`libpetsc-gnu-mvapich2-hpc`](#)
- [`petsc-gnu-mvapich2-hpc-devel`](#)

For general information about Lmod and modules, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 8.8 ScaLAPACK HPC Library — LAPACK Routines

The library ScaLAPACK (short for "Scalable LAPACK") includes a subset of LAPACK routines designed for distributed memory MIMD-parallel computers.

This library requires loading both a compiler toolchain and an MPI library flavor beforehand. To load this library, run:

```
module load scalapack
```


List of master packages:

- [`libblacs2-gnu-openmpi1-hpc`](#)
- [`libblacs2-gnu-openmpi1-hpc-devel`](#)
- [`libscalapack2-gnu-openmpi1-hpc`](#)
- [`libscalapack2-gnu-openmpi1-hpc-devel`](#)
- [`libblacs2-gnu-mvapich2-hpc`](#)
- [`libblacs2-gnu-mvapich2-hpc-devel`](#)
- [`libscalapack2-gnu-mvapich2-hpc`](#)
- [`libscalapack2-gnu-mvapich2-hpc-devel`](#)

For general information about Lmod and modules, see [Section 7.7, “Lmod — Lua-based Environment Modules”](#).

## 9 Obtaining Source Code


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