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# Trilinos Developers Guide

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# Trilinos Developers Guide

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## Abstract

The Trilinos Project is an effort to facilitate the design, development, integration and ongoing support of mathematical software libraries. A new software capability is introduced into Trilinos as a *package*. A Trilinos package is an integral unit usually developed by a small team of experts in a particular algorithms area such as algebraic preconditioners, nonlinear solvers, etc.

The Trilinos Developers Guide is a resource for new and existing Trilinos package developers. Topics covered include how to configure and build Trilinos, what is required to integrate an existing package into Trilinos and examples of how those requirements can be met, as well as what tools and services are available to Trilinos packages. Also discussed are some common practices that are followed by many Trilinos package developers. Finally, a snapshot of current Trilinos packages and their interoperability status is provided.

# Acknowledgement

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# Nomenclature

Package A collection of software focused on one primary class of numerical methods. Also a fundamental, integral unit in the Trilinos framework.

Trilinos The name of the project. Also a Greek term which, loosely translated means “a string of pearls,” meant to evoke an image that each Trilinos package is a pearl in its own right, but is even more valuable when combined with other packages.

new_package A sample Trilinos package containing all of the infrastructure to install a new package into the Trilinos framework. Contains the basic directory structure, a collection of sample configuration and build files and a sample “Hello World” package.

Anasazi An extensible and interoperable framework for large-scale eigenvalue algorithms.The motivation for this framework is to provide a generic interface to a collection of algorithms for solving large-scale eigenvalue problems.

AztecOO Linear solver package based on preconditioned Krylov methods. A follow-on to the Aztec solver package [19]. Supports all Aztec interfaces and functionality, but also provides significant new functionality.

Belos A Greek term meaning “arrow.” Belos is the next generation of iterative solvers. Belos solvers are written using “generic” programming techniques. In other words, Belos is written using TSF abstract interfaces and therefore has no explicit dependence on any concrete linear algebra library. Instead, Belos solvers can be used with any concrete linear algebra library that implements the TSF abstract interfaces.

Ifpack Object-oriented algebraic preconditioner, compatible with Epetra and AztecOO. Supports construction and use of parallel distributed memory preconditioners such as overlapping Schwarz domain decomposition, Jacobi scaling and local Gauss-Seidel relaxations.

Komplex Complex linear equation solver using equivalent real formulations [12], built on top of Epetra and AztecOO.

Meros Segregated preconditioning package. Provides scalable block preconditioning for problems that coupled simultaneous solution variables such as Navier-Stokes problems.

ML Algebraic multi-level preconditioner package. Provides scalable preconditioning capabilities for a variety of problem classes.

NOX A collection of nonlinear solvers, designed to be easily integrated into an application and used with many different linear solvers.

Petra A Greek term meaning "foundation." Trilinos has three Petra libraries: Epetra, Tpetra and Jpetra that provide basic classes for constructing and manipulating matrix, graph and vector objects. Epetra is the current production version that is split into two packages, one core and one extensions.

TSF Composed of several packages. TSFCore provides a basic collection of abstract interfaces to vectors, linear operators, solvers, etc. These interfaces provide a common interface for applications to access one or more packages that implement the abstract interface. These interfaces can also be used by other packages in Trilinos to accomplish the same purpose. TSF Extended builds on top of TSFCore, providing implicit aggregation capabilities and overloaded operators.

# Introduction

The Trilinos Project is an effort to facilitate the design, development, integration and ongoing support of mathematical software libraries. Trilinos provides a framework and set of tools for document and source code control, software issue tracking, developer and user communication, automatic testing, portable configuration and building, and software distribution. Trilinos also provides a set of core utility libraries that provide common vector, graph and matrix capabilities, as well as a common abstract interface for applications to access any appropriate Trilinos package.

A new software capability is introduced into Trilinos as a *package*. A Trilinos package is an integral unit usually developed by a small team of experts in a particular algorithms area such as algebraic preconditioners, nonlinear solvers, etc.

The overall objective of Trilinos is to promote rapid development and deployment of high-quality, state-of-the-art mathematical software in an environment that supports interoperability of packages while preserving package independence. The Trilinos design allows individual packages to grow and mature autonomously to the extent the algorithms and package developers dictate.

The Trilinos Developers Guide is meant to assist new and existing Trilinos package developers. Topics covered include how to configure and build Trilinos, what is required to integrate an existing package into Trilinos and examples of how those requirements can be met, as well as what tools and services are available to Trilinos packages. Also discussed are some common practices that are followed by many Trilinos package developers. Finally, a snapshot of current Trilinos packages and their interoperability status is provided, along with a list of supported computer platforms.

For a higher-level view of the Trilinos project, please see An Overview of the Trilinos Project [16]. The current set of packages in Trilinos is shown in Figure .

# How To Use This Guide

Although all sections of this guide will be useful to most developers, it is worth mentioning that this guide supports three types of development activities:

1. New Project: Development of a new package using little or no existing software as a base. All sections of this guide are appropriate reading.

2. Integration of an existing third-party software: In this case, existing software is being imported into the Trilinos framework. In this case, Section  is particularly important, as are Sections ,  and .

3. Ongoing development: For existing Trilinos package developers, Sections and  are designed as a reference for software engineering practices and policies for Trilinos development.

# Typographical Conventions

Our typographical conventions are found in Table 1.

| Notation | Example | Description |
|---|---|---|
| `Verbatim text` | `../configure --enable-mpi` | Commands, directory and file name examples, and other text associated with text displayed in a computer terminal window. |
| `CAPITALIZED_TEXT` | `CXXFLAGS` | Environment variables used to configure how tools such as compilers behave. |
| `[text in angle brackets]` | `../configure <user parameters>` | Optional parameters. |

**Table 1.** Typographical Conventions for This Document.

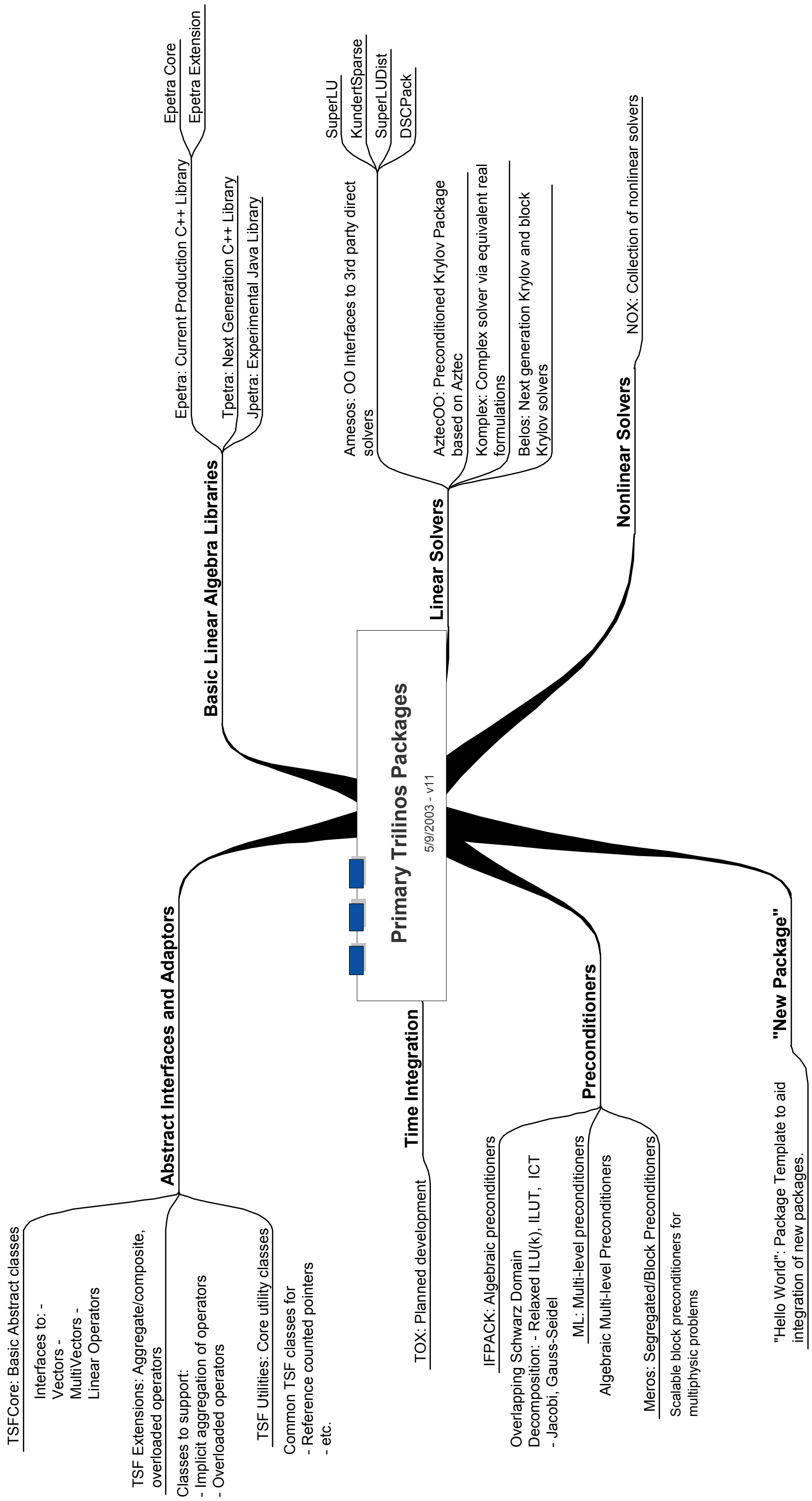
Primary Trilinos Packages
5/9/2003 - v11
Basic Linear Algebra Libraries
Epetra: Current Production C++ Library
Epetra Core
Epetra Extension
Tpetra: Next Generation C++ Library
Jpetra: Experimental Java Library
Linear Solvers
Amesos: OO Interfaces to 3rd party direct solvers
SuperLU
KundertSparse
SuperLUDist
DSCPack
AztecOO: Preconditioned Krylov Package based on Aztec
Komplex: Complex solver via equivalent real formulations
Belos: Next generation Krylov and block Krylov solvers
Nonlinear Solvers
NOX: Collection of nonlinear solvers
"New Package"
"Hello World": Package Template to aid integration of new packages.
Preconditioners
IFPACK: Algebraic preconditioners
Overlapping Schwarz Domain Decomposition: - Relaxed ILU(k), ILUT, ICT - Jacobi, Gauss-Seidel
ML: Multi-level preconditioners
Algebraic Multi-level Preconditioners
Meros: Segregated/Block Preconditioners
Scalable block preconditioners for multiphysic problems
Time Integration
TOX: Planned development
Abstract Interfaces and Adaptors
TSFCore: Basic Abstract classes
Interfaces to: - Vectors - MultiVectors - Linear Operators
TSF Extensions: Aggregate/composite, overloaded operators
Classes to support: - Implicit aggregation of operators - Overloaded operators
TSF Utilities: Core utility classes
Common TSF classes for - Reference counted pointers - etc.

**Figure 1.** Current collection of Trilinos Packages

# Getting Started

This chapter covers some of the basics that a developer will need to know when beginning to work on the Trilinos project. We address how to configure and build Trilinos, as well as how to add files to an existing package.

# Recommended Build Directory Structure

Via Autoconf and Automake the Trilinos configuration facilities provide a great deal of flexibility for configuring and building the existing Trilinos packages. However, unless you have prior experience with Autotools, we recommend the following process to build and maintain your local builds of Trilinos.

To start, we defined two useful terms:

- Source tree - The directory structure where source files are found. A source tree is obtained by expanding a distribution tar ball, or by checking out a copy of the Trilinos repository.
- Build tree - The directory structure where object and library files, as well as executables are located.

Although it is possible to run `./configure` from the source tree (in the directory where the configure file is located), we recommend that a user have separate build trees. The greatest advantage to having a separate build tree is that multiple builds of the libraries can be maintained from the same source tree, for example, serial and parallel libraries. A less obvious advantage is that this approach eliminates problems with configuring in a 'dirty' directory (one that has already been configured in).

**Key Point:** . . . we recommend that a user have separate build trees . . . multiple builds of the libraries can be maintained from the same source tree . . . eliminates problems with configuring in a 'dirty' directory . . .

Setting up a build tree is straight-forward. Figure illustrates the recommended layout. First, from the highest directory in the source tree (Trilinos for a repository copy, Trilinos-3.0.1 for a distribution), make a new directory - for an MPI build on a Linux platform, a typical name could be `LINUX_MPI` . Finally, from the new dirctory, type

**Command:** `../configure --with-mpi-compilers`

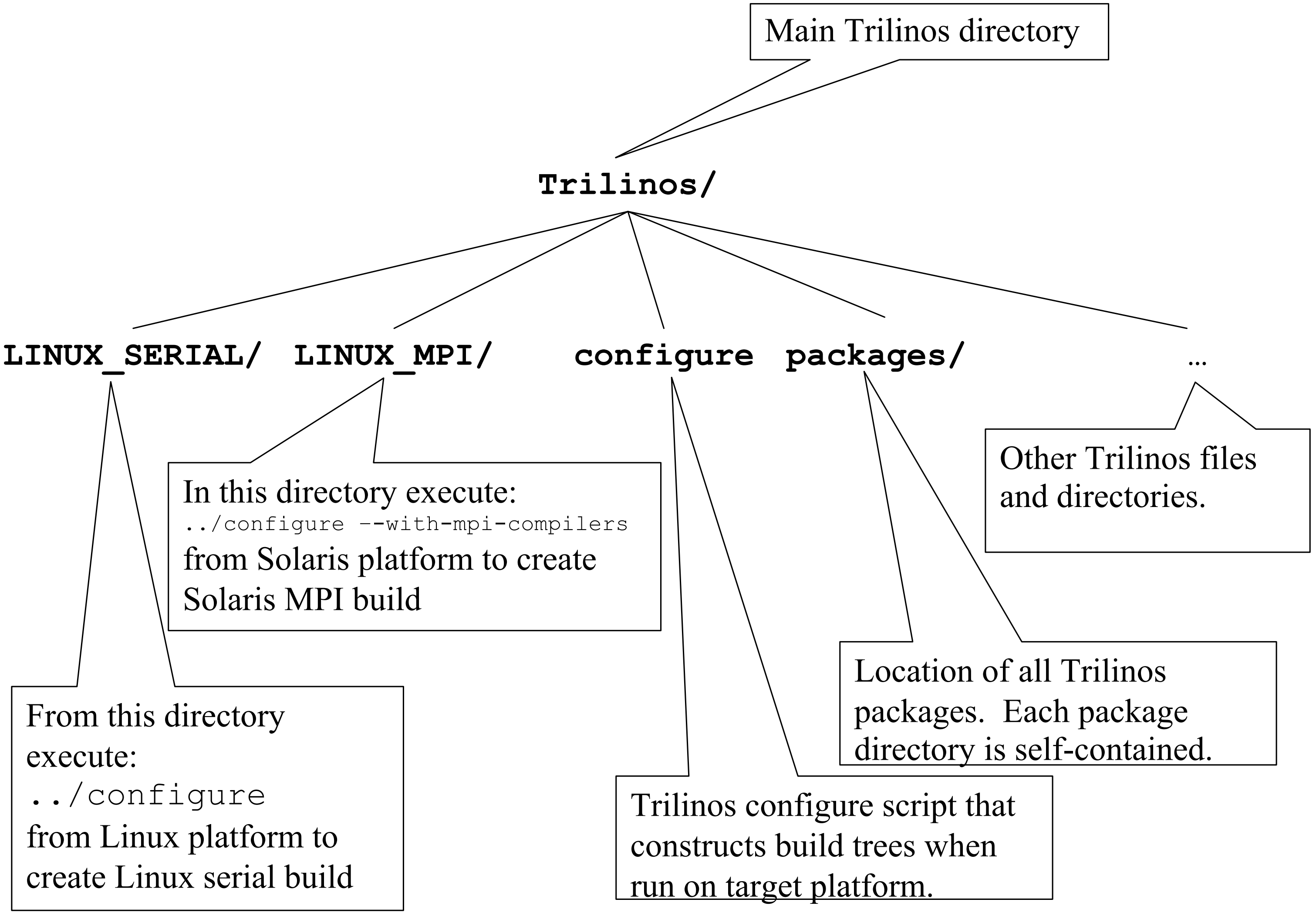

**Figure 2.** Recommended Layout for Trilinos Build Directories

(Note that various configure options might be necessary, see Section for details.) Finally, type

**Command:** `make`

In summary:

```
cd Trilinos
mkdir LINUX_MPI
cd LINUX_MPI
../configure --with-mpi-compilers
make
```

At this point, the MPI version of Trilinos on a Linux platform is built and completely contained in the `LINUX_MPI` directory. No files outside this directory have been modified. This procedure can be repeated for any number of build targets.

**Note:** Although we recommend the above location for build trees, they can be set up anywhere.

# Configuring Trilinos

To configure from a remote build tree, simply run the configure script in source tree from the root of the build tree. In the example above, cd to the SOLARIS_SERIAL directory and type

**Command:** `../configure <options as described below>`

A detailed list of configure options can be seen by typing

**Command:** `./configure --help=recursive`

from the top level of the source tree. This will display the help page for the Trilinos level as well as all Trilinos packages that use autoconf and automake. The output from this command is quite extensive. To view the help page for an individual package, cd to the home directory for the package in the source tree and type

**Command:** `./configure --help`

This command will also display the help page for Trilinos level options when used from the Trilinos home directory in the source tree.

The user needs to provide two important pieces of information at this stage. First, the user needs to describe what kind of a build is needed. For instance, serial or mpi, all of the packages, or just a proper subset.

For example, to configure for serial libraries, no action is necessary, but to configure for parallel libraries, a user must append appropriate arguments to the configure invocation line as described in “Trilinos Configuration Options”, section .

Also, to build the default set of Trilinos libraries, no action is necessary, but to exclude a default package, komplex for example, a user must append `--disable-komplex` to the configure invocation line. Similarly, to include a package that is not currently built by default, NOX for example, users must append `--enable-nox` to the configure invocation line. It is recommended that users always configure from the Trilinos level and use `--disable-<package>` as necessary, rather than trying to configure from a lower level. To see which packages build by default and which ones don't, simply cd to the Trilinos home directory and type

**Command:** `./configure --help`

**NOTES:**

1. **Ifpack versions:** Ifpack is divided into old and new versions. Future ifpack developments will replace all of old ifpack, but at this time some users will need to append `--enable-oldifpack` to the configure line.

2. **Enabling/Disabling package builds:** The configure process is set up to detect when a `--disable-<package>` option would break a package dependency. For example, ifpack depends on epetra, so if a user wants to build ifpack, but types `--disable-epetra` , epetra will be configured and built anyway. However, some of the tests and examples have different dependencies than the core package. It is possible that not all of these dependencies have been accounted for. Please submit a bug report for any problems found with this matter.

3. **Installing libraries and header files:** To install libraries and header files in a particular location, use `--prefix=<dir>` on the configure line. If this option is used, libraries will be located in `<dir>/lib` and header files in `<dir>/include/<package>` .

4. **Providing additional information to autotools:** Although autotools will at-

tempt to determine all configuration information on its own, in some situations the user must provide the name or location, or both, of anything that autotools needs and cannot find on its own. Also, if autotools selects, for example, the wrong BLAS library by default, the user must indicate which blas library to use. Other more obscure issues dealing with topics such as standards noncompliance are also dealt with here. If all required libraries (often BLAS, and LAPACK) are located in standard places, try configuring with what you have.

5. **Sample configure invocation scripts:** For a machine that requires additional configure line options, a good place to look for examples is `Trilinos/config` . There are configure invocation scripts here for various platforms. These scripts are named using the following naming convention: `arch_comm_machine` . For example `sgi64_mpi_atlantis` . Note that these scripts are examples only. Users should not necessarily expect to be able to find the perfect script and use it, but rather should choose a script for a similar machine, examine the options used in the script and figure out if those options make sense for the case at hand. Some of the scripts in the repository are not always up to date. If a user submits a script for a machine that few Trilinos developers have an account on, that script may become obsolete if it is not updated by the user who submitted it. Therefore, these scripts are primarily useful for the values of options such as `LDFLAGS` , `CPPFLAGS` , and `CXXFLAGS` .

   Users who create scripts for other machines are encouraged to check them into the repository for the benefit of other users. Users who do not have access to the repository can send their scripts to `jmwille@sandia.gov` .

# Building Trilinos

If the configure stage completed successfully, just type

**Command:** `make`

and if `--prefix` was specified,

**Command:** `make install`

The following section describes the configuration options mentioned above that are common to all Trilinos packages. These options DO NOT cover all options for all Trilinos packages.

# Trilinos Configuration Options

The following options apply to all Trilinos packages unless the option doesn't make sense for a particular package (for example, a package that does not include any Fortran code will not be sensitive to `F77=g77` ), or otherwise noted. For options specific to individual package, cd to the home directory of the source code of the individual package and type

**Command:** `./configure --help`

.

Basic Options

- `--enable-debug`

  (Nox only.) This turns on compiler debugger flags. It has not been fully tested. As an alternate, specify CXXFLAGS on the configure line.

- `--enable-opt`

  (Nox only.) This turns on compiler optimization flags. It has not been fully tested. As an alternate, specify CXXFLAGS on the configure line.

- `--with-cppflags`

  Specify additional preprocessor flags (e.g., ”-Dflag -Idir”)

- `--with-cxxflags`

  Specify additional C++ flags

- `--with-ldflags`

  Specify additional linker flags (e.g., ”-Ldir”)

- `--with-ar`

  Specify a special archiver command, the default is ”ar cru”.

Influential Environmental Variables

- `CC`

  C compiler command.

- `CFLAGS`

  C compiler flags.

- `CXX`

  C++ compiler command.

- `CXXFLAGS`

  C++ compiler flags.

- `LDFLAGS`

  Specify linker flags.

- `CPPFLAGS`

  C/C++ preprocessor flags.

- `CXXCPP`

  C++ preprocessor.

- `F77`

  Fortran 77 compiler command.

- `FFLAGS`

  Fortran 77 compiler flags.

MPI-Related Options

- `--enable-mpi`

  Enables MPI mode. Defines HAVE_MPI in the (Package)_Config.h file. Will test for the ability to preprocess the MPI header file and may test ability to link with MPI. This option is rarely necessary as many of the below options also turn MPI on.

- `--with-mpi-compilers`

  Sets CXX = mpicxx (or mpiCC if mpicxx not available), the CC = mpicc and F77 = mpif77. Automatically enables MPI mode. To use compilers other than these, specify mpi locations with the below options. If none of these options are necessary, don't forget to use `--enable-mpi` . In this case, CXX, CC, and F77 may also have to be set if the correct compilers are not chosen by default.

- `--with-mpi=MPIROOT`

  Specify the MPI root directory. Automatically enables MPI mode. If this option is set, `--with-mpi-incdir` and `--with-mpi-libdir` should not be used. `--with-mpi` is meant to be a shortcut for setting `--with-mpi-libdir=MPIROOT/lib` and `--with-mpi-incdir=MPIROOT/include` . Use these two options instead if these default locations are not correct.

- `--with-mpi-libdir=DIR`

  Specify the MPI libraries location. Defaults to MPIROOT/lib if `--with-mpi` is specified. If multiple directories must be specified, try `--with-ldflags="-L<dir1> -L<dir2>"` instead.

- `--with-mpi-libs="LIBS"`

  Specify the MPI libraries. Defaults to `"-lmpi"` if either `--with-mpi` or `--with-mpi-libdir` is specified.

- `--with-mpi-incdir=DIR`

  Specify the MPI include files location. Defaults to `MPIROOT/include` if `--with-mpi` is specified. If multiple directories must be specified, try `--with-cppflags="-I<dir1> -I<dir2>"` instead.

Developer-Related Options

- `--enable-maintainer-mode`

  Enable make rules and dependencies not useful (and sometimes confusing) to the casual installer.

Other important notes about the configure and build processes.

- Any code that links to Trilinos should define `HAVE_CONFIG_H` .

- Often the output from configure will be inadequate for diagnosing problems. A developer should look (in the buildtree) at the config.log file for the package that failed to configure properly. To figure out which package failed to configure, simply look at the bottom of the output from the `configure` command. One of the last lines should say something like:

  ```
  configure: error: /bin/sh ’../../../packages/epetra/configure’
  failed for packages/epetra.
  ```

This particular error indicates to look in `packages/epetra/config.log`. This file is useful for developers trying to build Trilinos, and those who are adding or editing autoconf-specific files such as configure.ac.

- The "classic" build system and Autotools do not mix. Trying to build with Autotools in a directory that contains a classic build will not work. Before attempting an autotools build, the classic build object, library, and executable files within the source tree should be removed.

# Adding and Removing Source Files

Commonly a developer needs to add files to or remove files from a Trilinos package. We outline the steps for adding or removing source files from a Trilinos package that uses Autotools. The below outline assumes the simple addition or removal of files. Special situations such as adding header file or library dependencies to a Trilinos package or conditionally compiling new files require a more complicated process. In addition, the following restrictions apply only to development and release branches. If a branch is established for a separate purpose (for example, to attempt an experimental restructuring of existing code), the restrictions do not apply. However, in this case, the restrictions do apply when any changes from the branch are to be merged back into the development branch.

1. Obtain the supported versions of Autoconf and Automake.

   The current supported versions of Autoconf and Automake are documented in the Trilinos repository. `Trilinos/config/AutotoolsVersionInfo` contains the information. The Trilinos team does not attempt to keep up with the latest versions of Autoconf and Automake, so please do not assume that the most recent versions are supported. The supported versions of Autoconf and Automake can always be found on software.sandia.gov. This makes software a good machine to bootstrap on. However, software does not currently have an mpi implementation installed.

2. Update source code from Trilinos repository

   Obtain the most current version of Trilinos (for the branch being worked on). From the top Trilinos directory type

   **Command:** `cvs -q update -dP`

3. Add new files to or remove obsolete files from the Trilinos repository

   To add new files abc.cpp and abc.h to the Trilinos repository, type

**Command:** `cvs add abc.cpp abc.h`

in the directory where the files are located (in a checked out version of the Trilinos repository). To remove the same files, type

**Command:** `cvs remove abc.cpp abc.h`

The above commands do not actually add the files to or remove the files from the repository, but simply prepare for the addition or removal of the files. The initial version of the file will be added to the repository later using `cvs commit`. However, this is a necessary step in the process.

4. List new files in or remove obsolete files from Makefile.am

   New source files should be placed into a category in the appropriate Makefile.am. Typically, the directory in which the new files are located will contain a Makefile.am. If not, the appropriate Makefile.am will be found in the Makefile.am that is in the parent directory directly above the directory in which the new files are located. The number of possibly categories to add files to varies a lot. For a test or example a developer will typically just add the files directly to a SOURCES primary. For a Trilinos package, there may be several categores of files. For example UTIL, CORE, and DIST, to name a few. Do not worry too much about which macro category to add the files to. The categories are simply a way to sort files into logical groups. To remove files from the build process, simply delete the file names from the appropriate Makefile.am.

5. Bootstrap

   First, from the top-level directory of the appropriate Trilinos package (for example Trilinos/packages/epetra), type

   **Command:** `./bootstrap`

   The bootstrap should complete without any errors, but the following warnings commonly occur:

   ```
   warning: do not use m4_patsubst: use patsubst or m4_bpatsubst
   warning: do not use m4_regexp: use regexp or m4_bregexp
   ```

6. Test the new code

   Reconfigure and rebuild the Trilinos package. Perform tests associated with the new code, as well as the rest of the tests for the package to insure that both the new code works and existing code has not been broken. When changes could possibly affect other packages, tests for affected packages should also be run. The simple way to run all of the required tests is to use the checkin test harness. This script can be found in `Trilinos/testharness/checkin-test-harness` . Directions explaining how to run the tests associated with the checkin test harness can be found in the comments at the top of the script itself.

7. Update source code from Trilinos repository

   Didn't we just do this? Yes, but there are two good reasons to do it again.

   Other developers could have committed changes during the past several steps of this process. Though is not likely, it is worth checking. If changes were committed, minimally the testing step will need to be redone. If files related to configuring or building were modified, more will have to be done if collisions occur. Some of the possibilities are beyond the scope of this introductory document, however we will briefly discuss the most common collision scenario. Typically the generated files will contain collisions (for example configure, Makefile.in, or aclocal.m4), while the changes in the files created by developers (for example configure.ac or Makefile.am) will be successfully merged by CVS. In this case, the best course of action is to remove the files with collisions, cd to the top level of the Trilinos package, perform a `cvs update` , and then begin the above process again from "Bootstrap" step. As long as the changes are merged in the non-generated files, bootstrapping should resolve the problem.

   An even better reason to update again before committing changes is to avoid confusion. After a bootstrap, all of the generated files will get an updated timestamp, but in most cases only some of the files will actually be modified. If a developer commits changes before updating, all of the generated files will be viewed as having been modified. This is bad for several reasons. One of the most important is that when committing changes, a developer should always verify that the list of files that are about to be committed makes sense. The list is guaranteed to not make sense if files are going to be committed that have not been changed. A cvs update will check to see if the file has really been changed or if it simply has a new timestamp.

8. Commit the changes to the Trilinos repository

   Once all of the above steps are completed, the final step is to commit the changes to the repository. Start by typing

   **Command:** `cvs commit`

   Now, look at the list of files that are to be added, removed or modified. It is easy to inadvertantly commit files. It is also easy to forget to use `cvs add` . If a file has not been added, it will not show up on the list of files to be added. Conversely, to remove a file, don't forget to use `cvs remove` .

Here are a few helpful tips to use when verifying the list of files to be committed. First, make sure that all files you modified directly appear in the list. Second, when modifying a Makefile.am, the corresponding Makefile.in will change also. Third, when modifying configure.ac, configure will also change, but some Makefile.in files may also change when using macros such as AC_SUBST. Finally, when unsure about whether or not a file should be in the commit list, abort the commit by closing the edior without saving, and chosing `abort` . Then, if abc.cpp is in question, type

**Command:** `cvs diff abc.cpp`

Then look at the diff output and see if it makes sense for the changes that were made. After verifying that all of the files that are in the list belong there, and that all files that belong in the list are, in fact, listed, remove unnecessary instances of “CVS: “ from the log message and enter an appropriate description of the changes that are to be committed. Don’t forget to reference any appropriate Bugzilla bug numbers. Further, detailed log messages make it easier to track problems in the future. It is a good habit to indicate which tests were run before making the change.

Finally, save the file, and exit the CVS editor to commit the changes.

When using the above process to commit new source code, the new source must be functioning properly, otherwise the repository will not be stable. At the same time, developers are encouraged put new code into the repository during initial development. This will ensure that work is backed up and provide version control. When adding unstable code to the repository, only two steps are necessary. First, use the `cvs add` command as mentioned above, and then modify the commit command slightly to commit only the new source by typing

**Command:** `cvs commit newfile1.cpp newfile2.cpp`

Provided that the new files are not added to the make structure, the addition of the new files should not negatively affect the repository. Distribution tarballs will even skip over the new source. A common log message for this type of commit is simply “Checking in for safe keeping; code is not yet funcitoning”. Sometimes developers will include a short description of what the code will do when complete.

# Services Available to Trilinos Packages

A number of services exist for Trilinos packages. Many of these services relate directly to the requirements and suggested practices for Trilinos packages. For example, the CVS repository is discussed below, and Trilinos packages must make use of this repository. Also, Bonsai, Bugzilla and Mailman are all tools that relate to suggested practices. (It should be noted that these services are not simply meant to satisfy SQE requirements. Rather, Bonsai, Bugzilla and Mailman have proved to be very useful tools. Using these tools together, along with the CVS repository, has led to a more time and cost effective code development process.) For more information about any of the below services, please contact the Trilinos Project Leader.

# Configuration Management

Autoconf [1], Automake [2] and Libtool [7] provide a robust, full-featured set of tools for building software across a broad set of platforms (see also the “Goat Book” [20]). Although these tools are not official standards, they are commonly used in many packages. Many existing Trilinos packages use Autoconf and Automake (and will use Libtool in the future). However, use of these tools is not required.

Package developers who are not currently using autotools, but would like to, can get a jump start by using a Trilinos package called “new_package”. This trivial package exists for one primary purpose. It walks a developer through the process of setting up a package to configure and build using autotools. General instructions for how to get started can be found in Section . Please note that new_package is a work in progess, suggestions and contributions are welcome, especially for FAQ’s.

Trilinos provides a set of M4 [5] macros that can be used by any other package when its Autoconf and Automake configure and build system is being setup. These macros perform common configuration tasks such as locating a valid LAPACK [11] library, or checking for a user- defined MPI C compiler. The macros can be found in the Trilinos CVS repository in Trilinos/config. These macros minimize the amount of redudant effort in using Autotools, and make it easier to apply a general change to the configure process for all packages.

# Regression Testing

Trilinos provides a variety of regression testing capabilities. Within a number of Trilinos packages, we employ “white box” testing where detailed information about the software is used and probed. In the future, Trilinos will perform “black box” testing of packages via the Trilinos Solver Framework (TSF) virtual class interfaces. Any package that implements the TSF interfaces (see Section  below) will be tested via this black box test environment.

# Test Harness

Trilinos packages that configure and build using Autotools can easily utilize the the Trilinos test harness. The Trilinos test harness is composed of two components.

One part of the test harness is used to run nightly tests on a number of platforms. This portion of the test harness performs a `cvs update` (gets the most recent source code) every night and then builds the libraries and runs any tests that have been integrated into the test harness.

Tests that are added as "daily" tests are run six time a week, while "weekly" tests are run once a week. Currently the nightly test harness only runs on Linux, IRIX64, and DEC/OSF1, but it will eventually run on 5-8 platforms. Packages that have not ported to a particular platform can be excluded from the testing process on that platform. Packages that do not have any tests integrated into the test harness can still benefit by testing that libraries build without errors.

The second component of the test harness is a script that should be executed by users before checking updates into the repository. This script is located in `Trilinos/testharness/checkin-test-harness` . The script provides an easy way for users to run all of the "daily" tests that have been added to the test harness for all packages from one location. Instructions for running the script can be found within the script itself.

Integrating existing tests into the testharness is not difficult. The process is discussed in `Trilinos/testharness/HowToAddToTestHarness` . Please note that this document is a work in progress.

# CVS Repository

Trilinos source code is maintained in a CVS [4] repository. It is very easy to add new packages to the repository. Packages that already use CVS can even retain their CVS history! To access the repository, one must have an account on software.sandia.gov. Once an account has been granted, set the following two environment variables (replace "your_user_name" with your user name on software):

**Command:** `CVSROOT :ext:your_user_name@software.sandia.gov:/space/CVS`

**Command:** `CVS_RSH ssh`

For those not familiar with CVS, a brief discussion covering some of the most common CVS commands is available in . For a more complete listing of CVS commands, see the Gnu CVS Home Page [4].

# Bonsai

A lot of useful information related to CVS history is accessible via a web-based interface package called Bonsai [8]. This tool can be found on the web at `http://software.sandia.gov/bonsai` . Bonsai gives a developer the ability to view the changes made to the files in the repository. The tool can be especially useful when trying to figure out which changes may have introduced bugs into a piece of code. Developers can search for changes based on filename, directory, branch, date, user who made the change, or any combination of these criteria. The entire revision histories of individual files can be utilized in finding the source of bugs. The differences between any two versions of a file may also be viewed.

# Bugzilla

Feature and issue reports are tracked using Bugzilla [9]. Bugzilla can be found on the web at `http://software.sandia.gov/bugzilla` . A Bugzilla account is necessary for submitting bugs. Those interested can sign up at the website. All bugs related to any package of Trilnos that uses Bugzilla should be submitted to Bugzilla. This even applies to cases in which one developer diagnoses and fixes a bug within a short period of time. A bug report is still very valuable in this case because it provides an artifact that outlines the problem and explains how the problem was fixed. A bug report should be filled out with as much detail as possible. Likewise, after a bug has been resolved, the developer should also provide a detailed description of the solution that was used.

NOTE: In the context of Bugzilla, “bug” can refer not only to an error in existing code, but also to a desired enhancement. For example, a bug report should be submitted to Bugzilla to report a segmentation fault that occurs when using an existing Ifpack preconditioner, and a bug report should also be submitted to request a new Ifpack preconditioner. “Issue” and “bug” are used interchangably in the discussion of Bugzilla in this guide.

# Mailman

Email lists are maintained for Trilinos as a whole and for each package through Mailman [6]. This tool can be found on the web at `http://software.sandia.gov/mailman/listinfo` . Those interested in signing up for one or more lists may do so at the website. Non-Sandians are able to sign up for the “Users” and “Announce” lists. Sandians should keep this in mind when posting to these lists.

Lists for new packages can be set up very easily. Each package usually has five mailing lists. The example mailing lists mentioned below are to be used for issues relating to all of Trilinos. The names for the lists pertaining to individual packages follow the same naming scheme, simply replace “Trilinos” with the name of the package. For example the list for Trilnos users is called Trilinos-Users and the email address is `trilinos-users@software.sandia.gov` The list for Epetra users is called Epetra-Users and the associated email address is `epetra-users@software.sandia.gov`

TIP: While those who use Epetra (or any other Trilinos package) are also “Trilinos users”, the lists are not set up to recognize this. In other words, those who subscribe to the Epetra-Users mailing list do not necessarily form a subset of those who subscribe to the Trilinos-Users mailing list. This is also true of all other list types. Keep this in mind when subscribing and posting to lists.

- Trilinos-Announce `trilinos-announce@software.sandia.gov`

  All Trilinos release announcements and other major news.

- Trilinos-Checkins `trilinos-checkins@software.sandia.gov`

  CVS commit log messages that are releated to Trilinos in general or packages that have not had separate lists established.

- Trilinos-Developers `trilinos-developers@software.sandia.gov`

  All discussions releated to Trilinos-specific development (not specific to a Trilinos package) are conducted via this list. Important development decisions that originate in other places (regular email, discussions, etc) should also be posted to this list (or to the appropriate package list). By doing this, the list archive can provide a record explaining why various changes were made over time.

- Trilinos-regression `trilinos-regression@software.sandia.gov`

  All regression test output that is not specific to a package.

- Trilinos-Users `trilinos-users@software.sandia.gov`

  List for Trilinos Users. General discussions about the use of Trilinos.

- Trilinos-Leaders `trilinos-leaders@software.sandia.gov`

  Mailing list for representatives for each Trilinos package. There are no leaders lists for individual packages.

# Portable Interface to BLAS and LAPACK

Portable interface to BLAS and LAPACK: The Basic Linear Algebra Subprograms (BLAS) [17, 14, 13] and LAPACK [11] provide a large repository of robust, high-performance mathematical software for serial and shared memory parallel dense linear algebra computations. However, the BLAS and LAPACK interfaces are Fortran specifications, and the mechanism for calling Fortran interfaces from C and C++ varies across computing platforms. Epetra (and Tpetra) provide a set of simple, portable interfaces to the BLAS and LAPACK that provide uniform access to the BLAS and LAPACK across a broad set of platforms. These interfaces are accessible to other packages.

# Trilinos Package Requirements

The philosophy of the Trilinos project is to minimize the number of explicit requirements placed on packages. Instead, we attempt to describe high-level requirements coupled with *suggested practices*. This approach allows freedom to define how requirements are satisfied yet, at the same time, provides guidance and support for packages that do not have a full set of established software engineering practices. In rare cases, requirements may be waived for packages on a case-by-case basis with the approval of the Trilinos Project Leader.

Package requirements can be split into two basic categories:

1. Interoperability mechanisms: Depending what a new Trilinos package does, it should be able to interact with one or more other Trilinos packages. Often this means being able to accept an application matrix and vector objects as either TSF objects or Epetra objects, and that the package implements relevant TSF abstract interfaces. Response to Trilinos configuration options also falls in this category.
2. Software engineering processes: This category includes formal support for software design, implementation and support, including processes for capturing user requirements, documenting design, source control, user documentation, issue tracking and product release.

Trilinos package requirements and suggested practices are summarized in Table 2.

Although there are several requirements listed in Table 2, we have structured the integration process so that packages can be incorporated into Trilinos in a gradual

| **Requirement** Package must: | **Suggested Practice** Package can: |
|---|---|
| Keep source files as a self-contained collection in a single directory under the `Trilinos/packages` directory in the Trilinos CVS repository. Change logs must be archieved and communicated to interested Trilinos developers. | Utilize Trilinos Mailman lists to archieve and communicate software change logs. |
| Have process in place to port to all supported platforms | Use the Trilinos Autotools environment and leverage the existing portability facilities already used by numerous packages. |
| Respond to all relevant configure options | Use Autoconf and Automake, utilizing the collection of Trilinos M4 macros to minimize extra effort. |
| Respond to software faults in a timely manner | Use Trilinos Bugzilla site to record and track software issues, responding to issues in order of priority. |
| Provide unit and reqression testing | Register test scripts with the Trilinos test harness, which runs nightly on a variety of supported platforms and can be used by developers before checking in changes. |

**Table 2.** Trilinos Package Requirements and Suggested Practices.

manner. Listed below are four levels of requirement compliance. It is common for new packages to address these steps one at a time, and not necessarily in the listed order.

# Add Package to Trilinos Repository

Except for rare instances, placing a package in the Trilinos CVS repository is a minimum requirement for any package to become part of Trilinos. Other than receiving approval from the Trilinos Project Leader to add a new package to Trilinos, there are no prerequisites for adding a package to the Trilinos repository. At this stage, it does not matter if the package is finished. In fact, we encourage developers to keep source files in the repository from package inception, so that source code is backed up and properly managed. Our primary restrictions are:

1. A package must be buildable on one or more platforms in order to be added to the Trilinos level configure and build structure.

2. A package must be portable to all supported platform in order to be built by default using the top-level Trilinos configure process.

A package can remain in a predistribution state indefinitely. When release branches are created, any packages not ready or approved for distribution can easily be omitted from the distribution.

# Port Package to All Supported Platforms

Although use of Trilinos Autotools is the easiest and most robust way to ensure portability across all supported platforms, a package is not required to use them. At the same time, a package must provide some mechanism to build across all platform that Trilinos supports. Typically, if not using autotools, this support would be in the form of platform-specific makefiles that the installer could invoke for a given platform.

# Respond to All Relevant Configure Options

The Trilinos top-level configure script accept numerous configuration options as described in Section . To the extent that each option is appropriate, a package should respond to each option. For example, if a package can be built with MPI support, it should respond to the `--enable-mpi` option.

Note that this does not mean the package must use Trilinos Autotools, but must simply be sensitive to certain defined parameters that are generated when the Trilinos autotools scripts are invoked.

# Respond to Issue Reports in a Timely Manner

The Trilinos Team does not have any specific requirements concerning how bugs should be submitted and processed. However, packages should have a process in place that deals with issue tracking. Packages developer teams that are looking for an efficient and useful issue tracking tool are encouraged to consider using Bugzilla, which is discussed in Section .

# Suggested Software Engineering Practices

There are many ways to define an effective software engineering process. As a result, the Trilinos project specifies very few *requirements*. At the same time, many software packages do not have well-defined practices to support good software engineering. In this section, we discuss suggested practices based on our experience with some common tools and processes for software engineering. We want to strongly emphasize that these are *suggested* practices only and we discuss them here in order to facilitate adoption of practices for packages that have few existing practices in place.

**Key Point:** . . . the Trilinos project specifies very few *requirements* . . . we discuss *suggested practices* here in order to facilitate adoption of practices for packages that have few existing practices in place . . .

# Preliminary Steps

Prior to anything else, a new Trilinos package should have the following infrastructure established. Visit the Trilinos home page [10] for information on who to contact for these prelimary steps.

The preliminary steps are:

1. Set up user accounts for each package developer on `software.sandia.gov` .
2. Establish Bugzilla Product and Component Definitions for the new package, identifying who will be default owner of each component.
3. Establish Email Lists for the package. Five lists will be defined:
   (a) `PackageName-Announce@software.sandia.gov` : Announcements such as new releases, feature lists and any other newsworthy items will be sent to this list. Any person interested in any aspect of the package should subscribe to this list.
   (b) `PackageName-Checkins@software.sandia.gov` List to which all CVS commit log message for the package are sent. Developers with an interest in the day-to-day activity of package development can subscribe to this list.

(c) `PackageName-Developers@software.sandia.gov` List by which all development discussions are conducted, or to which notes from development discussions are sent and archived. This is also the list to which detailed design documentation is sent for review and archiving.

(d) `PackageName-Regression@software.sandia.gov` List to which all automated regression test results are sent for archival purposes.

(e) `PackageName-Users@software.sandia.gov` User forum where package users can communicate with each other. Developers should monitor this list and interject comments as necessary.

These preliminary steps can generally be completed in a few hours. Once complete, the new package has a set of tools in place that address a large fraction of software engineering practices.

# Practices to Support the Software Lifecycle

One common view of software engineering processes breaks the process down into seven phases:

1. Requirements.
2. Specification.
3. Design.
4. Implementation.
5. Integration.
6. Maintenance.
7. Retirement/Replacement.

In this section we discuss suggested practices to address most of these phases. The value of adopting these practices is that they are commonly used or planned for use in a number of existing Trilinos packages. It is worth noting that testing is not a phase, but should be done at each of the above phases in the process as appropriate for that phase.

# Requirements

The majority of requirements for Trilinos packages come either directly or indirectly from funded research proposals and plans. Although these requirements are sometimes difficult to elicit from the proposals and plans, we assume that a package is satisfying requirements by virtue of being funded. Therefore we suggest that package developers track their requirements as part of the communication with funding sponsors. Regardless of the source of requirements, the appropriate documents should be kept under source control.

# Specification/Design

Package specifications can be done in many ways. An effective way for object-oriented, e.g., C++ packages is to use documented header files and a documentation tool such as Doxygen [3], and then communicate the generated HTML output to the package development team via the `package-developers@software.sandia.gov` email list. If appropriate, the clients for this feature should also be included on this correspondence. This approach satisfies both the specification and the design requirements in the case of object-oriented engineering of mathematical software.

Also worth noting in this section is that the end of the design and early part of the implementation phases is the ideal time to write the first set of unit tests. These tests can be used to confirm the interface structure and prepare for incremental implementation testing.

# Implementation

Assuming that the above approach is used to define a documented header file, implementation involves implementing the methods as specified and developing test code to verify the correctness of the implementation. Implementing new capabilites should never take place in a release branch. Changes to release branches should be limited to fixing broken code and related activities. For example, clarifying vague or incorrect documentation and making changes necessary to port to a new platform.

# Integration

Prior to checking any new code into the Trilinos CVS repository, all regression tests for any affected package should be run by the developer. Also, the developer should make a special point of confirming that nightly automatic regression tests ran successfully. Confirmation is easily done by visiting the archives for the `trilinos-regression@software.sandia.gov` . The archives contain the results of all Trilinos regression test runs. A developer will also see the results of the regression tests if their email address is explicitly listed in a regression test script.

# Maintenance

Trilinos provides a number of tools to facilitate the ongoing development and support of packages. CVS, Bugzilla, Mailman and the regression test harness are the most important ones.

1. **CVS:** The Trilinos CVS repository is the most important tool for proper maintenance. With each Trilinos release a release branch of the CVS repository is created that allows simultaneous, independent development on the main CVS branch and incremental feature development and bugfixes on the release branch. Prior to a release, each package is encouraged to stabilize its source on the main development branch, or create a tagged version of the package that is stabilized. At that point, the main Trilinos development branch will be tagged and branched using the versions of all packages as specified by the package leaders. After the Trilinos tag and branch is complete, package developers are encouraged to continue large scale active development on the main development branch, respond to bugfixes in the release branch and merge bugfixes from the release branch into the development branch. Further discussion on these topics is in Appendix . For a full discussion of advanced CVS topics, we recommend the book by Fogel and Bar [15].

2. **Bugzilla:** The Trilinos Bugzilla site allows users and developers to submit issues against a package. Issues may be submitted against the follwing components of a package:

   (a) Configuration and Building.

   (b) Documentation and Web Pages.

   (c) Examples.

   (d) Source code.

   (e) Tests.

   Issues may range from a critical source code bug to a new feature request. When an issue is submitted, the owner, submitter and any party that was explicitly listed will be notified upon submission of the issue, and when any subsequent update is made to the issue.

3. **Mail lists:** Trilinos mail lists also support ongoing maintenance by allowing developers to subscribe to the package checkins list. When subscribed to this list, all CVS commits made for the package will be sent in email form to the checkins list, and subscribers will see exactly what has changed. The other package lists mentioned in Section  above also facilitate ongoing communication between developers, users and clients.

4. **Test Harness:** The Trilinos test harness simplifies code maintenace in two ways. First, code is tested on a nightly basis on various platforms to help maintain portability. Second, developers can execute a check-in version of the test harness before committing changes. Developers can easily contribute to the coverage of the test harness. For more information about the test harness see Section .

## Retirement/Replacement

To the extent possible checkins to a release branch should not force interface changes for users. Even on the development branch, users should be notified (via the package-users mail list) that checkins are about to happen that would require an interface change to user code.

In general, we will be very slow to omit a package, or version of a package, that is in use unless there is equivalent interface and functionality support from a new package.

# Epetra and TSF: Two Special Trilinos Packages

In order to understand what Trilinos provides beyond the software engineering tools and the contributions of each Trilinos package, we briefly discuss two special Trilinos package collections: Petra and TSF. These two package collections are complimentary, with TSF providing a common abstract application programmer interface (API) for other Trilinos packages and Petra providing a common concrete implementation of basic classes used by most Trilinos packages.

## Petra

Matrices, vectors and graphs are basic objects used in most solver algorithms. Most Trilinos packages interact with these kinds of objects via abstract interfaces that allow a package to define what services and behaviors are expected from the objects, without enforcing a specific implementation. This facilitates integration of a Trilinos package into almost any existing application.

However, in order to use these packages, some concrete implementation of matrix and vector classes must be selected. Petra is an object model for parallel, distributed-memory, object-oriented matrix and vector classes. Presently there are three Petra libraries: Epetra, Jpetra and Tpetra. Of the three, Epetra is the most mature and the one presently used in production computing setttings. Epetra is a collection of concrete classes that supports the construction and use of vectors, sparse graphs, and dense and sparse matrices. It provides serial, parallel and distributed memory capabilities. It uses the BLAS and LAPACK where possible, and as a result has good performance characteristics.

In addition to providing easy construction and use of matrices, vectors and graphs in a parallel distributed memory environment, one of the most important aspects of Epetra is that every other Trilinos package can accept user data as Epetra objects. This facilitates the use of multiple Trilinos packages in combination. For example, Ifpack objects can be used as preconditioners for AztecOO, as can ML or Amesos objects. Users can also use Trilinos packages in sequence such as solving linear and eigen problems with the same matrix.

In summary, Epetra provides a common foundation for all other Trilinos packages while retaining an open architecture that allows any package to be used independently. Epetra also supports light-weight copyin of user data, allowing easy interoperability with other package such as PETSc.

# TSF

Many different algorithms are available to solve any given numerical problem. For example, there are many algorithms for solving a system of linear equations, and many solver packages are available to solve linear systems. Which package is appropriate is a function of many details about the problem being solved and the platform on which application is being run. However, even though there are many different solvers, conceptually, from an abstract view, these solvers are providing a similar capability, and it is advantageous to utilize this abstract view.be the coupling of linear solvers and eigensolvers in various ways. TSF is a collection of abstract classes that provides an application programmer interface (API) to perform the most common solver operations. It can provide a single interface to many different solvers and has powerful compositional mechanisms that support the light-weight construction of composite objects from a set of existing objects. As a result, TSF users gain easy access to many solvers and can bring multiple solvers to bear on a single problem.

TSF is split into several packages. The most important user-oriented classes are TSFCore and TSFExtended:

1. **TSFCore:** As its name implies, TSFCore contains a small set of core classes that are considered essential to almost any abstract linear algebra interface. The primary user classes in TSFCore are Vector, MultiVector, LinearOp and VectorSpace. TSFCore is discussed in detail in [18].
2. **TSFExtended:** TSFExtended builds on top of TSFCore and includes overloaded operators, block and composite operators, both of which support powerful abstraction capabilities. The Meros package relies on TSFExtended to implicitly construct sophisticated Schur compliment preconditioners in terms of exising component operators with little overhead in time or memory.

Both TSFCore and TSFExtended are important because they allow interfacing and sophisticated use of numerical linear algebra object without requiring the user or application to commit to any particular concrete linear algebra library. This approach allows us to leverage the investment in sophisticated abstract numerical algorithms across many concrete linear algebra libraries and gives application developers a single API that provides access to many solver packages.

# Integrating a Package into Trilinos

Before beginning to add a new package to Trilinos, permission must be granted by the Trilinos Project leader. In Sections , , and different aspects of adding a package to Trilinos are discussed. These sections cover how to add files to a package, what is required of a package, and how these requirements could be met, respectively. This section will address the steps that can be taken to integrate a new package into the Trilinos configure and build system. It is assumed throughout that a process like the one in Section has already been used to add all of the source files for the new package to the CVS repository. This section also assumes that the recommended directory structure for Trilinos packages (src, test, example, and doc subdirectories) is being used.

Some useful terminology for this section is listed in Table 3.

There are seven general steps that need to be followed to add a new package to the Trilinos Autotools configure and build system. Note that these steps do not have to be completed in the exact order listed below, nor does a step necessarily

| Term: | Definition: |
|---|---|
| autotool'ed package | A package that can be configured and built using Autotools. |
| new package | A package to be added to the Trilinos Autotools configure and build process. |
| new_package | A Trilinos package found in `Trilinos/packages/new_package` . Serves as a guide for adding new packages to the Trilinos Autotools configure and build processes. |
| np | The generic name for a new package that is used throughout this section. The source code for np is assumed to be located in `Trilinos/packages/np` . |

**Table 3.** Useful Terminology for Section .

have to be completed in its entirety before moving onto the next step. (For example, a portion of a library can be autotool'ed and tested before work begins on the rest of the library.) The seven steps are listed below. Note that new_package is a work in progress; comments are welcome.

1. Request services that are provided to Trilinos packages.

   See Section  for more information about services available to Trilinos packages such as mail lists and issue tracking. To request these services, contact the Trilinos Team Leader. It is helpful to complete this step early on because issue tracking can begin and mail lists can preserve initial commit comments.

2. Write the non-generated files necessary for Autoconf and Automake.

   Examples of all of the new, non-generated Autoconf and Automake files required to add a packages to the Trilinos Autotools configure and build processesare located within the new_package directory structure. Most of these fileswill need to be customized for each new package. See the individual example files for more details. Instructions for customizing are listed behind

   ```
   #np#
   ```

   in the following files:

   ```
   Trilinos/configure.ac
   Trilinos/packages/Makefile.am
   Trilinos/packages/new_package/Makefile.am
   Trilinos/packages/new_package/configure.ac
   Trilinos/packages/new_package/src/Makefile.am
   Trilinos/packages/new_package/example/Makefile.am
   Trilinos/packages/new_package/example/example1/Makefile.am
   Trilinos/packages/new_package/test/Makfile.am
   ```

```
Trilinos/packages/new_package/test/test1/Makefile.am
Trilinos/packages/new_package/test/scripts/Makfile.am
Trilinos/packages/new_package/test/scripts/daily/Makfile.am
Trilinos/packages/new_package/test/scripts/daily/mpi/Makfile.am
Trilinos/packages/new_package/test/scripts/daily/serial/Makfile.am
Trilinos/packages/new_package/test/scripts/weekly/Makfile.am
```

Note that not all of these files are used in building new_package, as it is a very simple package.

3. Create generated Autoconf and Automake files.

   IMPORTANT: Before starting this phase, please see `Trilinos/config/AutotoolsVersionInfo` , and obtain the correct version of both Autoconf and Automake.

   If `Trilinos/configure.ac` or `Trilinos/packages/Makefile.am` have been changed (these files will have changed if np is being added to the `Trilinos` level configure and build system), run

   **Command:** `./bootstrap`

   in the `Trilinos` directory. If any Autotools files at the `Trilinos/packages/np` level or lower have been changed, run

   **Command:** `./bootstrap`

   in the

   **Command:** `Trilinos/packages/np`

   directory.

   The bootstrap commands should complete without any errors, however, at this time it is not uncommon to have warnings similar to the following:

   ```
   warning: do not use m4_patsubst: use patsubst or m4_bpatsubst
   warning: do not use m4_regexp: use regexp or m4_bregexp
   ```

   These warnings will be fixed in the future.

4. Test and debug Autoconf and Automake files.

   Run `configure` with the appropriate options in a clean BUILD directory. Once the configure process completes successfully, type

   **Command:** `make`

to build the configured packages. For information about configuring and building Trilinos, see Section . Testing and debugging can become a long iterative process. Below are some tips for improving efficiency in this step.

- Consider disabling all of the packages that do not need to be built for the current task. When debugging the configure.ac script for np, consider configuring at the np level, as libraries that np is dependent on are not needed at the configure stage. (To do this, make sure to point at the np configure script from the build directory.)
- The `echo` command can be used in configure.ac to print out the value of variables for degugging purposes.
- The `AC_CHECK_FILE` macro can be used in configure.ac to check for the existence of a particular file or directory.
- Do not run `configure` in the source tree, always use a separate build tree.

5. Add all Autoconf and Automake files to the Trilinos CVS repository.

   The `bootstrap` command will generate files necessary for the configure and build processes. These files must be added to the repository because users are not required to have Autoconf or Automake. See Section  for infomation regarding how to add files to the repository.

   When the new files have been committed, a good sanity check is to checkout a new copy of Trilinos and attempt to configure and build. This will catch any files that have not been properly added.

6. Add regression tests to the Trilinos test harness.

   For more information about this step, see Section . It is not uncommon for packages to contribute tests to the test harness some time after the package has been added to Trilinos. However, it is important that all packages can be tested throughly via the test harness.

7. Perform tests.

   Buid with and without package options and run all tests associated with np on a variety of platforms. Make sure that dependencies have been properly established in the Autotools system so that users cannot disable packages that np is dependent on. Finally, run the checkin test harness to ensure that all Trilinos packages still build properly. For more information about how to use the checkin test harness, see Section .

# Improving Portability

Trilinos packages build on a wide variety of platforms. Below are a few tips for improving portability using mechanisms associated with Autoconf.

- Make sure that np_config.h is included in all your source files, directly or indirectly. The value of any package-specific options are pulled from this file. It is usually best to include it through a ConfigDefs file; read on for more information.
- Include np_config.h before (usually indirectly) including (AnyOtherPackage_ConfigDefs.h, or the Autotools PACKAGE macros will be improperly defined.
- Consider creating a file analogous to Epetra_ConfigDefs.h. This file takes care of various issues such as setting the value of package-specific options and including the best available versions of header files. For example, if np requires a math header file, configure should test for both cmath and math.h. Then the ConfigDefs file chooses to include cmath if it is available. If cmath is not available, math.h is included. If neither file is available, the configure stage will not complete successfully. All header files are included once in the ConfigDefs file, and the ConfigDefs file is included in all other source files. Don't forget to include np_config.h in the ConfigDefs file because that is the file that contains the results of the checks performed during the configure stage.

# Interoperability Status for Existing Trilinos Packages

Figure shows how the present collection of Trilinos packages depend on each other.

⊞ ← Depends On ▨ ← Can Use

| Package ↓ | Epetra | Epetra Ext | AztecOO | Komplex | Ifpack | Amesos | ML | NOX | TSF Core | TSF Ext | Belos | Meros | Anasazi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Epetra | ⊞ | | | | | | | | | | | | |
| Epetra Ext | ⊞ | ⊞ | | | | | | | | | | | |
| AztecOO | ⊞ | ⊞ | ⊞ | | | | | | | | | | |
| Komplex | ⊞ | ⊞ | ⊞ | ⊞ | | | | | | | | | |
| Ifpack | ⊞ | ⊞ | | | ⊞ | | | | | | | | |
| Amesos | ⊞ | ⊞ | | | | ⊞ | | | | | | | |
| ML | ▨ | ▨ | ▨ | | ▨ | ▨ | ⊞ | | | | | | |
| NOX | ▨ | ▨ | ▨ | | ▨ | ▨ | ⊞ | ⊞ | | | | | |
| TSFCore | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ⊞ | | ⊞ | | | | |
| TSF Ext | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ⊞ | | ⊞ | ⊞ | | | |
| Belos | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ⊞ | | ⊞ | ⊞ | ⊞ | | |
| Meros | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ⊞ | | ⊞ | ⊞ | ▨ | ⊞ | |
| Anasazi | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ⊞ | | ⊞ | ⊞ | ▨ | ▨ | ⊞ |

Based on this chart:

- AztecOO depends on Epetra, but Epetra is independent of AztecOO
- NOX can use Epetra, but is independent of Epetra.

**Figure 3.** Current Trilinos Package Dependencies

# References

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[4] Gnu cvs home page. http://www.gnu.org/software/cvs.

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# Commonly Used CVS Commands

- **Checking Out a Working Copy:** To get started, checkout a working copy of the development branch from the CVS repository. (Releases branches can be obtained by by checking out the appropriate tagged version of the repository. More about this below.)

  **Command:** `cvs checkout Trilinos`

- **Updating a Working Copy:** To update after a version has been obtained use the `cvs update` command. First, cd to the directory that is to be updated (often the Trilinos root directory). Then type:

  **Command:** `cvs -q update -dP`

  The "-q" option means "be somewhat quiet". Try an update without the "-q" to see exactly what the option does.

  The "-d" option means to get any new directories. For example, if a new package is added to the repository, but the "-d" option is not used, that new package will never appear in the working copy. However, the first time that the "-d" option is used, all of the new package directories will be downloaded, and from that time on, all CVS updates will update the directories that were downloaded. It is good practice to include this option for every CVS update.

  Finally the "-P" option "prunes" empty directories. This helps to keep the directory structure from getting more cluttered than it needs to. For example, the old "petra" and "tsf" packages were removed from the repository, but the directory structures will remain if this option is not specified. If an empty directory is needed, simply issue one update command without the "-P" and the empty directories will be restored.

- **Viewing Local Changes:** After saving changes to a working copy of a branch of the Trilinos repository, the differences between the most recently obtained version of the edited file(s) and the current local version of the file(s) can be viewed using the following command:

  **Command:** `cvs -q diff`

  The "-q" option again means "be somewhat quiet". Try a diff without the "-q" to see exactly what the option does.

  The diff command works recursively, but optionally accepts options that specify specific files and/or directories. For example, to see the diff's associated only with a file in the current directory named `abc.cpp` , as well as all files located (recursively) in the relative directory ’ examples, type

**Command:**

```
cvs -q diff abc.cpp examples
```