Installing and Using Red Hat Developer Toolset

Zuzana Zoubková
Red Hat Customer Content Services

Olga Tikhomirova
Red Hat Customer Content Services
otikhomi@redhat.com

Supriya Takkhi
Red Hat Customer Content Services

Jaromír Hradilek
Red Hat Customer Content Services

Matt Newsome
Red Hat Software Engineering

Robert Krátký
Red Hat Customer Content Services

Vladimír Slávik
Red Hat Customer Content Services
Abstract

Red Hat Developer Toolset is a Red Hat offering for developers on the Red Hat Enterprise Linux platform. The Red Hat Developer Toolset User Guide provides an overview of this product, explains how to invoke and use the Red Hat Developer Toolset versions of the tools, and links to resources with more in-depth information.
# Table of Contents

## PART I. INTRODUCTION

### CHAPTER 1. RED HAT DEVELOPER TOOLSET

1.1. ABOUT RED HAT DEVELOPER TOOLSET
   - What Is New in Red Hat Developer Toolset 9.1
1.2. MAIN FEATURES
1.3. COMPATIBILITY
   - Architecture support
1.4. GETTING ACCESS TO RED HAT DEVELOPER TOOLSET
   1.4.1. Using Red Hat Software Collections
1.5. INSTALLING RED HAT DEVELOPER TOOLSET
   1.5.1. Installing All Available Components
   1.5.2. Installing Individual Package Groups
   1.5.3. Installing Optional Packages
   1.5.4. Installing Debugging Information
1.6. UPDATING RED HAT DEVELOPER TOOLSET
   1.6.1. Updating to a Minor Version
   1.6.2. Updating to a Major Version
1.7. UNINSTALLING RED HAT DEVELOPER TOOLSET
1.8. USING RED HAT DEVELOPER TOOLSET CONTAINER IMAGES
1.9. ADDITIONAL RESOURCES
   - Online Documentation
   - See Also

## PART II. DEVELOPMENT TOOLS

### CHAPTER 2. GNU COMPILER COLLECTION (GCC)

2.1. GNU C COMPILER
   - 2.1.1. Installing the C Compiler
   - 2.1.2. Using the C Compiler
   - 2.1.3. Running a C Program
2.2. GNU C++ COMPILER
   - 2.2.1. Installing the C++ Compiler
   - 2.2.2. Using the C++ Compiler
   - 2.2.3. Running a C++ Program
   - 2.2.4. C++ Compatibility
     - 2.2.4.1. C++ ABI
2.3. GNU FORTRAN COMPILER
   - 2.3.1. Installing the Fortran Compiler
   - 2.3.2. Using the Fortran Compiler
   - 2.3.3. Running a Fortran Program
2.4. SPECIFICS OF GCC IN RED HAT DEVELOPER TOOLSET
2.5. ADDITIONAL RESOURCES
   - Installed Documentation
   - Online Documentation
   - See Also

### CHAPTER 3. GNU MAKE

3.1. INSTALLING MAKE
3.2. USING MAKE
3.3. USING MAKEFILES
3.4. ADDITIONAL RESOURCES
CHAPTER 9. STRACE ................................................................. 50
9.1. INSTALLING STRACE .................................................. 50
9.2. USING STRACE ............................................................ 50
  9.2.1. Redirecting Output to a File ...................................... 50
  9.2.2. Tracing Selected System Calls ................................... 51
  9.2.3. Displaying Time Stamps .......................................... 52
  9.2.4. Displaying a Summary ............................................ 53
  9.2.5. Tampering with System Call Results ......................... 53
9.3. ADDITIONAL RESOURCES ........................................... 54
      Installed Documentation ............................................. 54
      See Also ................................................................ 54

CHAPTER 10. LTRACE .............................................................. 55
10.1. INSTALLING LTRACE ................................................ 55
10.2. USING LTRACE .......................................................... 55
  10.2.1. Redirecting Output to a File .................................... 55
  10.2.2. Tracing Selected Library Calls ............................... 56
  10.2.3. Displaying Time Stamps ....................................... 57
  10.2.4. Displaying a Summary ....................................... 57
10.3. ADDITIONAL RESOURCES ......................................... 58
      Installed Documentation ............................................. 58
      Online Documentation ............................................... 58
      See Also ................................................................ 58

CHAPTER 11. MEMSTOMP ....................................................... 59
11.1. INSTALLING MEMSTOMP ......................................... 60
11.2. USING MEMSTOMP ................................................ 60
11.3. ADDITIONAL RESOURCES ........................................ 62
      Installed Documentation ............................................. 62
      See Also ................................................................ 62

PART IV. PERFORMANCE MONITORING TOOLS ............................ 63

CHAPTER 12. SYSTEMTAP ....................................................... 64
12.1. INSTALLING SYSTEMTAP ....................................... 64
12.2. USING SYSTEMTAP ................................................ 65
12.3. ADDITIONAL RESOURCES ........................................ 65
      Installed Documentation ............................................. 65
      Online Documentation ............................................... 65
      See Also ................................................................ 66

CHAPTER 13. VALGRIND ......................................................... 67
13.1. INSTALLING VALGRIND ....................................... 67
13.2. USING VALGRIND ................................................ 68
13.3. ADDITIONAL RESOURCES ........................................ 68
      Installed Documentation ............................................. 68
      Online Documentation ............................................... 68
      See Also ................................................................ 69

CHAPTER 14. OPROFILE .......................................................... 70
14.1. INSTALLING OPROFILE ....................................... 70
14.2. USING OPROFILE ................................................ 70
14.3. ADDITIONAL RESOURCES ........................................ 71
      Installed Documentation ............................................. 71
      Online Documentation ............................................... 71
PART I. INTRODUCTION
CHAPTER 1. RED HAT DEVELOPER TOOLSET

1.1. ABOUT RED HAT DEVELOPER TOOLSET

Red Hat Developer Toolset is a Red Hat offering for developers on the Red Hat Enterprise Linux platform. It provides a complete set of development and performance analysis tools that can be installed and used on multiple versions of Red Hat Enterprise Linux. Executables built with the Red Hat Developer Toolset toolchain can then also be deployed and run on multiple versions of Red Hat Enterprise Linux. For detailed compatibility information, see Section 1.3, “Compatibility”.

Red Hat Developer Toolset does not replace the default system tools provided with Red Hat Enterprise Linux 7 when installed on those platforms. Instead, a parallel set of developer tools provides an alternative, newer version of those tools for optional use by developers. The default compiler and debugger, for example, remain those provided by the base Red Hat Enterprise Linux system.

What Is New in Red Hat Developer Toolset 9.1

Since Red Hat Developer Toolset 4.1, the Red Hat Developer Toolset content is also available in the ISO format together with the rest of Red Hat Software Collections content at https://access.redhat.com/downloads, specifically for Server and Workstation. Note that packages that require the Optional channel, which are discussed in Section 1.5.3, “Installing Optional Packages”, cannot be installed from the ISO image.

Table 1.1. Red Hat Developer Toolset Components

<table>
<thead>
<tr>
<th>Name</th>
<th>Version</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCC</td>
<td>9.3.1</td>
<td>A portable compiler suite with support for C, C++, and Fortran.</td>
</tr>
<tr>
<td>binutils</td>
<td>2.32</td>
<td>A collection of binary tools and other utilities to inspect and manipulate object files and binaries.</td>
</tr>
<tr>
<td>elfutils</td>
<td>0.176</td>
<td>A collection of binary tools and other utilities to inspect and manipulate ELF files.</td>
</tr>
<tr>
<td>dwz</td>
<td>0.12</td>
<td>A tool to optimize DWARF debugging information contained in ELF shared libraries and ELF executables for size.</td>
</tr>
<tr>
<td>GDB</td>
<td>8.3</td>
<td>A command line debugger for programs written in C, C++, and Fortran.</td>
</tr>
<tr>
<td>ltrace</td>
<td>0.7.91</td>
<td>A debugging tool to display calls to dynamic libraries that a program makes. It can also monitor system calls executed by programs.</td>
</tr>
<tr>
<td>strace</td>
<td>5.1</td>
<td>A debugging tool to monitor system calls that a program uses and signals it receives.</td>
</tr>
<tr>
<td>memstomp</td>
<td>0.15</td>
<td>A debugging tool to identify calls to library functions with overlapping memory regions that are not allowed by various standards.</td>
</tr>
<tr>
<td>SystemTap</td>
<td>4.1</td>
<td>A tracing and probing tool to monitor the activities of the entire system without the need to instrument, recompile, install, and reboot.</td>
</tr>
<tr>
<td>Name</td>
<td>Version</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Valgrind</td>
<td>3.15.0</td>
<td>An instrumentation framework and a number of tools to profile applications in order to detect memory errors, identify memory management problems, and report any use of improper arguments in system calls.</td>
</tr>
<tr>
<td>OProfile</td>
<td>1.3.0</td>
<td>A system-wide profiler that uses the performance monitoring hardware on the processor to retrieve information about the kernel and executables on the system.</td>
</tr>
<tr>
<td>Dyninst</td>
<td>10.1.0</td>
<td>A library for instrumenting and working with user-space executables during their execution.</td>
</tr>
<tr>
<td>make</td>
<td>4.2.1</td>
<td>A dependency-tracking build automation tool.</td>
</tr>
<tr>
<td>annobin</td>
<td>8.79</td>
<td>A build security checking tool.</td>
</tr>
</tbody>
</table>

Red Hat Developer Toolset differs from "Technology Preview" compiler releases previously supplied in Red Hat Enterprise Linux in two important respects:

1. Red Hat Developer Toolset can be used on multiple major and minor releases of Red Hat Enterprise Linux, as detailed in Section 1.3, "Compatibility".

2. Unlike Technology Preview compilers and other tools shipped in earlier Red Hat Enterprise Linux, Red Hat Developer Toolset is fully supported under Red Hat Enterprise Linux Subscription Level Agreements, is functionally complete, and is intended for production use.

Important bug fixes and security errata are issued to Red Hat Developer Toolset subscribers in a similar manner to Red Hat Enterprise Linux for two years from the release of each major version release. A new major version of Red Hat Developer Toolset is released annually, providing significant updates for existing components and adding major new components. A single minor release, issued six months after each new major version release, provides a smaller update of bug fixes, security errata, and new minor components.

Additionally, the Red Hat Enterprise Linux Application Compatibility Specification also applies to Red Hat Developer Toolset (subject to some constraints on the use of newer C++11 language features, detailed in Section 2.2.4, "C++ Compatibility").

**IMPORTANT**

Applications and libraries provided by Red Hat Developer Toolset do not replace the Red Hat Enterprise Linux system versions, nor are they used in preference to the system versions. Using a framework called Software Collections, an additional set of developer tools is installed into the `/opt` directory and is explicitly enabled by the user on demand using the `scl` utility.

**1.2. MAIN FEATURES**

Red Hat Developer Toolset 9.1 brings the following changes:
The Red Hat Developer Toolset version of the GNU Compiler Collection (GCC) has been upgraded to version 9.3.1 with many new features and bug fixes.

The Red Hat Developer Toolset version of the GNU Debugger (GDB) has been upgraded to version 8.3 with many new features and bug fixes.

For a full list of changes and features introduced in this release, see Appendix B, Changes in Version 9.1.

1.3. COMPATIBILITY

Red Hat Developer Toolset 9.1 is available for Red Hat Enterprise Linux 7 for a number of architectures.

For ABI compatibility information, see Section 2.2.4, “C++ Compatibility”.

Table 1.2. Red Hat Developer Toolset 9.1 Compatibility

<table>
<thead>
<tr>
<th></th>
<th>Runs on Red Hat Enterprise Linux 7.5</th>
<th>Runs on Red Hat Enterprise Linux 7.6</th>
<th>Runs on Red Hat Enterprise Linux 7.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built with Red Hat Enterprise Linux 7.5</td>
<td>Supported</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Built with Red Hat Enterprise Linux 7.6</td>
<td>Not supported</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Built with Red Hat Enterprise Linux 7.7</td>
<td>Not Supported</td>
<td>Not Supported</td>
<td>Supported</td>
</tr>
</tbody>
</table>

Architecture support

Red Hat Developer Toolset is available on the following architectures:

- The 64-bit Intel and AMD architectures
- The 64-bit ARM architecture
- The IBM POWER architecture (big-endian)
- The little-endian variant of IBM POWER architecture
- The IBM Z architecture

1.4. GETTING ACCESS TO RED HAT DEVELOPER TOOLSET

Red Hat Developer Toolset is an offering distributed as a part of Red Hat Software Collections.

This content set is available to customers with Red Hat Enterprise Linux 7 subscriptions listed at https://access.redhat.com/solutions/472793.

Enable Red Hat Developer Toolset by using Red Hat Subscription Management. For information on how to register your system with this subscription management service, see the Red Hat Subscription Management collection of guides.

1.4.1. Using Red Hat Software Collections
Complete the following steps to attach a subscription that provides access to the repository for Red Hat Software Collections (which includes Red Hat Developer Toolset), and then enable that repository:

1. Determine the pool ID of a subscription that provides Red Hat Software Collections (and thus also Red Hat Developer Toolset). To do so, display a list of all subscriptions that are available for your system:

   ```bash
   # subscription-manager list --available
   ```

   For each available subscription, this command displays its name, unique identifier, expiration date, and other details related to your subscription. The pool ID is listed on a line beginning with **Pool ID**.

   For a complete list of subscriptions that provide access to Red Hat Developer Toolset, see https://access.redhat.com/solutions/472793.

2. Attach the appropriate subscription to your system:

   ```bash
   # subscription-manager attach --pool=pool_id
   ```

   Replace `pool_id` with the pool ID you determined in the previous step. To verify the list of subscriptions your system has currently attached, at any time:

   ```bash
   # subscription-manager list --consumed
   ```

3. Determine the exact name of the Red Hat Software Collections repository. Retrieve repository metadata and to display a list of available **Yum** repositories:

   ```bash
   # subscription-manager repos --list
   ```

   The repository names depend on the specific version of Red Hat Enterprise Linux you are using and are in the following format:

   ```
   rhel-variant-rhscl-version-rpms
   rhel-variant-rhscl-version-debug-rpms
   rhel-variant-rhscl-version-source-rpms
   ```

   In addition, certain packages, such as `devtoolset-9-gcc-plugin-devel`, depend on packages that are only available in the **Optional** channel. The repository names with these packages use the following format:

   ```
   rhel-version-variant-optional-rpms
   rhel-version-variant-optional-debug-rpms
   rhel-version-variant-optional-source-rpms
   ```

   For both the regular repositories and optional repositories, replace `variant` with the Red Hat Enterprise Linux system variant (**server** or **workstation**), and `version` with the Red Hat Enterprise Linux system version (**7**).

4. Enable the repositories from step no. 3:

   ```bash
   # subscription-manager repos --enable repository
   ```
Replace repository with the name of the repository to enable.

Once the subscription is attached to the system, you can install Red Hat Developer Toolset as described in Section 1.5, “Installing Red Hat Developer Toolset”. For more information on how to register your system using Red Hat Subscription Management and associate it with subscriptions, see the Red Hat Subscription Management collection of guides.

1.5. INSTALLING RED HAT DEVELOPER TOOLSET

Red Hat Developer Toolset is distributed as a collection of RPM packages that can be installed, updated, uninstalled, and inspected by using the standard package management tools that are included in Red Hat Enterprise Linux. Note that a valid subscription that provides access to the Red Hat Software Collections content set is required in order to install Red Hat Developer Toolset on your system. For detailed instructions on how to associate your system with an appropriate subscription and get access to Red Hat Developer Toolset, see Section 1.4, “Getting Access to Red Hat Developer Toolset”.

**IMPORTANT**

Before installing Red Hat Developer Toolset, install all available Red Hat Enterprise Linux updates.

1.5.1. Installing All Available Components

To install all components that are included in Red Hat Developer Toolset, install the devtoolset-9 package:

```
# yum install devtoolset-9
```

This installs all development, debugging, and performance monitoring tools, and other dependent packages to the system. Alternatively, you can choose to install only a selected package group as described in Section 1.5.2, “Installing Individual Package Groups”.

**NOTE**

Note that since Red Hat Developer Toolset 3.0, the scl-utils package is not a part of Red Hat Developer Toolset, which is a change from preceding versions where the scl utility was installed along with the Red Hat Developer Toolset software collection.

1.5.2. Installing Individual Package Groups

To make it easier to install only certain components, such as the integrated development environment or the software development toolchain, Red Hat Developer Toolset is distributed with a number of meta packages that allow you to install selected package groups as described in Table 1.3, “Red Hat Developer Toolset Meta Packages”.

### Table 1.3. Red Hat Developer Toolset Meta Packages

<table>
<thead>
<tr>
<th>Package Name</th>
<th>Description</th>
<th>Installed Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>devtoolset-9-perftools</td>
<td>Performance monitoring tools</td>
<td>SystemTap, Valgrind, OProfile, Dyninst</td>
</tr>
</tbody>
</table>
To install any of these meta packages:

```
# yum install package_name
```

Replace `package_name` with a space-separated list of meta packages you want to install. For example, to install only the development and debugging toolchain and packages that depend on it:

```
# yum install devtoolset-9-toolchain
```

Alternatively, you can choose to install all available components as described in Section 1.5.1, “Installing All Available Components”.

### 1.5.3. Installing Optional Packages

Red Hat Developer Toolset is distributed with a number of optional packages that are not installed by default. To list all Red Hat Developer Toolset packages that are available to you but not installed on your system:

```
$ yum list available devtoolset-9-\*  
```

To install any of these optional packages:

```
# yum install package_name
```

Replace `package_name` with a space-separated list of packages that you want to install. For example, to install the `devtoolset-9-gdb-gdbserver` and `devtoolset-9-gdb-doc` packages:

```
# yum install devtoolset-9-gdb-gdbserver devtoolset-9-gdb-doc
```

### 1.5.4. Installing Debugging Information

To install debugging information for any of the Red Hat Developer Toolset packages, make sure that the `yum-utils` package is installed and run:

```
# debuginfo-install package_name
```

For example, to install debugging information for the `devtoolset-9-dwz` package:

```
# debuginfo-install devtoolset-9-dwz
```

Note that in order to use this command, you need to have access to the repository with these packages. If your system is registered with Red Hat Subscription Management, enable the `rhel-variant-rhscl-version-debug-rpms` repository as described in Section 1.4, “Getting Access to Red Hat
For more information on how to get access to debuginfo packages, see https://access.redhat.com/site/solutions/9907.

NOTE

The devtoolset-9-package_name-debuginfo packages can conflict with the corresponding packages from the base Red Hat Enterprise Linux system or from other versions of Red Hat Developer Toolset. This conflict also occurs in a multilib environment, where 64-bit debuginfo packages conflict with 32-bit debuginfo packages.

Manually uninstall the conflicting debuginfo packages prior to installing Red Hat Developer Toolset 9.1 and install only relevant debuginfo packages when necessary.

1.6. UPDATING RED HAT DEVELOPER TOOLSET

1.6.1. Updating to a Minor Version

When a new minor version of Red Hat Developer Toolset is available, update your Red Hat Enterprise Linux installation:

```
# yum update
```

This updates all packages on your Red Hat Enterprise Linux system, including the Red Hat Developer Toolset versions of development, debugging, and performance monitoring tools, and other dependent packages.

IMPORTANT

Use of Red Hat Developer Toolset requires the removal of any earlier pre-release versions of it. Additionally, it is not possible to update to Red Hat Developer Toolset 9.1 from a pre-release version of Red Hat Developer Toolset, including beta releases. If you have previously installed any pre-release version of Red Hat Developer Toolset, uninstall it from your system as described in Section 1.7, “Uninstalling Red Hat Developer Toolset” and install the new version as documented in Section 1.5, “Installing Red Hat Developer Toolset”.

1.6.2. Updating to a Major Version

When a new major version of Red Hat Developer Toolset is available, you can install it in parallel with the previous version. For detailed instructions on how to install Red Hat Developer Toolset on your system, see Section 1.5, “Installing Red Hat Developer Toolset”.

1.7. UNINSTALLING RED HAT DEVELOPER TOOLSET

To uninstall Red Hat Developer Toolset packages from your system:

```
# yum remove devtoolset-9\* libasan libatomic libcilkrt libitm liblsan libtsan libubsan
```

This removes the GNU Compiler Collection, GNU Debugger, binutils, and other packages that are a part of Red Hat Developer Toolset from the system.
Red Hat Developer Toolset 9.1 for Red Hat Enterprise Linux 7 no longer includes the libatomic and libitm libraries, which the above command attempts to remove, because they are not required for a proper function of Red Hat Developer Toolset components on that system. Nevertheless, the above command works as expected even on Red Hat Enterprise Linux 7.

Note that the uninstallation of the tools provided by Red Hat Developer Toolset does not affect the Red Hat Enterprise Linux system versions of these tools.

1.8. USING RED HAT DEVELOPER TOOLSET CONTAINER IMAGES

Docker-formatted container images can be used to run Red Hat Developer Toolset components inside virtual software containers, thus isolating them from the host system and allowing for their rapid deployment. For detailed description of the Red Hat Developer Toolset docker-formatted container images and Red Hat Developer Toolset Dockerfiles, see Using Red Hat Software Collections Container Images.

The docker package, which contains the Docker daemon, command-line tool, and other necessary components for building and using docker-formatted container images, is currently available only for the Server variant of the Red Hat Enterprise Linux 7 product.

Follow the instructions outlined at Getting Docker in RHEL 7 to set up an environment for building and using docker-formatted container images.

1.9. ADDITIONAL RESOURCES

For more information about Red Hat Developer Toolset and Red Hat Enterprise Linux, see the resources listed below.

Online Documentation

- Red Hat Subscription Management collection of guides – The Red Hat Subscription Management collection of guides provides detailed information on how to manage subscriptions on Red Hat Enterprise Linux.


- Red Hat Enterprise Linux 7 Developer Guide – The Developer Guide for Red Hat Enterprise Linux 7 provides more information on the Eclipse IDE, libraries and runtime support, compiling and building, debugging, and profiling on these systems.

- Red Hat Enterprise Linux 7 Installation Guide – The Installation Guide for Red Hat Enterprise Linux 7 explains how to obtain, install, and update the system.


- Using Red Hat Software Collections Container Images – This book provides information on how to use container images based on Red Hat Software Collections. The available container images
include applications, daemons, databases, as well as the Red Hat Developer Toolset container images. The images can be run on Red Hat Enterprise Linux 7 Server and Red Hat Enterprise Linux Atomic Host.

- **Get Started with Docker Formatted Container Images on Red Hat Systems** – The guide contains a comprehensive overview of information about building and using docker-formatted container images on Red Hat Enterprise Linux 7 and Red Hat Enterprise Linux Atomic.

**See Also**

- **Appendix B, Changes in Version 9.1** – A list of changes and improvements over the version of the Red Hat Developer Toolset tools in the previous version of Red Hat Developer Toolset.
PART II. DEVELOPMENT TOOLS
CHAPTER 2. GNU COMPILER COLLECTION (GCC)

The GNU Compiler Collection, commonly abbreviated GCC, is a portable compiler suite with support for a wide selection of programming languages.

Red Hat Developer Toolset is distributed with GCC 9.3.1. This version is more recent than the version included in Red Hat Enterprise Linux and provides a number of bug fixes and enhancements.

2.1. GNU C COMPILER

2.1.1. Installing the C Compiler

In Red Hat Developer Toolset, the GNU C compiler is provided by the devtoolset-9-gcc package and is automatically installed with devtoolset-9-toolchain as described in Section 1.5, “Installing Red Hat Developer Toolset”.

2.1.2. Using the C Compiler

To compile a C program on the command line, run the gcc compiler as follows:

```bash
$ scl enable devtoolset-9 'gcc -o output_file source_file...'
```

This creates a binary file named output_file in the current working directory. If the -o option is omitted, the compiler creates a file named a.out by default.

When you are working on a project that consists of several source files, it is common to compile an object file for each of the source files first and then link these object files together. This way, when you change a single source file, you can recompile only this file without having to compile the entire project. To compile an object file on the command line:

```bash
$ scl enable devtoolset-9 'gcc -o object_file -c source_file'
```

This creates an object file named object_file. If the -o option is omitted, the compiler creates a file named after the source file with the .o file extension. To link object files together and create a binary file:

```bash
$ scl enable devtoolset-9 'gcc -o output_file object_file...'
```

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset gcc as default:

```bash
$ scl enable devtoolset-9 'bash'
```
NOTE

To verify the version of gcc you are using at any point:

```
$ which gcc
```

Red Hat Developer Toolset’s gcc executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset gcc:

```
$ gcc -v
```

### Example 2.1. Compiling a C Program on the Command Line

Consider a source file named `hello.c` with the following contents:

```c
#include <stdio.h>

int main(int argc, char *argv[]) {
    printf("Hello, World\n");
    return 0;
}
```

Compile this source code on the command line by using the gcc compiler from Red Hat Developer Toolset:

```
$ scl enable devtoolset-9 'gcc -o hello hello.c'
```

This creates a new binary file called `hello` in the current working directory.

### 2.1.3. Running a C Program

When gcc compiles a program, it creates an executable binary file. To run this program on the command line, change to the directory with the executable file and run it:

```
$ ./file_name
```

### Example 2.2. Running a C Program on the Command Line

Assuming that you have successfully compiled the `hello` binary file as shown in Example 2.1, “Compiling a C Program on the Command Line”, you can run it by typing the following at a shell prompt:

```
$ ./hello
Hello, World!
```

### 2.2. GNU C++ COMPILER
2.2.1. Installing the C++ Compiler

In Red Hat Developer Toolset, the GNU C++ compiler is provided by the `devtoolset-9-gcc-c++` package and is automatically installed with the `devtoolset-9-toolchain` package as described in Section 1.5, “Installing Red Hat Developer Toolset”.

2.2.2. Using the C++ Compiler

To compile a C++ program on the command line, run the `g++` compiler as follows:

```
$scl enable devtoolset-9 'g++ -o output_file source_file...'
```

This creates a binary file named `output_file` in the current working directory. If the `-o` option is omitted, the `g++` compiler creates a file named `a.out` by default.

When you are working on a project that consists of several source files, it is common to compile an object file for each of the source files first and then link these object files together. This way, when you change a single source file, you can recompile only this file without having to compile the entire project. To compile an object file on the command line:

```
$scl enable devtoolset-9 'g++ -o object_file -c source_file'
```

This creates an object file named `object_file`. If the `-o` option is omitted, the `g++` compiler creates a file named after the source file with the `.o` file extension. To link object files together and create a binary file:

```
$scl enable devtoolset-9 'g++ -o output_file object_file...'
```

Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset `g++` as default:

```
$scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of `g++` you are using at any point:

```
$ which g++
```

Red Hat Developer Toolset’s `g++` executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset `g++`:

```
$ g++ -v
```

Example 2.3. Compiling a C++ Program on the Command Line

Consider a source file named `hello.cpp` with the following contents:

```
#include <iostream>
```
using namespace std;

int main(int argc, char *argv[]) {
    cout << "Hello, World!" << endl;
    return 0;
}

Compile this source code on the command line by using the `g++` compiler from Red Hat Developer Toolset:

```bash
$ scl enable devtoolset-9 'g++ -o hello hello.cpp'
```

This creates a new binary file called `hello` in the current working directory.

### 2.2.3. Running a C++ Program

When `g++` compiles a program, it creates an executable binary file. To run this program on the command line, change to the directory with the executable file and run it:

```bash
$ ./file_name
```

**Example 2.4. Running a C++ Program on the Command Line**

Assuming that you have successfully compiled the `hello` binary file as shown in **Example 2.3, “Compiling a C++ Program on the Command Line”**, you can run it:

```bash
$ ./hello
Hello, World!
```

### 2.2.4. C++ Compatibility

All compilers from Red Hat Enterprise Linux versions 5, 6, and 7 and from Red Hat Developer Toolset versions 1, 2, 3, 4, and 6 in any `std` mode are compatible with any other of those compilers in C++98 mode.

A compiler in C++11 or C++14 mode is only guaranteed to be compatible with another compiler in C++11 or C++14 mode if they are from the same release series (for example from Red Hat Developer Toolset 6.x).

**IMPORTANT**

- Compilers in Red Hat Developer Toolset 7.x and 8.x can build code using C++17 but this capability is experimental and not supported by Red Hat.
- All compatibility information mentioned in this section is relevant only for Red Hat-supplied versions of the GCC C++ compiler.

#### 2.2.4.1. C++ ABI

Any C++98-compliant binaries or libraries built by the Red Hat Developer Toolset toolchain explicitly with `-std=c++98` or `-std=gnu++98` can be freely mixed with binaries and shared libraries built by the Red Hat Enterprise Linux 5, 6 or 7 system GCC.
The default language standard setting for Red Hat Developer Toolset is C++14 with GNU extensions, equivalent to explicitly using option `-std=gnu++14`.

Using the C++14 language version is supported in Red Hat Developer Toolset when all C++ objects compiled with the respective flag have been built using Red Hat Developer Toolset 6 or later. Objects compiled by the system GCC in its default mode of C++98 are also compatible, but objects compiled with the system GCC in C++11 or C++14 mode are not compatible.

Using the C++17 language version is experimental and possible in Red Hat Developer Toolset only when all C++ objects compiled with the respective flag have been built using the same major version of GCC. Because later major versions of Red Hat Developer Toolset may use a later major release of GCC, forward compatibility of objects, binary files, and libraries built with the `-std=c++17` and `-std=gnu++17` options cannot be guaranteed.

**IMPORTANT**

Use of C++11 and C++14 features in your application requires careful consideration of the above ABI compatibility information.

The mixing of objects, binaries and libraries, built by the Red Hat Enterprise Linux 7 system toolchain GCC using the `-std=c++0x` or `-std=gnu++0x` flags, with those built with the `-std=c++11` or `-std=gnu++11` or `-std=c++14` or `-std=gnu++14` flags using the GCC in Red Hat Developer Toolset is explicitly not supported.

Aside from the C++11 and C++14 ABI, discussed above, the Red Hat Enterprise Linux Application Compatibility Specification is unchanged for Red Hat Developer Toolset. When mixing objects built with Red Hat Developer Toolset with those built with the Red Hat Enterprise Linux 7 toolchain (particularly `.o`/`.a` files), the Red Hat Developer Toolset toolchain should be used for any linkage. This ensures any newer library features provided only by Red Hat Developer Toolset are resolved at link-time.

A new standard mangling for SIMD vector types has been added to avoid name clashes on systems with vectors of varying lengths. The compiler in Red Hat Developer Toolset uses the new mangling by default. It is possible to use the previous standard mangling by adding the `-fabi-version=2` or `-fabi-version=3` options to GCC C++ compiler calls. To display a warning about code that uses the old mangling, use the `-Wabi` option.

On Red Hat Enterprise Linux 7, the GCC C++ compiler still uses the old mangling by default, but emits aliases with the new mangling on targets that support strong aliases. It is possible to use the new standard mangling by adding the `-fabi-version=4` option to compiler calls. To display a warning about code that uses the old mangling, use the `-Wabi` option.

### 2.3. GNU FORTRAN COMPILER

#### 2.3.1. Installing the Fortran Compiler

In Red Hat Developer Toolset, the GNU Fortran compiler is provided by the `devtoolset-9-gcc-gfortran` package and is automatically installed with `devtoolset-9-toolchain` as described in Section 1.5, “Installing Red Hat Developer Toolset”.

#### 2.3.2. Using the Fortran Compiler

To compile a Fortran program on the command line, run the `gfortran` compiler as follows:

```
$ scl enable devtoolset-9 'gfortran -o output_file source_file...'
```
This creates a binary file named `output_file` in the current working directory. If the `-o` option is omitted, the compiler creates a file named `a.out` by default.

When you are working on a project that consists of several source files, it is common to compile an object file for each of the source files first and then link these object files together. This way, when you change a single source file, you can recompile only this file without having to compile the entire project. To compile an object file on the command line:

```bash
$ scl enable devtoolset-9 'gfortran -o object_file -c source_file'
```

This creates an object file named `object_file`. If the `-o` option is omitted, the compiler creates a file named after the source file with the `.o` file extension. To link object files together and create a binary file:

```bash
$ scl enable devtoolset-9 'gfortran -o output_file object_file..'
```

Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset `gfortran` as default:

```bash
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of `gfortran` you are using at any point:

```bash
$ which gfortran
```

Red Hat Developer Toolset’s `gfortran` executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset `gfortran`:

```bash
$ gfortran -v
```

**Example 2.5. Compiling a Fortran Program on the Command Line**

Consider a source file named `hello.f` with the following contents:

```
program hello
  print *, "Hello, World!"
end program hello
```

Compile this source code on the command line by using the `gfortran` compiler from Red Hat Developer Toolset:

```bash
$ scl enable devtoolset-9 'gfortran -o hello hello.f'
```

This creates a new binary file called `hello` in the current working directory.

**2.3.3. Running a Fortran Program**
When `gfortran` compiles a program, it creates an executable binary file. To run this program on the command line, change to the directory with the executable file and run it:

```
$ ./file_name
```

### Example 2.6. Running a Fortran Program on the Command Line

Assuming that you have successfully compiled the `hello` binary file as shown in Example 2.5, “Compiling a Fortran Program on the Command Line”, you can run it:

```
$ ./hello
Hello, World!
```

## 2.4. SPECIFICS OF GCC IN RED HAT DEVELOPER TOOLSET

### Static linking of libraries

Certain more recent library features are statically linked into applications built with Red Hat Developer Toolset to support execution on multiple versions of Red Hat Enterprise Linux. This creates an additional minor security risk as standard Red Hat Enterprise Linux errata do not change this code. If the need arises for developers to rebuild their applications due to this risk, Red Hat will communicate this using a security erratum.

**IMPORTANT**

Because of this additional security risk, developers are strongly advised not to statically link their entire application for the same reasons.

### Specify libraries after object files when linking

In Red Hat Developer Toolset, libraries are linked using linker scripts which might specify some symbols through static archives. This is required to ensure compatibility with multiple versions of Red Hat Enterprise Linux. However, the linker scripts use the names of the respective shared object files. As a consequence, the linker uses different symbol handling rules than expected, and does not recognize symbols required by object files when the option adding the library is specified before options specifying the object files:

```
$ scl enable devtoolset-9 'gcc -lsomelib objfile.o'
```

Using a library from the Red Hat Developer Toolset in this manner results in the linker error message *undefined reference to symbol*. To prevent this problem, follow the standard linking practice, and specify the option adding the library after the options specifying the object files:

```
$ scl enable devtoolset-9 'gcc objfile.o -lsomelib'
```

Note that this recommendation also applies when using the base Red Hat Enterprise Linux version of GCC.

## 2.5. ADDITIONAL RESOURCES
For more information about the GNU Compiler Collections and its features, see the resources listed below.

**Installed Documentation**

- **gcc** — The manual page for the gcc compiler provides detailed information on its usage; with few exceptions, g++ accepts the same command line options as gcc. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man gcc'
  ```

- **gfortran** — The manual page for the gfortran compiler provides detailed information on its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man gfortran'
  ```

- **C++ Standard Library Documentation** — Documentation on the C++ standard library can be optionally installed:

  ```
  # yum install devtoolset-9-libstdc++-docs
  ```


**Online Documentation**

- **Red Hat Enterprise Linux 7 Developer Guide** — The Developer Guide for Red Hat Enterprise Linux 7 provides in-depth information about GCC.

- **Using the GNU Compiler Collection** — The upstream GCC manual provides an in-depth description of the GNU compilers and their usage.

- **The GNU C++ Library** — The GNU C++ library documentation provides detailed information about the GNU implementation of the standard C++ library.

- **The GNU Fortran Compiler** — The GNU Fortran compiler documentation provides detailed information on gfortran’s usage.

**See Also**

- **Chapter 1, Red Hat Developer Toolset** — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 4, binutils** — Instructions on using binutils, a collection of binary tools to inspect and manipulate object files and binaries.

- **Chapter 5, elfutils** — Instructions on using elfutils, a collection of binary tools to inspect and manipulate ELF files.

- **Chapter 6, dwz** — Instructions on using the dwz tool to optimize DWARF debugging information contained in ELF shared libraries and ELF executables for size.

- **Chapter 8, GNU Debugger (GDB)** — Instructions on debugging programs written in C, C++, and Fortran.
CHAPTER 3. GNU MAKE

The GNU make utility, commonly abbreviated make, is a tool for controlling the generation of executables from source files. make automatically determines which parts of a complex program have changed and need to be recompiled. make uses configuration files called Makefiles to control the way programs are built.

Red Hat Developer Toolset is distributed with make 4.2.1. This version is more recent than the version included in Red Hat Enterprise Linux and provides a number of bug fixes and enhancements.

3.1. INSTALLING MAKE

In Red Hat Developer Toolset, GNU make is provided by the devtoolset-9-make package and is automatically installed with devtoolset-9-toolchain as described in Section 1.5, “Installing Red Hat Developer Toolset”.

3.2. USING MAKE

To build a program without using a Makefile, run the make tool as follows:

```bash
$ scl enable devtoolset-9 'make source_file_without_extension'
```

This command makes use of implicit rules that are defined for a number of programming languages, including C, C++, and Fortran. The result is a binary file named `source_file_without_extension` in the current working directory.

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset make as default:

```bash
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of make you are using at any point:

```bash
$ which make
```

Red Hat Developer Toolset’s make executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset make:

```bash
$ make -v
```

Example 3.1. Building a C Program Using make

Consider a source file named `hello.c` with the following contents:

```c
#include <stdio.h>

int main(int argc, char *argv[]) {
```
Build this source code using the implicit rules defined by the `make` utility from Red Hat Developer Toolset:

```
$ scl enable devtoolset-9 'make hello'
cc     hello.c   -o hello
```

This creates a new binary file called `hello` in the current working directory.

### 3.3. USING MAKEFILES

To build complex programs that consist of a number of source files, `make` uses configuration files called `Makefiles` that control how to compile the components of a program and build the final executable. Makefiles can also contain instructions for cleaning the working directory, installing and uninstalling program files, and other operations.

`make` automatically uses files named `GNUmakefile`, `makefile`, or `Makefile` in the current directory. To specify another file name, use the `-f` option:

```
$ make -f make_file
```

Describing the details of Makefile syntax is beyond the scope of this guide. See `GNU make`, the upstream `GNU make` manual, which provides an in-depth description of the `GNU make` utility, Makefile syntax, and their usage.

The full `make` manual is also available in the Texinfo format as a part of your installation. To view this manual:

```
$ scl enable devtoolset-9 'info make'
```

#### Example 3.2. Building a C Program Using a Makefile

Consider the following universal Makefile named `Makefile` for building the simple C program introduced in Example 3.1, “Building a C Program Using make”. The Makefile defines some variables and specifies four rules, which consist of targets and their recipes. Note that the lines with recipes must start with the TAB character:

```c
printf(“Hello, World\n”);
return 0;
}

Build this source code using the implicit rules defined by the `make` utility from Red Hat Developer Toolset:

```
$ scl enable devtoolset-9 'make hello'
cc     hello.c   -o hello
```

This creates a new binary file called `hello` in the current working directory.

### 3.3. USING MAKEFILES

To build complex programs that consist of a number of source files, `make` uses configuration files called `Makefiles` that control how to compile the components of a program and build the final executable. Makefiles can also contain instructions for cleaning the working directory, installing and uninstalling program files, and other operations.

`make` automatically uses files named `GNUmakefile`, `makefile`, or `Makefile` in the current directory. To specify another file name, use the `-f` option:

```
$ make -f make_file
```

Describing the details of Makefile syntax is beyond the scope of this guide. See `GNU make`, the upstream `GNU make` manual, which provides an in-depth description of the `GNU make` utility, Makefile syntax, and their usage.

The full `make` manual is also available in the Texinfo format as a part of your installation. To view this manual:

```
$ scl enable devtoolset-9 'info make'
```

#### Example 3.2. Building a C Program Using a Makefile

Consider the following universal Makefile named `Makefile` for building the simple C program introduced in Example 3.1, “Building a C Program Using make”. The Makefile defines some variables and specifies four rules, which consist of targets and their recipes. Note that the lines with recipes must start with the TAB character:

```
CC=gcc
CFLAGS=-c -Wall
SOURCE=hello.c
OBJ=$(SOURCE:.c=.o)
EXE=hello

all: $(SOURCE) $(EXE)
 $(EXE): $(OBJ)
   $(CC) $(OBJ) -o $@
.o:.c
   $(CC) $(CFLAGS) $< -o $@
```
clean:
  rm -rf $(OBJ) $(EXE)

To build the hello.c program using this Makefile, run the make utility:

```bash
$ scl enable devtoolset-9 'make'
gcc -c -Wall hello.c -o hello.o
gcc hello.o -o hello
```

This creates a new object file hello.o and a new binary file called hello in the current working directory.

To clean the working directory, run:

```bash
$ scl enable devtoolset-9 'make clean'
rm -rf hello.o hello
```

This removes the object and binary files from the working directory.

### 3.4. ADDITIONAL RESOURCES

For more information about the GNU make tool and its features, see the resources listed below.

**Installed Documentation**

- **make(1)** — The manual page for the make utility provides information on its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```bash
  $ scl enable devtoolset-9 'man make'
  ```

- The full make manual, which includes detailed information about Makefile syntax, is also available in the Texinfo format. To display the info manual for the version included in Red Hat Developer Toolset:

  ```bash
  $ scl enable devtoolset-9 'info make'
  ```

**Online Documentation**

- **GNU make** — The upstream GNU make manual provides an in-depth description of the GNU make utility, Makefile syntax, and their usage.

**See Also**

- **Chapter 1, Red Hat Developer Toolset** — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 2, GNU Compiler Collection (GCC)** — Instructions on using the GNU Compiler Collection, a portable compiler suite with support for a wide selection of programming languages.

- **Chapter 4, binutils** — Instructions on using binutils, a collection of binary tools to inspect and manipulate object files and binaries.
• Chapter 5, *elfutils* — Instructions on using *elfutils*, a collection of binary tools to inspect and manipulate ELF files.

• Chapter 6, *dwz* — Instructions on using the *dwz* tool to optimize DWARF debugging information contained in ELF shared libraries and ELF executables for size.

• Chapter 8, *GNU Debugger (GDB)* — Instructions on debugging programs written in C, C++, and Fortran.
CHAPTER 4. BINUTILS

binutils is a collection of various binary tools, such as the GNU linker, GNU assembler, and other utilities that allow you to inspect and manipulate object files and binaries. See Table 4.1, “Tools Included in binutils for Red Hat Developer Toolset” for a complete list of binary tools that are distributed with the Red Hat Developer Toolset version of binutils.

Red Hat Developer Toolset is distributed with binutils 2.32. This version is more recent than the version included in Red Hat Enterprise Linux and the previous release of Red Hat Developer Toolset and provides bug fixes and enhancements.

Table 4.1. Tools Included in binutils for Red Hat Developer Toolset

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>addr2line</td>
<td>Translates addresses into file names and line numbers.</td>
</tr>
<tr>
<td>ar</td>
<td>Creates, modifies, and extracts files from archives.</td>
</tr>
<tr>
<td>as</td>
<td>The GNU assembler.</td>
</tr>
<tr>
<td>c++filt</td>
<td>Decodes mangled C++ symbols.</td>
</tr>
<tr>
<td>dwp</td>
<td>Combines DWARF object files into a single DWARF package file.</td>
</tr>
<tr>
<td>elfedit</td>
<td>Examines and edits ELF files.</td>
</tr>
<tr>
<td>gprof</td>
<td>Display profiling information.</td>
</tr>
<tr>
<td>ld</td>
<td>The GNU linker.</td>
</tr>
<tr>
<td>ld.bfd</td>
<td>An alternative to the GNU linker.</td>
</tr>
<tr>
<td>ld.gold</td>
<td>Another alternative to the GNU linker.</td>
</tr>
<tr>
<td>nm</td>
<td>Lists symbols from object files.</td>
</tr>
<tr>
<td>objcopy</td>
<td>Copies and translates object files.</td>
</tr>
<tr>
<td>objdump</td>
<td>Displays information from object files.</td>
</tr>
<tr>
<td>ranlib</td>
<td>Generates an index to the contents of an archive to make access to this archive faster.</td>
</tr>
<tr>
<td>readelf</td>
<td>Displays information about ELF files.</td>
</tr>
<tr>
<td>size</td>
<td>Lists section sizes of object or archive files.</td>
</tr>
</tbody>
</table>
### 4.1. INSTALLING BINUTILS

In Red Hat Developer Toolset, binutils are provided by the devtoolset-9-binutils package and are automatically installed with devtoolset-9-toolchain as described in Section 1.5, “Installing Red Hat Developer Toolset”.

### 4.2. USING THE GNU ASSEMBLER

To produce an object file from an assembly language program, run the as tool as follows:

```bash
$ scl enable devtoolset-9 'as option ... -o object_file source_file'
```

This creates an object file named `object_file` in the current working directory.

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset as default:

```bash
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of as you are using at any point:

```bash
$ which as
```

Red Hat Developer Toolset’s as executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset as:

```bash
$ as -v
```

### 4.3. USING THE GNU LINKER

To create an executable binary file or a library from object files, run the ld tool as follows:

```bash
$ scl enable devtoolset-9 'ld option ... -o output_file object_file ...'
```

This creates a binary file named `output_file` in the current working directory. If the -o option is omitted, the compiler creates a file named `a.out` by default.
Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset ld as default:

```bash
$scl enable devtoolset-9 'bash'
```

**NOTE**
To verify the version of ld you are using at any point:

```bash
$ which ld
```

Red Hat Developer Toolset’s ld executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset ld:

```bash
$ ld -v
```

### 4.4. USING OTHER BINARY TOOLS

The `binutils` provide many binary tools other than a linker and an assembler. For a complete list of these tools, see Table 4.1, “Tools Included in binutils for Red Hat Developer Toolset”.

To execute any of the tools that are a part of binutils:

```bash
$scl enable devtoolset-9 'tool option ... file_name'
```

See Table 4.1, “Tools Included in binutils for Red Hat Developer Toolset” for a list of tools that are distributed with `binutils`. For example, to use the `objdump` tool to inspect an object file:

```bash
$scl enable devtoolset-9 'objdump option ... object_file'
```

Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset binary tools as default:

```bash
$scl enable devtoolset-9 'bash'
```

**NOTE**
To verify the version of `binutils` you are using at any point:

```bash
$ which objdump
```

Red Hat Developer Toolset’s objdump executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset objdump:

```bash
$objdump -v
```
4.5. SPECIFICS OF BINUTILS IN RED HAT DEVELOPER TOOLSET

Static linking of libraries

Certain more recent library features are statically linked into applications built with Red Hat Developer Toolset to support execution on multiple versions of Red Hat Enterprise Linux. This creates an additional minor security risk as standard Red Hat Enterprise Linux errata do not change this code. If the need arises for developers to rebuild their applications due to this risk, Red Hat will communicate this using a security erratum.

**IMPORTANT**

Because of this additional security risk, developers are strongly advised not to statically link their entire application for the same reasons.

Specify libraries after object files when linking

In Red Hat Developer Toolset, libraries are linked using linker scripts which might specify some symbols through static archives. This is required to ensure compatibility with multiple versions of Red Hat Enterprise Linux. However, the linker scripts use the names of the respective shared object files. As a consequence, the linker uses different symbol handling rules than expected, and does not recognize symbols required by object files when the option adding the library is specified before options specifying the object files:

```bash
$scl enable devtoolset-9 'ld -lsomelib objfile.o'
```

Using a library from the Red Hat Developer Toolset in this manner results in the linker error message `undefined reference to symbol`. To prevent this problem, follow the standard linking practice, and specify the option adding the library after the options specifying the object files:

```bash
$scl enable devtoolset-9 'ld objfile.o -lsomelib'
```

Note that this recommendation also applies when using the base Red Hat Enterprise Linux version of `binutils`.

4.6. ADDITIONAL RESOURCES

For more information about `binutils`, see the resources listed below.

Installed Documentation

- `as(1)`, `ld(1)`, `addr2line(1)`, `ar(1)`, `c++filt(1)`, `dwp(1)`, `elfedit(1)`, `gprof(1)`, `nm(1)`, `objcopy(1)`, `objdump(1)`, `ranlib(1)`, `readelf(1)`, `size(1)`, `strings(1)`, `strip(1)` – Manual pages for various `binutils` tools provide more information about their respective usage. To display a manual page for the version included in Red Hat Developer Toolset:

  ```bash
  $ scl enable devtoolset-9 'man tool'
  ```

Online Documentation

- [Documentation for `binutils`](#) – The `binutils` documentation provides an in-depth description of the binary tools and their usage.

See Also
• Chapter 1, *Red Hat Developer Toolset* — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

• Chapter 5, *elfutils* — Information on how to use *elfutils*, a collection of binary tools to inspect and manipulate ELF files.

• Chapter 2, *GNU Compiler Collection (GCC)* — Information on how to compile programs written in C, C++, and Fortran.
elfutils is a collection of various binary tools, such as eu-objdump, eu-readelf, and other utilities that allow you to inspect and manipulate ELF files. See Table 5.1, "Tools Included in elfutils for Red Hat Developer Toolset" for a complete list of binary tools that are distributed with the Red Hat Developer Toolset version of elfutils.

Red Hat Developer Toolset is distributed with elfutils 0.176. This version is more recent than the version included the previous release of Red Hat Developer Toolset and provides some bug fixes and enhancements.

Table 5.1. Tools Included in elfutils for Red Hat Developer Toolset

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>eu-add2line</td>
<td>Translates addresses into file names and line numbers.</td>
</tr>
<tr>
<td>eu-ar</td>
<td>Creates, modifies, and extracts files from archives.</td>
</tr>
<tr>
<td>eu-elfcmp</td>
<td>Compares relevant parts of two ELF files for equality.</td>
</tr>
<tr>
<td>eu-elflint</td>
<td>Verifies that ELF files are compliant with the generic ABI (gABI) and psABI (processor-specific supplement ABI) specification.</td>
</tr>
<tr>
<td>eu-findtextrel</td>
<td>Locates the source of text relocations in files.</td>
</tr>
<tr>
<td>eu-make-debug-archive</td>
<td>Creates an offline archive for debugging.</td>
</tr>
<tr>
<td>eu-nm</td>
<td>Lists symbols from object files.</td>
</tr>
<tr>
<td>eu-objdump</td>
<td>Displays information from object files.</td>
</tr>
<tr>
<td>eu-ranlib</td>
<td>Generates an index to the contents of an archive to make access to this archive faster.</td>
</tr>
<tr>
<td>eu-readelf</td>
<td>Displays information about ELF files.</td>
</tr>
<tr>
<td>eu-size</td>
<td>Lists section sizes of object or archive files.</td>
</tr>
<tr>
<td>eu-stack</td>
<td>A new utility for unwinding processes and cores.</td>
</tr>
<tr>
<td>eu-strings</td>
<td>Displays printable character sequences in files.</td>
</tr>
<tr>
<td>eu-strip</td>
<td>Discards all symbols from object files.</td>
</tr>
<tr>
<td>eu-unstrip</td>
<td>Combines stripped files with separate symbols and debug information.</td>
</tr>
</tbody>
</table>
5.1. INSTALLING ELFUTILS

In Red Hat Developer Toolset, elfutils is provided by the devtoolset-9-elfutils package and is automatically installed with devtoolset-9-toolchain as described in Section 1.5, “Installing Red Hat Developer Toolset”.

5.2. USING ELFUTILS

To execute any of the tools that are part of elfutils, run the tool as follows:

$ scl enable devtoolset-9 'tool option ... file_name'

See Table 5.1, “Tools Included in elfutils for Red Hat Developer Toolset” for a list of tools that are distributed with elfutils. For example, to use the eu-objdump tool to inspect an object file:

$ scl enable devtoolset-9 'eu-objdump option ... object_file'

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset binary tools as default:

$ scl enable devtoolset-9 'bash'

NOTE

To verify the version of elfutils you are using at any point:

$ which eu-objdump

Red Hat Developer Toolset’s eu-objdump executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset eu-objdump:

$ eu-objdump -V

5.3. ADDITIONAL RESOURCES

For more information about elfutils, see the resources listed below.

See Also

- Chapter 1, Red Hat Developer Toolset – An overview of Red Hat Developer Toolset and more information on how to install it on your system.
- Chapter 2, GNU Compiler Collection (GCC) – Instructions on compiling programs written in C, C++, and Fortran.
- Chapter 4, binutils – Instructions on using binutils, a collection of binary tools to inspect and manipulate object files and binaries.
- Chapter 6, dwz – Instructions on using the dwz tool to optimize DWARF debugging information contained in ELF shared libraries and ELF executables for size.
CHAPTER 6. DWZ

**dwz** is a command line tool that attempts to optimize DWARF debugging information contained in ELF shared libraries and ELF executables for size. To do so, **dwz** replaces DWARF information representation with equivalent smaller representation where possible and reduces the amount of duplication by using techniques from Appendix E of the *DWARF Standard*.

Red Hat Developer Toolset is distributed with **dwz 0.12**.

### 6.1. INSTALLING DWZ

In Red Hat Developer Toolset, the **dwz** utility is provided by the **devtoolset-9-dwz** package and is automatically installed with **devtoolset-9-toolchain** as described in Section 1.5, “Installing Red Hat Developer Toolset”.

### 6.2. USING DWZ

To optimize DWARF debugging information in a binary file, run the **dwz** tool as follows:

```
$ scl enable devtoolset-9 'dwz option... file_name'
```

Note that you can execute any command using the **scl** utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset **dwz** as default:

```
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of **dwz** you are using at any point:

```
$ which dwz
```

Red Hat Developer Toolset’s **dwz** executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset **dwz**:

```
$ dwz -v
```

### 6.3. ADDITIONAL RESOURCES

For more information about **dwz** and its features, see the resources listed below.

**Installed Documentation**

- **dwz**(1) – The manual page for the **dwz** utility provides detailed information on its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ``
  $ scl enable devtoolset-9 'man dwz'
  ```
• Chapter 1, *Red Hat Developer Toolset* — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

• Chapter 2, *GNU Compiler Collection (GCC)* — Instructions on compiling programs written in C, C++, and Fortran.

• Chapter 4, *binutils* — Instructions on using *binutils*, a collection of binary tools to inspect and manipulate object files and binaries.

• Chapter 5, *elfutils* — Instructions on using *elfutils*, a collection of binary tools to inspect and manipulate ELF files.
CHAPTER 7. ANNOBIN

The Annobin project consists of the `annobin` plugin and the `annocheck` program.

The `annobin` plugin scans the GNU Compiler Collection (GCC) command line, the compilation state, and the compilation process, and generates the ELF notes. The ELF notes record how the binary was built and provide information for the `annocheck` program to perform security hardening checks.

The security hardening checker is part of the `annocheck` program and is enabled by default. It checks the binary files to determine whether the program was built with necessary security hardening options and compiled correctly. `annocheck` is able to recursively scan directories, archives, and RPM packages for ELF object files.

NOTE
The files must be in ELF format. `annocheck` does not handle any other binary file types.

7.1. INSTALLING ANNOBIN

In Red Hat Developer Toolset, the `annobin` plugin and the `annocheck` program are provided by the `devtoolset-9-gcc` package and are installed as described in Section 1.5.3, “Installing Optional Packages”.

7.2. USING ANNOBIN PLUGIN

To pass options to the `annobin` plugin with `gcc`, use:

$ scl enable devtoolset-9 'gcc -fplugin=annobin -fplugin-arg-annobin-option file-name'

Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset as default:

$ scl enable devtoolset-9 'bash'

NOTE
To verify the version of `annobin` you are using at any point:

$ which annobin

Red Hat Developer Toolset’s `annobin` executable path will begin with `/opt`.

7.3. USING ANNOCHECK

To scan files, directories or RPM packages with the `annocheck` program:

$ scl enable devtoolset-9 'annocheck file-name'

NOTE
`annocheck` only looks for ELF files. Other file types are ignored.
Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset as as default:

```
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of `annocheck` you are using at any point:

```
$ which annocheck
```

Red Hat Developer Toolset’s `annocheck` executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset `annocheck`:

```
$ annocheck --version
```

### 7.4. ADDITIONAL RESOURCES

For more information about `annocheck`, `annobin` and its features, see the resources listed below.

**Installed Documentation**

- `annocheck(1)` – The manual page for the `annocheck` utility provides detailed information on its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man annocheck'
  ```

- `annobin(1)` – The manual page for the `annobin` utility provides detailed information on its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man annobin'
  ```
PART III. DEBUGGING TOOLS
CHAPTER 8. GNU DEBUGGER (GDB)

The GNU Debugger, commonly abbreviated as GDB, is a command line tool that can be used to debug programs written in various programming languages. It allows you to inspect memory within the code being debugged, control the execution state of the code, detect the execution of particular sections of code, and much more.

Red Hat Developer Toolset is distributed with GDB 8.3. This version is more recent than the version included in Red Hat Enterprise Linux and the previous release of Red Hat Developer Toolset and provides some enhancements and numerous bug fixes.

8.1. INSTALLING THE GNU DEBUGGER

In Red Hat Developer Toolset, the GNU Debugger is provided by the devtoolset-9-gdb package and is automatically installed with devtoolset-9-toolchain as described in Section 1.5, “Installing Red Hat Developer Toolset”.

8.2. PREPARING A PROGRAM FOR DEBUGGING

Compiling Programs with Debugging Information

To compile a C program with debugging information that can be read by the GNU Debugger, make sure the gcc compiler is run with the -g option:

```
$ scl enable devtoolset-9 'gcc -g -o output_file input_file...'
```

Similarly, to compile a C++ program with debugging information:

```
$ scl enable devtoolset-9 'g++ -g -o output_file input_file...'
```

Example 8.1. Compiling a C Program With Debugging Information

Consider a source file named fibonacci.c that has the following contents:

```
#include <stdio.h>
#include <limits.h>

int main (int argc, char *argv[]) {
    unsigned long int a = 0;
    unsigned long int b = 1;
    unsigned long int sum;

    while (b < LONG_MAX) {
        printf("%ld ", b);
        sum = a + b;
        a = b;
        b = sum;
    }

    return 0;
}
```

Compile this program on the command line using GCC from Red Hat Developer Toolset with debugging information for the GNU Debugger.
$ scl enable devtoolset-9 'gcc -g -o fibonacci fibonacci.c'

This creates a new binary file called fibonacci in the current working directory.

**Installing Debugging Information for Existing Packages**
To install debugging information for a package that is already installed on the system:

```bash
# debuginfo-install package_name
```

Note that the **yum-utilis** package must be installed for the **debuginfo-install** utility to be available on your system.

**Example 8.2. Installing Debugging Information for the glibc Package**

Install debugging information for the **glibc** package:

```bash
# debuginfo-install glibc
```

**8.3. RUNNING THE GNU DEBUGGER**
To run the **GNU Debugger** on a program you want to debug:

```bash
$ scl enable devtoolset-9 'gdb file_name'
```

This starts the **gdb** debugger in interactive mode and displays the default prompt, *(gdb)*. To quit the debugging session and return to the shell prompt, run the following command at any time:

*(gdb)* **quit**

Note that you can execute any command using the **scl** utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset **gdb** as default:

```bash
$ scl enable devtoolset-9 'bash'
```
NOTE
To verify the version of \texttt{gdb} you are using at any point:

\begin{verbatim}
$ which gdb
\end{verbatim}

Red Hat Developer Toolset’s \texttt{gdb} executable path will begin with \texttt{/opt}. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset \texttt{gdb}:

\begin{verbatim}
$ gdb -v
\end{verbatim}

Example 8.3. Running the \texttt{gdb} Utility on the fibonacci Binary File

This example assumes that you have successfully compiled the \texttt{fibonacci} binary file as shown in Example 8.1, “Compiling a C Program With Debugging Information”.

Start debugging \texttt{fibonacci} with \texttt{gdb}:

\begin{verbatim}
$ scl enable devtoolset-9 'gdb fibonacci'
\end{verbatim}

\texttt{GNU gdb (GDB) Red Hat Enterprise Linux 8.2-2.el7}
\texttt{Copyright (C) 2017 Free Software Foundation, Inc.}
\texttt{License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>}
\texttt{This is free software: you are free to change and redistribute it.}
\texttt{There is NO WARRANTY, to the extent permitted by law. Type "show copying"}
\texttt{and "show warranty" for details.}
\texttt{This GDB was configured as "x86_64-redhat-linux-gnu".}
\texttt{Type "show configuration" for configuration details.}
\texttt{For bug reporting instructions, please see:}
\texttt{<http://www.gnu.org/software/gdb/bugs/>}.
\texttt{Find the GDB manual and other documentation resources online at:}
\texttt{<http://www.gnu.org/software/gdb/documentation/>}.
\texttt{For help, type "help".}
\texttt{Type "apropos word" to search for commands related to "word"...}
\texttt{Reading symbols from fibonacci...done.}
\texttt{(gdb)}

8.4. LISTING SOURCE CODE

To view the source code of the program you are debugging:

\begin{verbatim}
(gdb) list
\end{verbatim}

Before you start the execution of the program you are debugging, \texttt{gdb} displays the first ten lines of the source code, and any subsequent use of this command lists another ten lines. Once you start the execution, \texttt{gdb} displays the lines that are surrounding the line on which the execution stops, typically when you set a breakpoint.

You can also display the code that is surrounding a particular line:

\begin{verbatim}
(gdb) list file_name:line_number
\end{verbatim}
Similarly, to display the code that is surrounding the beginning of a particular function:

```
(gdb) list file_name:function_name
```

Note that you can change the number of lines the `list` command displays:

```
(gdb) set listsize number
```

**Example 8.4. Listing the Source Code of the fibonacci Binary File**

The `fibonacci.c` file listed in Example 8.1, “Compiling a C Program With Debugging Information” has exactly 17 lines. Assuming that you have compiled it with debugging information and you want the `gdb` utility to be capable of listing the entire source code, you can run the following command to change the number of listed lines to 20:

```
(gdb) set listsize 20
```

You can now display the entire source code of the file you are debugging by running the `list` command with no additional arguments:

```
(gdb) list
1       #include <stdio.h>
2       #include <limits.h>
3
4       int main (int argc, char *argv[]) {
5         unsigned long int a = 0;
6         unsigned long int b = 1;
7         unsigned long int sum;
8
9         while (b < LONG_MAX) {
10            printf("%ld ", b);
11            sum = a + b;
12            a = b;
13            b = sum;
14        }
15
16        return 0;
17      }
```

### 8.5. SETTING BREAKPOINTS

**Setting a New Breakpoint**

To set a new breakpoint at a certain line:

```
(gdb) break file_name:line_number
```

You can also set a breakpoint on a certain function:

```
(gdb) break file_name:function_name
```

**Example 8.5. Setting a New Breakpoint**
This example assumes that you have compiled the `fibonacci.c` file listed in Example 8.1, “Compiling a C Program With Debugging Information” with debugging information.

Set a new breakpoint at line 10:

```
(gdb) break 10
Breakpoint 1 at 0x4004e5: file fibonacci.c, line 10.
```

Listing Breakpoints
To display a list of currently set breakpoints:

```
(gdb) info breakpoints
```

Example 8.6. Listing Breakpoints
This example assumes that you have followed the instructions in Example 8.5, “Setting a New Breakpoint”.

Display the list of currently set breakpoints:

```
(gdb) info breakpoints
Num     Type           Disp Enb Address            What
1       breakpoint     keep y   0x00000000004004e5 in main at fibonacci.c:10
```

Deleting Existing Breakpoints
To delete a breakpoint that is set at a certain line:

```
(gdb) clear line_number
```

Similarly, to delete a breakpoint that is set on a certain function:

```
(gdb) clear function_name
```

Example 8.7. Deleting an Existing Breakpoint
This example assumes that you have compiled the `fibonacci.c` file listed in Example 8.1, “Compiling a C Program With Debugging Information” with debugging information.

Set a new breakpoint at line 7:

```
(gdb) break 7
Breakpoint 2 at 0x4004e3: file fibonacci.c, line 7.
```

Remove this breakpoint:

```
(gdb) clear 7
Deleted breakpoint 2
```
8.6. STARTING EXECUTION

To start an execution of the program you are debugging:

```
(gdb) run
```

If the program accepts any command line arguments, you can provide them as arguments to the `run` command:

```
(gdb) run argument...
```

The execution stops when the first breakpoint (if any) is reached, when an error occurs, or when the program terminates.

Example 8.8. Executing the fibonacci Binary File

This example assumes that you have followed the instructions in Example 8.5, "Setting a New Breakpoint".

Execute the `fibonacci` binary file:

```
(gdb) run
Starting program: /home/john/fibonacci
Breakpoint 1, main (argc=1, argv=0x7fffffffe4d8) at fibonacci.c:10
10          printf("%ld ", b);
```

8.7. DISPLAYING CURRENT VALUES

The `gdb` utility allows you to display the value of almost anything that is relevant to the program, from a variable of any complexity to a valid expression or even a library function. However, the most common task is to display the value of a variable.

To display the current value of a certain variable:

```
(gdb) print variable_name
```

Example 8.9. Displaying the Current Values of Variables

This example assumes that you have followed the instructions in Example 8.8, "Executing the fibonacci Binary File" and the execution of the `fibonacci` binary stopped after reaching the breakpoint at line 10.

Display the current values of variables `a` and `b`:

```
(gdb) print a
$1 = 0
(gdb) print b
$2 = 1
```
8.8. CONTINUING EXECUTION

To resume the execution of the program you are debugging after it reached a breakpoint:

(gdb) continue

The execution stops again when another breakpoint is reached. To skip a certain number of breakpoints (typically when you are debugging a loop):

(gdb) continue number

The gdb utility also allows you to stop the execution after executing a single line of code:

(gdb) step

Finally, you can execute a certain number of lines:

(gdb) step number

Example 8.10. Continuing the Execution of the fibonacci Binary File

This example assumes that you have followed the instructions in Example 8.8, “Executing the fibonacci Binary File”, and the execution of the fibonacci binary stopped after reaching the breakpoint at line 10.

Resume the execution:

(gdb) continue
Continuing.

Breakpoint 1, main (argc=1, argv=0x7fffffffe4d8) at fibonacci.c:10
10          printf("%ld ", b);

The execution stops the next time the breakpoint is reached.

Execute the next three lines of code:

(gdb) step 3
13          b = sum;

This allows you to verify the current value of the sum variable before it is assigned to b:

(gdb) print sum
$3 = 2

8.9. ADDITIONAL RESOURCES

For more information about the GNU Debugger and all its features, see the resources listed below.

Installed Documentation
Installing the `devtoolset-9-gdb-doc` package provides the following documentation in HTML and PDF formats in the `/opt/rh/devtoolset-9/root/usr/share/doc/devtoolset-9-gdb-doc-8.3` directory:

- The *Debugging with GDB* book, which is a copy of the upstream material with the same name. The version of this document exactly corresponds to the version of GDB available in Red Hat Developer Toolset.

- The *GDB’s Obsolete Annotations* document, which lists the obsolete GDB level 2 annotations.

### Online Documentation

- **Red Hat Enterprise Linux 7 Developer Guide** — The *Developer Guide* for Red Hat Enterprise Linux 7 provides more information on the GNU Debugger and debugging.

- **GDB Documentation** — The upstream GDB documentation includes the *GDB User Manual* and other reference material.

### See Also

- **Chapter 1, *Red Hat Developer Toolset*** — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 2, *GNU Compiler Collection (GCC)** — Further information on how to compile programs written in C, C++, and Fortran.

- **Chapter 9, *strace*** — Instructions on using the *strace* utility to monitor system calls that a program uses and signals it receives.

- **Chapter 11, *memstomp*** — Instructions on using the *memstomp* utility to identify calls to library functions with overlapping memory regions that are not allowed by various standards.
CHAPTER 9. STRACE

`strace` is a diagnostic and debugging tool for the command line that can be used to trace system calls that are made and received by a running process. It records the name of each system call, its arguments, and its return value, as well as signals received by the process and other interactions with the kernel, and prints this record to standard error output or a selected file.

Red Hat Developer Toolset is distributed with `strace 5.1`.

9.1. INSTALLING STRACE

In Red Hat Enterprise Linux, the `strace` utility is provided by the `devtoolset-9-strace` package and is automatically installed with `devtoolset-9-toolchain` as described in Section 1.5, “Installing Red Hat Developer Toolset”.

9.2. USING STRACE

To run the `strace` utility on a program you want to analyze:

```
$ scl enable devtoolset-9 'strace program argument...'
```

Replace `program` with the name of the program you want to analyze, and `argument` with any command line options and arguments you want to supply to this program. Alternatively, you can run the utility on an already running process by using the `-p` command line option followed by the process ID:

```
$ scl enable devtoolset-9 'strace -p process_id'
```

Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset `strace` as default:

```
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of `strace` you are using at any point:

```
$ which strace
```

Red Hat Developer Toolset’s `strace` executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset `strace`:

```
$ strace -V
```

9.2.1. Redirecting Output to a File

By default, `strace` prints the name of each system call, its arguments and the return value to standard error output. To redirect this output to a file, use the `-o` command line option followed by the file name:

```
$ scl enable devtoolset-9 'strace -o file_name program argument...'
```
Example 9.1. Redirecting Output to a File

Consider a slightly modified version of the `fibonacci` file from Example 8.1, “Compiling a C Program With Debugging Information”. This executable file displays the Fibonacci sequence and optionally allows you to specify how many members of this sequence to list. Run the `strace` utility on this file and redirect the trace output to `fibonacci.log`:

```
$ scl enable devtoolset-9 'strace -o fibonacci.log ./fibonacci 20'
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181 6765
```

This creates a new plain-text file called `fibonacci.log` in the current working directory.

9.2.2. Tracing Selected System Calls

To trace only a selected set of system calls, run the `strace` utility with the `-e` command line option:

```
$ scl enable devtoolset-9 'strace -e expression program argument..'
```

Replace `expression` with a comma-separated list of system calls to trace or any of the keywords listed in Table 9.1, “Commonly Used Values of the `-e` Option”. For a detailed description of all available values, see the `strace(1)` manual page.

Table 9.1. Commonly Used Values of the `-e` Option

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%file</td>
<td>System calls that accept a file name as an argument.</td>
</tr>
<tr>
<td>%process</td>
<td>System calls that are related to process management.</td>
</tr>
<tr>
<td>%network</td>
<td>System calls that are related to networking.</td>
</tr>
<tr>
<td>%signal</td>
<td>System calls that are related to signal management.</td>
</tr>
<tr>
<td>%ipc</td>
<td>System calls that are related to inter-process communication (IPC).</td>
</tr>
<tr>
<td>%desc</td>
<td>System calls that are related to file descriptors.</td>
</tr>
</tbody>
</table>

Note that the syntax `-e expression` is a shorthand for the full form `-e trace=expression`.

Example 9.2. Tracing Selected System Calls

Consider the `employee` file from Example 11.1, “Using memstomp”. Run the `strace` utility on this executable file and trace only the `mmap` and `munmap` system calls:

```
$ scl enable devtoolset-9 'strace -e mmap,munmap ./employee'
```
9.2.3. Displaying Time Stamps

To prefix each line of the trace with the exact time of the day in hours, minutes, and seconds, run the `strace` utility with the `-t` command line option:

```
$ scl enable devtoolset-9 'strace -t program argument..'
```

To also display milliseconds, supply the `-t` option twice:

```
$ scl enable devtoolset-9 'strace -tt program argument..'
```

To prefix each line of the trace with the time required to execute the respective system call, use the `-r` command line option:

```
$ scl enable devtoolset-9 'strace -r program argument..'
```

Example 9.3. Displaying Time Stamps

Consider an executable file named `pwd`. Run the `strace` utility on this file and include time stamps in the output:

```
$ scl enable devtoolset-9 'strace -tt pwd'
19:43:28.011815 execve("./pwd", ["./pwd"], [/* 36 vars */]) = 0
19:43:28.012128 brk(0)                  = 0xcd3000
19:43:28.012174 mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fc869cb0000
19:43:28.012427 open("/etc/ld.so.cache", O_RDONLY) = 3
19:43:28.012446 fstat(3, {st_mode=S_IFREG|0644, st_size=61239, ...}) = 0
```

John,john@example.com Doe,
9.2.4. Displaying a Summary

To display a summary of how much time was required to execute each system call, how many times were these system calls executed, and how many errors were encountered during their execution, run the *strace* utility with the `-c` command line option:

```
$ scl enable devtoolset-9 'strace -c program argument..'
```

**Example 9.4. Displaying a Summary**

Consider an executable file named `lsblk`. Run the *strace* utility on this file and display a trace summary:

```
$ scl enable devtoolset-9 'strace -c lsblk > /dev/null'
```

<table>
<thead>
<tr>
<th>% time</th>
<th>seconds</th>
<th>usecs/call</th>
<th>calls</th>
<th>errors</th>
<th>syscall</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.88</td>
<td>0.000055</td>
<td>1</td>
<td>106</td>
<td>16</td>
<td>open</td>
</tr>
<tr>
<td>19.12</td>
<td>0.000013</td>
<td>0</td>
<td>140</td>
<td></td>
<td>munmap</td>
</tr>
<tr>
<td>0.00</td>
<td>0.000000</td>
<td>0</td>
<td>148</td>
<td></td>
<td>read</td>
</tr>
<tr>
<td>0.00</td>
<td>0.000000</td>
<td>0</td>
<td>1</td>
<td></td>
<td>write</td>
</tr>
<tr>
<td>0.00</td>
<td>0.000000</td>
<td>0</td>
<td>258</td>
<td></td>
<td>close</td>
</tr>
<tr>
<td>0.00</td>
<td>0.000000</td>
<td>0</td>
<td>37</td>
<td></td>
<td>stat</td>
</tr>
</tbody>
</table>

...  

```
100.00 0.000068 1790 35 total
```

9.2.5. Tampering with System Call Results

Simulating errors returned from system calls can help identify missing error handling in programs.

To make a program receive a generic error as the result of a particular system call, run the *strace* utility with the `-e fault=` option and supply the system call:

```
$ scl enable devtoolset-9 'strace -e fault=syscall program argument..'
```

To specify the error type or return value, use the `-e inject=` option:

```
$ scl enable devtoolset-9 'strace -e inject=syscall:retval=return-value program argument'
$ scl enable devtoolset-9 'strace -e inject=syscall:error=error-type program argument'
```

Note that specifying the error type and return value is mutually exclusive.

**Example 9.5. Tampering with System Call Results**

Consider an executable file named `lsblk`. Run the *strace* utility on this file and make the `mmap()` system call return an error.
### 9.3. ADDITIONAL RESOURCES

For more information about `strace` and its features, see the resources listed below.

**Installed Documentation**

- `strace(1)` — The manual page for the `strace` utility provides detailed information about its usage.
  
  To display the manual page for the version included in Red Hat Developer Toolset:
  
  ```
  $ scl enable devtoolset-9 'man strace'
  ```

**See Also**

- Chapter 1, *Red Hat Developer Toolset* — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- Chapter 10, *ltrace* — Instructions on tracing program library calls using the `ltrace` tool.

- Chapter 8, *GNU Debugger (GDB)* — Instructions on debugging programs written in C, C++, and Fortran.

- Chapter 11, *memstomp* — Instructions on using the `memstomp` utility to identify calls to library functions with overlapping memory regions that are not allowed by various standards.
CHAPTER 10. LTRACE

**ltrace** is a diagnostic and debugging tool for the command line that can be used to display calls that are made to shared libraries. It uses the dynamic library hooking mechanism, which prevents it from tracing calls to statically linked libraries. **ltrace** also displays return values of the library calls. The output is printed to standard error output or to a selected file.

Red Hat Developer Toolset is distributed with **ltrace 0.7.91**. While the base version **ltrace** remains the same as in the previous release of Red Hat Developer Toolset, various enhancements and bug fixes have ported.

10.1. INSTALLING LTRACE

In Red Hat Enterprise Linux, the **ltrace** utility is provided by the **devtoolset-9-ltrace** package and is automatically installed with **devtoolset-9-toolchain** as described in Section 1.5, “Installing Red Hat Developer Toolset”.

10.2. USING LTRACE

To run the **ltrace** utility on a program you want to analyze:

```
$ scl enable devtoolset-9 'ltrace program argument...'
```

Replace `program` with the name of the program you want to analyze, and `argument` with any command line options and arguments you want to supply to this program. Alternatively, you can run the utility on an already running process by using the `-p` command line option followed by the process ID:

```
$ scl enable devtoolset-9 'ltrace -p process_id'
```

Note that you can execute any command using the **scl** utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset **ltrace** as default:

```
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of **ltrace** you are using at any point:

```
$ which ltrace
```

Red Hat Developer Toolset’s **ltrace** executable path will begin with `/opt`. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset **ltrace**:

```
$ ltrace -V
```

10.2.1. Redirecting Output to a File

By default, **ltrace** prints the name of each system call, its arguments and the return value to standard error output. To redirect this output to a file, use the `-o` command line option followed by the file name:
$ scl enable devtoolset-9 'ltrace -o file_name program argument...'

Replace file_name with the name of the file.

Example 10.1. Redirecting Output to a File

Consider a slightly modified version of the fibonacci file from Example 8.1, “Compiling a C Program With Debugging Information”. This executable file displays the Fibonacci sequence and optionally allows you to specify how many members of this sequence to list. Run the ltrace utility on this file and redirect the trace output to fibonacci.log:

$ scl enable devtoolset-9 'ltrace -o fibonacci.log ./fibonacci 20'

This creates a new plain-text file called fibonacci.log in the current working directory.

10.2.2. Tracing Selected Library Calls

To trace only a selected set of library calls, run the ltrace utility with the -e command line option:

$ scl enable devtoolset-9 'ltrace -e expression program argument...'

Replace expression with a chain of rules to specify the library calls to trace. The rules can consist of patterns that identify symbol names (such as malloc or free) and patterns that identify library SONAMEs (such as libc.so). For example, to trace call to the malloc and free function but to omit those that are done by the libc library:

$ scl enable devtoolset-9 'ltrace -e malloc+free-@libc.so* program'

Example 10.2. Tracing Selected Library Calls

Consider the ls command. Run the ltrace utility on this program and trace only the opendir, readdir, and closedir function calls:

$ scl enable devtoolset-9 'ltrace -e opendir+readdir+closedir ls'

For a detailed description of available filter expressions, see the ltrace(1) manual page.
10.2.3. Displaying Time Stamps

To prefix each line of the trace with the exact time of the day in hours, minutes, and seconds, run the `ltrace` utility with the `-t` command line option:

```sh
$ scl enable devtoolset-9 'ltrace -t program argument...'
```

To also display milliseconds, supply the `-t` option twice:

```sh
$ scl enable devtoolset-9 'ltrace -tt program argument...'
```

To prefix each line of the trace with the time required to execute the respective system call, use the `-r` command line option:

```sh
$ scl enable devtoolset-9 'ltrace -r program argument...'
```

**Example 10.3. Displaying Time Stamps**

Consider the `pwd` command. Run the `ltrace` utility on this program and include time stamps in the output:

```sh
$ scl enable devtoolset-9 'ltrace -tt pwd'

13:27:19.631371 __libc_start_main( ["pwd"] <unfinished ...>
13:27:19.632240 getenv("POSIXLY_CORRECT")                        = nil
13:27:19.632520 strrchr("pwd", '/')                              = nil
13:27:19.632786 setlocale(LC_ALL, ")                            = "en_US.UTF-8"
13:27:19.633220 bindtextdomain("coreutils", "/usr/share/locale") = "/usr/share/locale"
13:27:19.633471 textdomain("coreutils")                          = "coreutils"
(...) 13:27:19.637110 exited (status 0)
```

10.2.4. Displaying a Summary

To display a summary of how much time was required to execute each system call and how many times were these system calls executed, run the `ltrace` utility with the `-c` command line option:

```sh
$ scl enable devtoolset-9 'ltrace -c program argument...'
```

**Example 10.4. Displaying a Summary**

Consider the `lsblk` command. Run the `ltrace` utility on this program and display a trace summary:

```sh
$ scl enable devtoolset-9 'ltrace -c lsblk > /dev/null'

% time    seconds usecs/call    calls    function
----------- ----------- ----------- --------- -------------------
53.60 0.261644 261644 1   __libc_start_main
4.48 0.021848 58 374 mbtowc
4.41 0.021524 57 374 wcwidth
4.39 0.021409 57 374 __ctype_get_mb_cur_max
4.38 0.021359 57 374 iswprint
4.06 0.019838 74 266 readdir64
3.21 0.015652 69 224 strlen
10.3. ADDITIONAL RESOURCES

For more information about ltrace and its features, see the resources listed below.

Installed Documentation

- **ltrace(1)** – The manual page for the ltrace utility provides detailed information about its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man ltrace'
  ```

Online Documentation

- **ltrace for RHEL 6 and 7** – This article on the Red Hat Developer Blog offers additional in-depth information (including practical examples) on how to use ltrace for application debugging.

See Also

- **Chapter 1, Red Hat Developer Toolset** – An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 9, strace** – Instructions on tracing program system calls using the strace tool.

- **Chapter 8, GNU Debugger (GDB)** – Instructions on debugging programs written in C, C++, and Fortran.

- **Chapter 11, memstomp** – Instructions on using the memstomp utility to identify calls to library functions with overlapping memory regions that are not allowed by various standards.
memstomp is a command line tool that can be used to identify function calls with overlapping memory regions in situations when such an overlap is not permitted by various standards. It intercepts calls to the library functions listed in Table 11.1, “Function Calls Inspected by memstomp” and for each memory overlap, it displays a detailed backtrace to help you debug the problem.

Similarly to Valgrind, the memstomp utility inspects applications without the need to recompile them. However, it is much faster than this tool and therefore serves as a convenient alternative to it.

Red Hat Developer Toolset is distributed with memstomp 0.1.5.

Table 11.1. Function Calls Inspected by memstomp

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>memcpy</td>
<td>Copies $n$ bytes from one memory area to another and returns a pointer to the second memory area.</td>
</tr>
<tr>
<td>memccpy</td>
<td>Copies a maximum of $n$ bytes from one memory area to another and stops when a certain character is found. It either returns a pointer to the byte following the last written byte, or NULL if the given character is not found.</td>
</tr>
<tr>
<td>mempcpy</td>
<td>Copies $n$ bytes from one memory area to another and returns a pointer to the byte following the last written byte.</td>
</tr>
<tr>
<td>strcpy</td>
<td>Copies a string from one memory area to another and returns a pointer to the second string.</td>
</tr>
<tr>
<td>stpcpy</td>
<td>Copies a string from one memory area to another and returns a pointer to the terminating null byte of the second string.</td>
</tr>
<tr>
<td>strncpy</td>
<td>Copies a maximum of $n$ characters from one string to another and returns a pointer to the second string.</td>
</tr>
<tr>
<td>stpncpy</td>
<td>Copies a maximum of $n$ characters from one string to another. It either returns a pointer to the terminating null byte of the second string, or if the string is not null-terminated, a pointer to the byte following the last written byte.</td>
</tr>
<tr>
<td>strcat</td>
<td>Appends one string to another while overwriting the terminating null byte of the second string and adding a new one at its end. It returns a pointer to the new string.</td>
</tr>
<tr>
<td>strncat</td>
<td>Appends a maximum of $n$ characters from one string to another while overwriting the terminating null byte of the second string and adding a new one at its end. It returns a pointer to the new string.</td>
</tr>
<tr>
<td>wmemcpy</td>
<td>The wide-character equivalent of the memcpy() function that copies $n$ wide characters from one array to another and returns a pointer to the second array.</td>
</tr>
<tr>
<td>Function</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>wmempcpy</td>
<td>The wide-character equivalent of the <code>mempcpy()</code> function that copies a wide-character from one array to another and returns a pointer to the byte following the last written wide character.</td>
</tr>
<tr>
<td>wcscpy</td>
<td>The wide-character equivalent of the <code>strcpy()</code> function that copies a wide-character string from one array to another and returns a pointer to the second array.</td>
</tr>
<tr>
<td>wcsncpy</td>
<td>The wide-character equivalent of the <code>strncpy()</code> function that copies a maximum of <code>n</code> wide characters from one array to another and returns a pointer to the second string.</td>
</tr>
<tr>
<td>wcscat</td>
<td>The wide-character equivalent of the <code>strcat()</code> function that appends one wide-character string to another while overwriting the terminating null byte of the second string and adding a new one at its end. It returns a pointer to the new string.</td>
</tr>
<tr>
<td>wcsncat</td>
<td>The wide-character equivalent of the <code>strncat()</code> function that appends a maximum of <code>n</code> wide characters from one array to another while overwriting the terminating null byte of the second wide-character string and adding a new one at its end. It returns a pointer to the new string.</td>
</tr>
</tbody>
</table>

### 11.1. INSTALLING MEMSTOMP

In Red Hat Developer Toolset, the `memstomp` utility is provided by the `devtoolset-9-memstomp` package and is automatically installed with `devtoolset-9-toolchain` as described in Section 1.5, “Installing Red Hat Developer Toolset”.

### 11.2. USING MEMSTOMP

To run the `memstomp` utility on a program you want to analyze:

```
$ scl enable devtoolset-9 'memstomp program argument...'
```

To immediately terminate the analyzed program when a problem is detected, run the utility with the `--kill` (or `-k` for short) command line option:

```
$ scl enable devtoolset-9 'memstomp --kill program argument...'
```

The use of the `--kill` option is especially recommended if you are analyzing a multi-threaded program; the internal implementation of backtraces is not thread-safe and running the `memstomp` utility on a multi-threaded program without this command line option can therefore produce unreliable results.

Additionally, if you have compiled the analyzed program with the debugging information or this debugging information is available to you, you can use the `--debug-info` (or `-d`) command line option to produce a more detailed backtrace:

```
$ scl enable devtoolset-9 'memstomp --debug-info program argument...'
```

For detailed instructions on how to compile your program with the debugging information built in the binary file, see Section 8.2, “Preparing a Program for Debugging”. For information on how to install debugging information for any of the Red Hat Developer Toolset packages, see Section 1.5.4, “Installing
Debugging Information”.

Note that you can execute any command using the `scl` utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset `memstomp` as default:

```bash
$ scl enable devtoolset-9 'bash'
```

**Example 11.1. Using memstomp**

In the current working directory, create a source file named `employee.c` with the following contents:

```c
#include <stdio.h>
#include <string.h>

#define BUFSIZE 80

int main(int argc, char *argv[]) {
    char employee[BUFSIZE] = "John,Doe,john@example.com";
    char name[BUFSIZE] = {0};
    char surname[BUFSIZE] = {0};
    char *email;
    size_t length;

    /* Extract the information: */
    memccpy(name, employee, ';', BUFSIZE);
    length = strlen(name);
    memccpy(surname, employee + length, ';', BUFSIZE);
    length += strlen(surname);
    email = employee + length;

    /* Compose the new entry: */
    strcat(employee, surname);
    strcpy(employee, name);
    strcat(employee, email);

    /* Print the result: */
    puts(employee);

    return 0;
}
```

Compile this program into a binary file named `employee`:

```bash
$ scl enable devtoolset-9 'gcc -rdynamic -g -o employee employee.c'
```

To identify erroneous function calls with overlapping memory regions:

```bash
$ scl enable devtoolset-9 'memstomp --debug-info ./employee'
memstomp: 0.1.4 successfully initialized for process employee (pid 14887).

strcat(dest=0x7fff13afc265, src=0x7fff13afc269, bytes=21) overlap for employee(14887)
    ??:0 strcpy()
    ??:0 strcat()
```
11.3. ADDITIONAL RESOURCES

For more information about memstomp and its features, see the resources listed below.

Installed Documentation

- **memstomp**(1) – The manual page for the memstomp utility provides detailed information about its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man memstomp'
  ```

See Also

- **Chapter 1, Red Hat Developer Toolset** – An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 8, GNU Debugger (GDB)** – Instructions on debugging programs written in C, C++, and Fortran.

- **Chapter 9, strace** – Instructions on using the strace utility to monitor system calls that a program uses and signals it receives.

- **Chapter 13, Valgrind** – Instructions on using the Valgrind tool to profile applications and detect memory errors and memory management problems, such as the use of uninitialized memory, improper allocation and freeing of memory, and the use of improper arguments in system calls.
CHAPTER 12. SYSTEMTAP

SystemTap is a tracing and probing tool that allows users to monitor the activities of the entire system without needing to instrument, recompile, install, and reboot. It is programmable with a custom scripting language, which gives it expressiveness (to trace, filter, and analyze) and reach (to look into the running kernel and applications).

SystemTap can monitor various types of events, such as function calls within the kernel or applications, timers, tracepoints, performance counters, and so on. Some included example scripts produce output similar to `netstat`, `ps`, `top`, and `iostat`, others include pretty-printed function callgraph traces or tools for working around security bugs.

Red Hat Developer Toolset is distributed with SystemTap 4.1. This version is more recent than the version included in the previous release of Red Hat Developer Toolset and provides numerous bug fixes and enhancements.

Table 12.1. Tools Distributed with SystemTap for Red Hat Developer Toolset

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stap</td>
<td>Translates probing instructions into C code, builds a kernel module, and loads it into a running Linux kernel.</td>
</tr>
<tr>
<td>stapdyn</td>
<td>The Dyninst backend for SystemTap.</td>
</tr>
<tr>
<td>staprun</td>
<td>Loads, unloads, attaches to, and detaches from kernel modules built with the stap utility.</td>
</tr>
<tr>
<td>stapsh</td>
<td>Serves as a remote shell for SystemTap.</td>
</tr>
<tr>
<td>stap-prep</td>
<td>Determines and—if possible—downloads the kernel information packages that are required to run SystemTap.</td>
</tr>
<tr>
<td>stap-merge</td>
<td>Merges per-CPU files. This script is automatically executed when the stap utility is executed with the -b command line option.</td>
</tr>
<tr>
<td>stap-report</td>
<td>Gathers important information about the system for the purpose of reporting a bug in SystemTap.</td>
</tr>
<tr>
<td>stap-server</td>
<td>A compile server, which listens for requests from stap clients.</td>
</tr>
</tbody>
</table>

12.1. INSTALLING SYSTEMTAP

In Red Hat Developer Toolset, SystemTap is provided by the devtoolset-9-systemtap package and is automatically installed with devtoolset-9-perftools as described in Section 1.5, “Installing Red Hat Developer Toolset”.

In order to place instrumentation into the Linux kernel, SystemTap may also require installation of additional packages with debugging information. To determine which packages to install, run the stap-prep utility as follows:

```
$ scl enable devtoolset-9 'stap-prep'
```
Note that if you execute this command as the root user, the utility automatically offers the packages for installation. For more information on how to install these packages on your system, see the Red Hat Enterprise Linux 7 SystemTap Beginners Guide.

12.2. USING SYSTEMTAP

To execute any of the tools that are part of SystemTap:

```bash
$ scl enable devtoolset-9 'tool option...'
```

See Table 12.1, “Tools Distributed with SystemTap for Red Hat Developer Toolset” for a list of tools that are distributed with SystemTap. For example, to run the stap tool to build an instrumentation module:

```bash
$ scl enable devtoolset-9 'stap option... argument...'
```

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset SystemTap as default:

```bash
$ scl enable devtoolset-9 'bash'
```

NOTE

To verify the version of SystemTap you are using at any point:

```bash
$ which stap
```

Red Hat Developer Toolset’s stap executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset SystemTap:

```bash
$ stap -V
```

12.3. ADDITIONAL RESOURCES

For more information about SystemTap and its features, see the resources listed below.

Installed Documentation

- stap(1) – The manual page for the stap command provides detailed information on its usage, as well as references to other related manual pages. To display the manual page for the version included in Red Hat Developer Toolset:

  ```bash
  $ scl enable devtoolset-9 'man stap'
  ```

- staprun(8) – The manual page for the staprun command provides detailed information on its usage. To display the manual page for the version included in Red Hat Developer Toolset:

  ```bash
  $ scl enable devtoolset-9 'man staprun'
  ```

Online Documentation

- **Red Hat Enterprise Linux 7 SystemTap Tapset Reference** – The *SystemTap Tapset Reference* for Red Hat Enterprise Linux 7 provides further details about SystemTap.

- **The SystemTap Documentation** – The *SystemTap* documentation provides further documentation about SystemTap, and numerous examples of the SystemTap scripts.

See Also

- **Chapter 1, Red Hat Developer Toolset** – An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 13, Valgrind** – Instructions on using the Valgrind tool to profile applications and detect memory errors and memory management problems, such as the use of uninitialized memory, improper allocation and freeing of memory, and the use of improper arguments in system calls.

- **Chapter 14, OProfile** – Instructions on using the OProfile tool to determine which sections of code consume the greatest amount of CPU time and why.

- **Chapter 15, Dyninst** – Instructions on using the Dyninst library to instrument a user-space executable.
Valgrind is an instrumentation framework that ships with a number of tools for profiling applications. It can be used to detect various memory errors and memory-management problems, such as the use of uninitialized memory or an improper allocation and freeing of memory, or to identify the use of improper arguments in system calls. For a complete list of profiling tools that are distributed with the Red Hat Developer Toolset version of Valgrind, see Table 13.1, “Tools Distributed with Valgrind for Red Hat Developer Toolset”.

Valgrind profiles an application by rewriting it and instrumenting the rewritten binary. This allows you to profile your application without the need to recompile it, but it also makes Valgrind significantly slower than other profilers, especially when performing extremely detailed runs. It is therefore not suited to debugging time-specific issues, or kernel-space debugging.

Red Hat Developer Toolset is distributed with Valgrind 3.15.0. This version is more recent than the version included in the previous release of Red Hat Developer Toolset and provides numerous bug fixes and enhancements.

Table 13.1. Tools Distributed with Valgrind for Red Hat Developer Toolset

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memcheck</td>
<td>Detects memory management problems by intercepting system calls and checking all read and write operations.</td>
</tr>
<tr>
<td>CacheGrind</td>
<td>Identifies the sources of cache misses by simulating the level 1 instruction cache (I1), level 1 data cache (D1), and unified level 2 cache (L2).</td>
</tr>
<tr>
<td>CallGrind</td>
<td>Generates a call graph representing the function call history.</td>
</tr>
<tr>
<td>HelGrind</td>
<td>Detects synchronization errors in multithreaded C, C++, and Fortran programs that use POSIX threading primitives.</td>
</tr>
<tr>
<td>DRD</td>
<td>Detects errors in multithreaded C and C++ programs that use POSIX threading primitives or any other threading concepts that are built on top of these POSIX threading primitives.</td>
</tr>
<tr>
<td>Massif</td>
<td>Monitors heap and stack usage.</td>
</tr>
</tbody>
</table>

13.1. INSTALLING VALGRIND

In Red Hat Developer Toolset, Valgrind is provided by the devtoolset-9-valgrind package and is automatically installed with devtoolset-9-perftools.

For detailed instructions on how to install Red Hat Developer Toolset and related packages to your system, see Section 1.5, “Installing Red Hat Developer Toolset”.

NOTE

Note that if you use Valgrind in combination with the GNU Debugger, it is recommended that you use the version of GDB that is included in Red Hat Developer Toolset to ensure that all features are fully supported.
13.2. USING VALGRIND

To run any of the Valgrind tools on a program you want to profile:

```
$ scl enable devtoolset-9 'valgrind --tool=tool program argument...'
```

See Table 13.1, “Tools Distributed with Valgrind for Red Hat Developer Toolset” for a list of tools that are distributed with Valgrind. The argument of the --tool command line option must be specified in lower case, and if this option is omitted, Valgrind uses Memcheck by default. For example, to run Cachegrind on a program to identify the sources of cache misses:

```
$ scl enable devtoolset-9 'valgrind --tool=cachegrind program argument...'
```

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset Valgrind as default:

```
$ scl enable devtoolset-9 'bash'
```

**NOTE**

To verify the version of Valgrind you are using at any point:

```
$ which valgrind
```

Red Hat Developer Toolset’s valgrind executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset Valgrind:

```
$ valgrind --version
```

13.3. ADDITIONAL RESOURCES

For more information about Valgrind and its features, see the resources listed below.

**Installed Documentation**

- [valgrind(1)] — The manual page for the valgrind utility provides detailed information on how to use Valgrind. To display the manual page for the version included in Red Hat Developer Toolset:

  ```
  $ scl enable devtoolset-9 'man valgrind'
  ```


**Online Documentation**


- Red Hat Enterprise Linux 7 Performance Tuning Guide — The Performance Tuning Guide for Red Hat Enterprise Linux 7 provide more detailed information about using Valgrind to profile applications.
See Also

- **Chapter 1, Red Hat Developer Toolset** — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 11, memstomp** — Instructions on using the **memstomp** utility to identify calls to library functions with overlapping memory regions that are not allowed by various standards.

- **Chapter 12, SystemTap** — An introduction to the **SystemTap** tool and instructions on how to use it to monitor the activities of a running system.

- **Chapter 14, OProfile** — Instructions on using the **OProfile** tool to determine which sections of code consume the greatest amount of CPU time and why.

- **Chapter 15, Dyninst** — Instructions on using the **Dyninst** library to instrument a user-space executable.
CHAPTER 14. OPROFILE

OProfile is a low overhead, system-wide profiler that uses the performance-monitoring hardware on the processor to retrieve information about the kernel and executables on the system, such as when memory is referenced, the number of level 2 cache (L2) requests, and the number of hardware interrupts received. It consists of a configuration utility, a daemon for collecting data, and a number of tools that can be used to transform the data into a human-readable form. For a complete list of tools that are distributed with the Red Hat Developer Toolset version of OProfile, see Table 14.1, “Tools Distributed with OProfile for Red Hat Developer Toolset”.

OProfile profiles an application without adding any instrumentation by recording the details of every nth event. This allows it to consume fewer resources than Valgrind, but it also causes its samples to be less precise. Unlike Valgrind, which only collects data for a single process and its children in user-space, OProfile is well suited to collect system-wide data on both user-space and kernel-space processes, and requires root privileges to run.

Red Hat Developer Toolset is distributed with OProfile 1.3.0.

Table 14.1. Tools Distributed with OProfile for Red Hat Developer Toolset

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>operf</td>
<td>Records samples either for a single process or system-wide using the Linux Performance Events subsystem.</td>
</tr>
<tr>
<td>opannotate</td>
<td>Generates an annotated source file or assembly listing from the profiling data.</td>
</tr>
<tr>
<td>oparchive</td>
<td>Generates a directory containing executable, debug, and sample files.</td>
</tr>
<tr>
<td>opgprof</td>
<td>Generates a summary of a profiling session in a format compatible with gprof.</td>
</tr>
<tr>
<td>ophelp</td>
<td>Displays a list of available events.</td>
</tr>
<tr>
<td>opimport</td>
<td>Converts a sample database file from a foreign binary format to the native format.</td>
</tr>
<tr>
<td>opjitconv</td>
<td>Converts a just-in-time (JIT) dump file to the Executable and Linkable Format (ELF).</td>
</tr>
<tr>
<td>oreport</td>
<td>Generates image and symbol summaries of a profiling session.</td>
</tr>
<tr>
<td>ocount</td>
<td>A new tool for counting the number of times particular events occur during the duration of a monitored command.</td>
</tr>
</tbody>
</table>

14.1. INSTALLING OPROFILE

In Red Hat Developer Toolset, OProfile is provided by the devtoolset-9-oprofile package and is automatically installed with devtoolset-9-perftools as described in Section 1.5, “Installing Red Hat Developer Toolset”.

14.2. USING OPROFILE

To run any of the tools that are distributed with OProfile:
# scl enable devtoolset-9 'tool option…'

See Table 14.1, “Tools Distributed with OProfile for Red Hat Developer Toolset” for a list of tools that are distributed with OProfile. For example, to use the ophelp command to list available events in the XML format:

$ scl enable devtoolset-9 'ophelp -X'

Note that you can execute any command using the scl utility, causing it to be run with the Red Hat Developer Toolset binaries used in preference to the Red Hat Enterprise Linux system equivalent. This allows you to run a shell session with Red Hat Developer Toolset OProfile as default:

$ scl enable devtoolset-9 'bash'

NOTE

To verify the version of OProfile you are using at any point:

$ which operf

Red Hat Developer Toolset’s operf executable path will begin with /opt. Alternatively, you can use the following command to confirm that the version number matches that for Red Hat Developer Toolset OProfile:

# operf --version

14.3. ADDITIONAL RESOURCES

For more information about OProfile and its features, see the resources listed below.

Installed Documentation

- oprofile(1) – The manual page named oprofile provides an overview of OProfile and available tools. To display the manual page for the version included in Red Hat Developer Toolset:

  $ scl enable devtoolset-9 'man oprofile'

- opannotate(1), oparchive(1), operf(1), opgprof(1), ophelp(1), opimport(1), opreport(1) – Manual pages for various tools distributed with OProfile provide more information on their respective usage. To display the manual page for the version included in Red Hat Developer Toolset:

  scl enable devtoolset-9 'man tool'

Online Documentation


See Also

- **Chapter 1, Red Hat Developer Toolset** — An overview of Red Hat Developer Toolset and more information on how to install it on your system.

- **Chapter 12, SystemTap** — An introduction to SystemTap and instructions on how to use it to monitor the activities of a running system.

- **Chapter 13, Valgrind** — Instructions on using the Valgrind tool to profile applications and detect memory errors and memory management problems, such as the use of uninitialized memory, improper allocation and freeing of memory, and the use of improper arguments in system calls.

- **Chapter 15, Dyninst** — Instructions on using the Dyninst library to instrument a user-space executable.
CHAPTER 15. DYNINST

The Dyninst library provides an application programming interface (API) for instrumenting and working with user-space executables during their execution. It can be used to insert code into a running program, change certain subroutine calls, or even remove them from the program. It serves as a valuable debugging and performance-monitoring tool. The Dyninst API is also commonly used along with SystemTap to allow non-root users to instrument user-space executables.

Red Hat Developer Toolset is distributed with Dyninst 10.1.0.

15.1. INSTALLING DYNINST

In Red Hat Developer Toolset, the Dyninst library is provided by the devtoolset-9-dyninst package and is automatically installed with devtoolset-9-perftools as described in Section 1.5, “Installing Red Hat Developer Toolset”. In addition, it is recommended that you also install the GNU Compiler Collection provided by the devtoolset-9-toolchain package.

If you intend to write a custom instrumentation for binaries, install the relevant header files:

```
# yum install devtoolset-9-dyninst-devel
```

You can also install API documentation for this library:

```
# yum install devtoolset-9-dyninst-doc
```

For a complete list of documents that are included in the devtoolset-9-dyninst-doc package, see Section 15.3, “Additional Resources”. For detailed instructions on how to install optional packages to your system, see Section 1.5, “Installing Red Hat Developer Toolset”.

15.2. USING DYNINST

15.2.1. Using Dyninst with SystemTap

To use Dyninst along with SystemTap to allow non-root users to instrument user-space executables, run the stap command with the --dyninst (or --runtime=dyninst) command line option. This tells stap to translate a SystemTap script into C code that uses the Dyninst library, compile this C code into a shared library, and then load the shared library and run the script. Note that when executed like this, the stap command also requires the -c or -x command line option to be specified.

To use the Dyninst runtime to instrument an executable file:

```
$ scl enable devtoolset-9 "stap --dyninst -c 'command option... argument...'
```

Similarly, to use the Dyninst runtime to instrument a user’s process:

```
$ scl enable devtoolset-9 "stap --dyninst -x process_id option... argument..."
```

See Chapter 12, SystemTap for more information about the Red Hat Developer Toolset version of SystemTap. For a general introduction to SystemTap and its usage, see the SystemTap Beginners Guide for Red Hat Enterprise Linux 7.

Example 15.1. Using Dyninst with SystemTap
Consider a source file named `exercise.C` that has the following contents:

```c
#include <stdio.h>

void print_iteration(int value) {
    printf("Iteration number %d\n", value);
}

int main(int argc, char **argv) {
    int i;
    printf("Enter the starting number: ");
    scanf("%d", &i);
    for(; i>0; --i)
        print_iteration(i);
    return 0;
}
```

This program prompts the user to enter a starting number and then counts down to 1, calling the `print_iteration()` function for each iteration in order to print the number to the standard output. Compile this program on the command line using the `g++` compiler from Red Hat Developer Toolset:

```bash
$ scl enable devtoolset-9 'g++ -g -o exercise exercise.C'
```

Now consider another source file named `count.stp` with the following contents:

```stap
#!/usr/bin/stap

global count = 0

probe process.function("print_iteration") {
    count++
}

probe end {
    printf("Function executed %d times.\n", count)
}
```

This `SystemTap` script prints the total number of times the `print_iteration()` function was called during the execution of a process. Run this script on the `exercise` binary file:

```bash
$ scl enable devtoolset-9 "stap --dyninst -c './exercise' count.stp"
```

Enter the starting number: 5
Iteration number 5
Iteration number 4
Iteration number 3
Iteration number 2
Iteration number 1
Function executed 5 times.

### 15.2.2. Using Dyninst as a Stand-alone Library

Before using the `Dyninst` library as a part of your application, set the value of the `DYNINSTAPI_RT_LIB` environment variable to the path to the runtime library file:
$ export DYNINSTAPI_RT_LIB=/opt/rh/devtoolset-9/root/usr/lib64/dyninst/libdyninstAPI_RT.so

This sets the DYNINSTAPI_RT_LIB environment variable in the current shell session.

Example 15.2, “Using Dyninst as a Stand-alone Application” illustrates how to write and build a program to monitor the execution of a user-space process. For a detailed explanation of how to use Dyninst, see the resources listed in Section 15.3, “Additional Resources”.

Example 15.2. Using Dyninst as a Stand-alone Application

Consider the exercise.C source file from Example 15.1, “Using Dyninst with SystemTap”: this program prompts the user to enter a starting number and then counts down to 1, calling the print_iteration() function for each iteration in order to print the number to standard output.

Now consider another source file named count.C with the following contents:

```c
#include <stdio.h>
#include <fcntl.h>
#include "BPatch.h"
#include "BPatch_process.h"
#include "BPatch_function.h"
#include "BPatch_Vector.h"
#include "BPatch_thread.h"
#include "BPatch_point.h"

void usage() {
    fprintf(stderr, "Usage: count <process_id> <function>\n");
}

// Global information for counter
BPatch_variableExpr *counter = NULL;

void createCounter(BPatch_process *app, BPatch_image *appImage) {
    int zero = 0;
    counter = app->malloc(*appImage->findType("int"));
    counter->writeValue(&zero);
}

bool interceptfunc(BPatch_process *app,
    BPatch_image *appImage,
    char *funcName) {
    BPatch_Vector<BPatch_function *> func;
    appImage->findFunction(funcName, func);
    if(func.size() == 0) {
        fprintf(stderr, "Unable to find function to instrument()\n");
        exit (-1);
    }
    BPatch_Vector<BPatch_snippet *> incCount;
    BPatch_Vector<BPatch_point *> *points;
    points = func[0]->findPoint(BPatch_entry);
    if(((*points).size() == 0) {
        exit (-1);
    }
    BPatch_arithExpr counterPlusOne(BPatch_plus, *counter, BPatch_constExpr(1));
```
BPatch_arithExpr addCounter(BPatch_assign, *counter, counterPlusOne);

    return app->insertSnippet(addCounter, *points);
}

void printCount(BPatch_thread *thread, BPatch_exitType) {
    int val = 0;
    counter->readValue(&val, sizeof(int));
    fprintf(stderr, "Function executed %d times.\n", val);
}

int main(int argc, char *argv[]) {
    int pid;
    BPatch bpatch;
    if (argc != 3) {
        usage();
        exit(1);
    }
    pid = atoi(argv[1]);
    BPatch_process *app = bpatch.processAttach(NULL, pid);
    if (!app) exit (-1);
    BPatch_image *applImage = app->getImage();
    createCounter(app, applImage);
    fprintf(stderr, "Finding function %s(): ", argv[2]);
    BPatch_Vector<BPatch_function*> countFuncs;
    fprintf(stderr, "OK
Instrumenting function %s(): ", argv[2]);
    interceptfunc(app, applImage, argv[2]);
    bpatch.registerExitCallback(printCount);
    fprintf(stderr, "OK
Waiting for process %d to exit...
", pid);
    app->continueExecution();
    while (!app->isTerminated())
        bpatch.waitForStatusChange();
    return 0;
}

Note that a client application is expected to destroy all BPatch objects before any of the Dyninst library destructors are called. Otherwise the mutator might terminate unexpectedly with a segmentation fault. To work around this problem, set the BPatch object of the mutator as a local variable in the main() function. Or, if you need to use BPatch as a global variable, manually detach all the mutatee processes before the mutator exits.

This program accepts a process ID and a function name as command line arguments and then prints the total number of times the function was called during the execution of the process. You can use the following Makefile to build these two files:

```
DTS      = /opt/rh/devtoolset-9/root
CXXFLAGS = -g -I$(DTS)/usr/include/dyninst
LBITS   := $(shell getconf LONG_BIT)
ifeq ($(LBITS),64)
    DYNINSTLIBS = $(DTS)/usr/lib64/dyninst
else
    DYNINSTLIBS = $(DTS)/usr/lib/dyninst
endif

.PHONY: all
```
To compile the two programs on the command line using the `g++` compiler from Red Hat Developer Toolset, run the `make` utility:

```
$ scl enable devtoolset-9 make
```

This creates new binary files called `exercise` and `count` in the current working directory.

In one shell session, execute the `exercise` binary file as follows and wait for it to prompt you to enter the starting number:

```
$ ./exercise
Enter the starting number:
```

Do not enter this number. Instead, start another shell session and type the following at its prompt to set the `DYNINSTAPI_RT_LIB` environment variable and execute the `count` binary file:

```
$ export DYNINSTAPI_RT_LIB=/opt/rh/devtoolset-9/root/usr/lib64/dyninst/libdyninstAPI_RT.so
$ ./count `pidof exercise` print_iteration
```

```
Finding function print_iteration(): OK
Instrumentation function print_iteration(): OK
Waiting for process 8607 to exit... 
```

Now switch back to the first shell session and enter the starting number as requested by the `exercise` program. For example:

```
Enter the starting number: 5
Iteration number 5
Iteration number 4
Iteration number 3
Iteration number 2
Iteration number 1
```

When the `exercise` program terminates, the `count` program displays the number of times the `print_iteration()` function was executed:

```
Function executed 5 times.
```
15.3. ADDITIONAL RESOURCES

For more information about Dyninst and its features, see the resources listed below.

Installed Documentation
The `devtoolset-9-dyninst-doc` package installs the following documents in the `/opt/rh/devtoolset-9/root/usr/share/doc/devtoolset-9-dyninst-doc-10.1.0/` directory:

- **DynC API Programmer’s Guide** — An introduction to DynC API is stored in the `dynC_API.pdf` file.
- **StackwalkerAPI Programmer’s Guide** — A detailed description of StackwalkerAPI is stored in the `stackwalker.pdf` file.
- **SymtabAPI Programmer’s Guide** — An introduction to SymtabAPI is stored in the `SymtabAPI.pdf` file.

For information on how to install this package on your system, see Section 15.1, “Installing Dyninst”.

Online Documentation

- **Dyninst Home Page** — The project home page provides links to additional documentation and related publications.
- **Red Hat Enterprise Linux 7 SystemTap Tapset Reference** — The *SystemTap Tapset Reference* for Red Hat Enterprise Linux 7 provides further details about SystemTap.

See Also

- **Chapter 1, Red Hat Developer Toolset** — An overview of Red Hat Developer Toolset and more information on how to install it on your system.
- **Chapter 12, SystemTap** — An introduction to SystemTap and instructions on how to use it to monitor the activities of a running system.
- **Chapter 13, Valgrind** — Instructions on using the Valgrind tool to profile applications and detect memory errors and memory management problems, such as the use of uninitialized memory, improper allocation and freeing of memory, and the use of improper arguments in system calls.
• Chapter 14, *OProfile*—Instructions on using the *OProfile* tool to determine which sections of code consume the greatest amount of *CPU* time and why.
PART V. COMPILER TOOLSETS
The descriptions of the three compiler toolsets:

- LLVM Toolset
- Go Toolset
- Rust Toolset

have been moved to a separate documentation set under Red Hat Developer Tools.
PART VI. GETTING HELP
CHAPTER 17. ACCESSING RED HAT PRODUCT DOCUMENTATION

Red Hat Product Documentation located at https://access.redhat.com/site/documentation/ serves as a central source of information. It is currently translated in 23 languages, and for each product, it provides different kinds of books from release and technical notes to installation, user, and reference guides in HTML, PDF, and EPUB formats.

Below is a brief list of documents that are directly or indirectly relevant to this book.

Red Hat Developer Toolset


- Using Red Hat Software Collections Container Images – The Using Red Hat Software Collections Container Images provides instructions for obtaining, configuring, and using container images that are shipped with Red Hat Software Collections, including the Red Hat Developer Toolset container images.

- Red Hat Software Collections Packaging Guide – The Software Collections Packaging Guide explains the concept of Software Collections and documents how to create, build, and extend them.

Red Hat Enterprise Linux


- Red Hat Enterprise Linux 7 Installation Guide – The Installation Guide for Red Hat Enterprise Linux 7 explains how to obtain, install, and update the system.

CHAPTER 18. CONTACTING GLOBAL SUPPORT SERVICES

Unless you have a Self-Support subscription, when both the Red Hat Documentation website and Customer Portal fail to provide the answers to your questions, you can contact Global Support Services (GSS).

18.1. GATHERING REQUIRED INFORMATION

Several items of information should be gathered before contacting GSS.

Background Information
Ensure you have the following background information at hand before calling GSS:

- Hardware type, make, and model on which the product runs
- Software version
- Latest upgrades
- Any recent changes to the system
- An explanation of the problem and the symptoms
- Any messages or significant information about the issue

NOTE
If you ever forget your Red Hat login information, it can be recovered at https://access.redhat.com/site/help/LoginAssistance.html.

Diagnostics
The diagnostics report for Red Hat Enterprise Linux is required as well. This report is also known as a sosreport and the program to create the report is provided by the sos package. To install the sos package and all its dependencies on your system:

```
# yum install sos
```

To generate the report:

```
# sosreport
```

For more information, access the Knowledgebase article at https://access.redhat.com/kb/docs/DOC-3593.

Account and Contact Information
In order to help you, GSS requires your account information to customize their support, as well contact information to get back to you. When you contact GSS ensure you have your:

- Red Hat customer number or Red Hat Network (RHN) login name
- Company name
- Contact name
Preferred method of contact (phone or email) and contact information (phone number or email address)

**Issue Severity**
Determining an issue's severity is important to allow the GSS team to prioritize their work. There are four levels of severity.

**Severity 1 (urgent)**
A problem that severely impacts your use of the software for production purposes. It halts your business operations and has no procedural workaround.

**Severity 2 (high)**
A problem where the software is functioning, but production is severely reduced. It causes a high impact to business operations, and no workaround exists.

**Severity 3 (medium)**
A problem that involves partial, non-critical loss of the use of the software. There is a medium to low impact on your business, and business continues to function by utilizing a workaround.

**Severity 4 (low)**
A general usage question, report of a documentation error, or a recommendation for a future product improvement.

For more information on determining the severity level of an issue, see [https://access.redhat.com/support/policy/severity](https://access.redhat.com/support/policy/severity).

Once the issue severity has been determined, submit a service request through the Customer Portal under the **Connect** option, or at [https://access.redhat.com/support/contact/technicalSupport.html](https://access.redhat.com/support/contact/technicalSupport.html). Note that you need your Red Hat login details in order to submit service requests.

If the severity is level 1 or 2, then follow up your service request with a phone call. Contact information and business hours are found at [https://access.redhat.com/support/contact/technicalSupport.html](https://access.redhat.com/support/contact/technicalSupport.html).

If you have a premium subscription, then after hours support is available for Severity 1 and 2 cases.

Turn-around rates for both premium subscriptions and standard subscription can be found at [https://access.redhat.com/support/offerings/production/sla.html](https://access.redhat.com/support/offerings/production/sla.html).

### 18.2. ESCALATING AN ISSUE

If you feel an issue is not being handled correctly or adequately, you can escalate it. There are two types of escalations:

**Technical escalation**
If an issue is not being resolved appropriately or if you need a more senior resource to attend to it.

**Management escalation**
If the issue has become more severe or you believe it requires a higher priority.

More information on escalation, including contacts, is available at [https://access.redhat.com/support/policy/mgt_escalation.html](https://access.redhat.com/support/policy/mgt_escalation.html).

### 18.3. RE-OPENING A SERVICE REQUEST

If there is more relevant information regarding a closed service request (such as the problem reoccurring), you can re-open the request via the Red Hat Customer Portal at
https://access.redhat.com/support/policy/mgt_escalation.html or by calling your local support center, the details of which can be found at https://access.redhat.com/support/contact/technicalSupport.html.

**IMPORTANT**

In order to re-open a service request, you need the original service-request number.

### 18.4. ADDITIONAL RESOURCES

For more information, see the resources listed below.

**Online Documentation**

- **Getting Started** — The *Getting Started* page serves as a starting point for people who purchased a Red Hat subscription and offers the *Red Hat Welcome Kit* and the *Quick Guide to Red Hat Support* for download.

- **How can a RHEL Self-Support subscription be used?** — A Knowledgebase article for customers with a Self-Support subscription.

- **Red Hat Global Support Services and public mailing lists** — A Knowledgebase article that answers frequent questions about public Red Hat mailing lists.
APPENDIX A. CHANGES IN VERSION 9.0

The sections below document features and compatibility changes introduced in Red Hat Developer Toolset 9.0.

A.1. CHANGES IN GCC

Red Hat Developer Toolset 9.0 is distributed with GCC 9.3.1.

The following features have been added or modified since the previous release of Red Hat Developer Toolset:

General Improvements

- All command-line options that accept byte-size arguments now accept 64-bit integers and standard SI and IEC suffixes.
- A new option is added: `-flive-patching=[inline-only-static|inline-clone]`. It provides safe compilation for live patching.
- GCC diagnostics are improved:
  - The left margin now shows line numbers. To configure this feature, use the `-fno-diagnostics-show-line-numbers` option.
  - Regions of the source code can now be labeled to show relevant information, for example types within an expression. To disable labels, use the `-fno-diagnostics-show-labels` option.
- The alignment-related options `-falign-functions`, `-falign-labels`, `-falign-loops`, and `-falign-jumps` are now supported for a secondary alignment, for example `-falign-loops=n:m:n2:m2`.
- A new pair of profiling options is added: `-fprofile-filter-files` and `-fprofile-exclude-files`. These options help to filter which source files are instrumented.
- The following built-in functions are added:
  - The `__builtin_expect_with_probability` function provides the branch prediction probability hints to the optimizer.
  - The `__builtin_has_attribute` function determines whether a function, type, or variable is declared with an attribute.
  - The `__builtin_speculation_safe_value` function helps mitigate against unsafe speculative execution.
- The new `copy` function attribute is added. Use it with functions, variables, or types.
- Numerous code generation improvements are added including inter-procedural, profile-driven, and link-time optimization improvements, for example:
  - Switch expansion is improved by using a different strategy for a subset of switch cases. Strategies include a jump table, a bit test, and a decision tree.
- The GCOV command-line utility is improved. For example, the intermediate format of the GCOV tool is now a new JSON format.

Language Features
Notable changes related to languages include:

C family

- C and C++ compilers now partially support version 5.0 of the OpenMP specification.
- A new extension `__builtin_convervector` is added for vector conversions.
- A new warning `-Waddress-of-packed-member` is added. It is enabled by default and warns about an unaligned pointer value from the address of a packed member of a struct or union.
- Some existing warnings are enhanced.

C

- Experimental support for `-std=c2x` is added.
- A new warning `-Wabsolute-value` is added. It warns for calls to standard functions that compute the absolute value of an argument when a more appropriate standard function is available.

C++

- New warnings are added:
  - The `-Wredundant-move` option is implied by `-Wextra` and warns about redundant calls to `std::move`.
  - The `-Wpessimizing-move` option is implied by `-Wall` and warns when a call to `std::move` prevents copy elision.
  - The `-Winit-list-lifetime` option is on by default. It warns when using `std::initializer_list` may result in a dangling pointer.
- The C++ front end now has experimental support for some C++2a draft features with the `-std=c++2a` or `-std=gnu++2a` flags.
- Error-reporting diagnostics are improved.

Architecture and Processor Support

Changes to architecture and processor support include:

The 64-bit ARM architecture

The following processors are now supported (the GCC identifiers are provided in parentheses):

- ARM Cortex-A76 (cortex-a76)
- ARM Cortex-A55/Cortex-A76 DynamIQ big.LITTLE (cortex-a76.cortex-a55)
- ARM Neoverse N1 (neoverse-n1)
- ARM Neoverse E1 processor (-mcpu=neoverse-e1)

AMD64 and Intel 64

- Intel MPX (Memory Protection Extensions) are no longer supported.
- New ISA extension support for Intel PTWRITE is added.
• Intel CPU named Cascade Lake with AVX512 extensions are now supported.

IBM Z

• The ARCH(13) architecture is now supported.
• Built-in features for the new vector instructions are added. Use the -mzvector option to enable them.
• Support for ESA architecture machines G5 and G6 is deprecated.

A.2. CHANGES IN GDB

Red Hat Developer Toolset 9.0 is distributed with GDB 8.3.

The following features have been added or modified since the previous release of Red Hat Developer Toolset:

General Improvements

• GDB and GDBserver now allow accessing additional registers on the IBM POWER systems (PPR, DSCR, TAR, EBB/PMU, and HTM registers).
• GDB and GDBserver now support the IPv6 connections. Pass the IPv6 addresses using the [ADDRESS]:PORT notation or the regular ADDRESS:PORT method.
• GDB in batch mode now exits with status 1 if the last command to be executed fails.
• Terminal styling is now available for the CLI and the TUI. For a list of styling commands, see Output Styling section of the GDB User Manual. The GNU Source Highlight program can also be used for source code styling.

New Commands

• frame apply [all | COUNT | -COUNT | level LEVEL...] [FLAG]... COMMAND
  • Apply to some frames only.
  • Use the FLAG arguments to choose the required output and to set a method to handle errors that you may get when applying COMMAND to a frame.
• The taas COMMAND syntax is a shorter version of thread apply all -s COMMAND.
  • Apply to all the threads including threads with errors and empty output.
• The faas COMMAND syntax is a shorter version of frame apply all -s COMMAND.
  • Apply to all the frames including frames with errors and empty output.
• The tfaas COMMAND syntax is a shorter version of thread apply all -s frame apply all -s COMMAND.
  • Apply to all the frames of all the threads including frames and threads with errors and empty output.

Changed Commands

• Changes to the frame, select-frame, and info frame CLI commands:
• These commands now accept the frame specification. It can be a frame level or one of the keywords level, address, function, or view followed by a parameter.

• A keyword is required to select a frame by address or to view a frame outside of the current backtrace.

• Selecting a frame by level is unchanged.

• The MI comment -stack-select-frame is unchanged.

• target remote FILENAME and target extended-remote FILENAME

  • If FILENAME is a Unix domain socket, GDB attempts to connect to this socket and will not open FILENAME as a character device.

• info args [-q] [-t TYPEREGEXP] [NAMEREGEXP]
info functions [-q] [-t TYPEREGEXP] [NAMEREGEXP]
info locals [-q] [-t TYPEREGEXP] [NAMEREGEXP]
info variables [-q] [-t TYPEREGEXP] [NAMEREGEXP]
The preceding four commands now have a new [-t TYPEREGEXP] flag. It returns matching entities to types matching TYPEREGEXP. The [-q] flag disables printing headers or information messages.

• info functions
info types
info variables
rbreak
The preceding four commands now determine entities’ syntax based on the language chosen in the set language option. The set language auto option automatically chooses the language of the shown entities.

• thread apply [all | COUNT | -COUNT] [FLAG]...

  • New [FLAG] arguments are added. Use the [FLAG] arguments to choose the required output and to set a method to handle errors that you can get when applying COMMAND to a frame.

Python API

• A new progspace property is added for the gdb.Inferior type. It is the program space associated with that inferior.

• A new objfiles method is added to the gdb.Progspace type. It returns the list of objfiles associated with that program space.

• A new constructor is added to the gdb.Value type. It is used to construct a gdb.Value from a Python buffer object and a gdb.Type.

• The following new domains are added to reflect changes to the GDB core: gdb.SYMBOL_LOC_COMMON_BLOCK, gdb.SYMBOL_MODULE_DOMAIN, and gdb.SYMBOL_COMMON_BLOCK_DOMAIN.

A.3. CHANGES IN BINUTILS

Red Hat Developer Toolset 9.0 is distributed with binutils 2.32.
The following features have been added or modified since the previous release of Red Hat Developer Toolset:

**The Assembler**

- A new command-line option is added: `--generate-missing-build-notes=yes`. It creates GNU Build Attribute notes if the input sources do not contain such notes.

- Specific to the AMD64 and Intel 64 architecture:
  - The assembler now has a `-mvexwig=[0|1]` option to control encoding of VEX.W-ignored (WIG) VEX instructions.
  - A new `-mx86-used-note=[yes|no]` option allows to choose if GNU property notes are generated. These notes are based on the input assembler.
  - The new `-O[2|s]` command line options enable alternate, shorter instruction encoding.

**The BFD Linker**

- The default behavior of the linker is now to create separate code and data segments. This makes binaries bigger, but safer, because the loader can turn off write permission to the code segment.
  - Use a command-line option `-z noseparate-code` to disable this behavior. The linker will create one segment as before.

- A linker map file, created with the `-Map` command-line option, now includes details of property changes that happen when merging GNU property notes.

- The `--trace` option does not report members within an archive anymore. This makes the option more useful when generating a list of files that should be packaged for a linker bug report.
  - To report members within an archive give the option twice.

**The GOLD Linker**

- Warning messages for relocations that refer to discarded sections are improved.

- The new `--debug=plugin` option allows for easier debugging of plug-in-related problems.

- The new `-z keep_text_section_prefix` option provides compatibility with the BFD linker.

- Support for the 64-bit ARM architecture is improved.

- The `.note.gnu.property` sections from Linux ABI extensions are now supported.

- Intel Indirect Branch Tracking (IBT) and Shadow Stack (AMD64 and Intel 64 only) are now supported.

**Other Binary Utilities**

- The `addr2line`, `c++filt`, `nm`, and `objdump` tools now have a limit on the maximum amount of recursion that is allowed while demangling strings. The value for this limit is defined by the `DEMANGLE_RECURSE_LIMIT` constant. This constant has the value of 2048 in `binutils` shipped as part of Red Hat Developer Toolset 9.0.

- The `--no-recurse-limit` option can be used to remove the limit mentioned above. It restores the behavior of earlier versions of these tools. This option allows demangling of very complicated
names, but it also leaves the tools vulnerable to stack exhaustion from maliciously constructed mangled names.

- The `ar` archive manager now supports an `O` modifier to display member offsets inside an archive.

- `Objdump`: the `--disassemble` option now takes a parameter specifying the starting symbol for disassembly. Disassembly will continue from this symbol up to the next symbol or the end of the function.

- The disassembler for the 64-bit ARM processors can now show notes that are created when a system finds inconsistencies with instructions that may result in invalid instructions. These notes can be turned on with the `-M notes` option to `objdump`. The disassembler also creates warnings when a combination of an instruction and a named register is invalid.

### A.4. CHANGES IN STRACE

Red Hat Developer Toolset 9.0 is distributed with `strace 5.1`.

The following features have been added or modified since the previous release of Red Hat Developer Toolset:

**License**

- The test suite is now provided under the terms of the GNU General Public License version 2 or later.

- The rest of `strace` is now provided under the terms of the GNU Lesser General Public License version 2.1 or later.

**Changes in Behavior**

- If `strace` is interrupted by a signal that it handles (currently one of `SIGHUP`, `SIGINT`, `SIGQUIT`, `SIGPIPE`, or `SIGTERM`), `strace` terminates itself with this signal.

- The `-D` option now implies `-I4`: by default `strace` ignores `SIGHUP`, `SIGINT`, `SIGQUIT`, `SIGPIPE`, `SIGTERM`, `SIGTIN`, `SIGTTOU`, and `SIGTSTP` when the `-D` option is used.

- A diagnostic message is no longer printed if an attempt to restart a process has failed with ESRCH. This feature addresses BZ#1662936.

- The ASCII dump no longer tries to read the whole buffer at once. As a result, it can fail with a diagnostic message after dumping only a part. The amount of preceding zeros printed for offset is now chosen in a way to accommodate all the digits of all the offsets being printed.

**Improvements**

- Stack trace printing on receiving signals is implemented.

- Named constant printing styles support configured by `-X` option is enhanced.

- Decoding of the following system calls has been added: `clock_gettime64`, `clock_settime64`, `clock_adjtime64`, `clock_getres_time64`, `clock_nanosleep_time64`, `timer_gettime64`, `timer_settime64`, `timerfd_gettime64`, `timerfd_settime64`, `utimensat_time64`, `pselect6_time64`, `ppoll_time64`, `io_pgetevents_time64`, `recvmsg_time64`. 
Decoding of the `bpf` system call is enhanced.

Decoding of the following ioctl commands is implemented: `BLKGETZONESZ`, `BLKGETNRZONES`, `KVM_CHECK_EXTENSION`, `NBD_*`, and `RND*`.

Decoding of the `AF_PACKET` protocols in the `s` socket system call is implemented.

Decoding of the `SOL_XDP` socket option names is implemented.

Decoding of the `getsockopt` `SO_ERROR` and `SO_TIMESTAMP* _NEW` options is enhanced.

Decoding of the `IFLA_*`, `NETCONFA_*`, and `SMC_DIAG_*` netlink attributes is enhanced.

Decoding of the `pkey_mprotect`, `pkey_alloc`, and `pkey_free` system calls is now available on IBM Z architecture.

Decoding of the direct IPC system calls is now available on IBM POWER and IBM Z architecture.

Decoding of the `kexec_file_load` and `rseq` system calls is now available on the 64-bit ARM architecture.

**A.5. CHANGES IN SYSTEMTAP**

Red Hat Developer Toolset 9.0 is distributed with SystemTap 4.1.

The following features have been added or modified since the previous release of Red Hat Developer Toolset:

- The eBPF runtime backend can handle more features of the scripting language such as string variables and rich formatted printing.
- Performance of the translator is significantly improved.
- The DWARF4 debuginfo constructs can now extract more types of data in optimized C code.

**A.6. CHANGES IN VALGRIND**

Red Hat Developer Toolset 9.0 is distributed with Valgrind 3.15.0.

The following features have been added or modified since the previous release of Red Hat Developer Toolset:

- AMD64: the RDRAND and F16C instruction set extensions are now supported.
- Cacheegrind: the `cgannotate` tool has a new option `--show-percs`. It prints percentages next to all event counts.
- Callgrind: `callgrindannotate` has a new option `--show-percs`. It prints percentages next to all event counts.
- Massif: the default value for `--read-inline-info` is now yes.
Memcheck: the \texttt{--xtree-leak=yes} option now activates the \texttt{--show-leak-kinds=all} option.

A new option is added: \texttt{--show-error-list=no|yes}.

- It lists detected errors and used suppressions after the run is ended.
- In the previous version of Valgrind this information was only shown in \texttt{-v verbose} mode.
- The short option \texttt{-s} is equivalent to \texttt{--show-error-list=yes}.

The DHAT tool is non-experimental now. It is improved and has received a GUI. Changes and new features include:

- To use DHAT, run a new command \texttt{--tool=dhat}. The old command \texttt{--tool=exp-dhat} is not supported.
- The \texttt{--show-top-n} and \texttt{--sort-by} options are removed. When the program ends, DHAT prints only minimal data and writes all profiling data to a file.
- A new viewer is added: \texttt{dh_view.html}.
  - It is a JavaScript program that should be run in a browser.
  - It is shipped as \texttt{/usr/libexec/valgrind/dh_view.html}.
  - To see profile results with the viewer, follow the instructions from a message that is printed after a run finishes.
- DHAT manual is shipped as \texttt{/usr/share/doc/valgrind/html/dh-manual.html}.

### A.7. CHANGES IN OPROFILE

Red Hat Developer Toolset 9.0 is distributed with OProfile 1.3.0.

The following features have been modified since the previous release of Red Hat Developer Toolset:

- OProfile now correctly maps samples from binaries generated by the GCC compiler back to the source code. It applies to the GCC compiler shipped as part of Red Hat Developer Toolset 9.0.
- OProfile ocount now correctly terminates any child processes created as a result of errors in performance monitoring hardware setup. OProfile ocount no longer creates orphan processes when an error occurs during performance monitoring hardware setup.

### A.8. CHANGES IN DYNINST

Red Hat Developer Toolset 9.0 is distributed with Dyninst 10.1.0.

The following feature has been improved since the previous release of Red Hat Developer Toolset:

- Start-up time has been improved by using parallel code analysis.

**NOTE**

Dyninst 10.1.0 is only available for AMD64 and Intel 64 and does not run on IBM POWER and the 64-bit ARM architecture.
APPENDIX B. CHANGES IN VERSION 9.1

The sections below document features and bug fixes introduced in Red Hat Developer Toolset 9.1.

B.1. CHANGES IN GCC

Red Hat Developer Toolset 9.1 is distributed with GCC 9.3.1, which provides numerous bug fixes and enhancements.

One of the most notable bug fixes is:

- Previously, using C++ object files compiled with GCC versions earlier than 9.1.0 could cause ABI incompatibilities. When the C++ std::rotate algorithm was called with an empty range, the compiled program could terminate unexpectedly with a divide-by-zero error (as a SIGFPE signal). This problem is fixed for GCC 9.2.0 and future releases. To work around this problem, recompile all objects that might call std::rotate with an empty range.

Bug#90920

B.2. CHANGES IN MAKE

Red Hat Developer Toolset 9.1 is distributed with make 4.2.1.

The following bug has been fixed since the previous release of Red Hat Developer Toolset:

- Previously, make slowed down when using parallel builds because make sub-processes could become temporarily unresponsive while waiting for their turn to run. As a consequence, builds with high -j values could slow down or run at lower effective -j values. In Red Hat Developer Toolset 9.1, make's job control logic has become non-blocking and, as a result, builds with high -j values should run at full -j speed.

BZ#1785447

B.3. CHANGES IN BINUTILS

Red Hat Developer Toolset 9.1 is distributed with binutils 2.32.

The following bug has been fixed since the previous release of Red Hat Developer Toolset:

- Previously, when a user instructed the linker to perform garbage collection, the linker could, under certain circumstances, erroneously remove weak symbol references from a program. As a consequence, the program considered such a symbol undefined, even if it was provided by a shared library. In Red Hat Developer Toolset 9.1, the problem is fixed. The weak reference remains in the program and is correctly resolved at run time.

BZ#1804325

B.4. CHANGES IN STRACE

Red Hat Developer Toolset 9.1 is distributed with strace 5.1.

The following bugs have been fixed since the previous release of Red Hat Developer Toolset:

- Previously, strace did not print stack trace for the first several system calls, up to the first system call that affects memory maps of the traced process, when strace was attached to processes using the -p option. In Red Hat Developer Toolset 9.1, the problem is fixed.

BZ#1790057
Previously, `strace` failed some internal tests in an environment with the `kernel-alt` package installed. In Red Hat Developer Toolset 9.1, the problem is fixed by enabling:

- decoding of the Linux kernel Crypto API netlink protocol;
- RTM_DELMDB, RTM_GETMDB, and RTM_NEWMDB netlink messages;
- FRA_UID_RANGE, NDTA_CONFIG, NDTA_STATS, RTA_MFC_STATS, and RTA_VIA netlink attributes.
  
  BZ#1758201

B.5. CHANGES IN LTRACE

Red Hat Developer Toolset 9.1 is distributed with `ltrace 0.7.91`.

The following bug has been fixed since the previous release of Red Hat Developer Toolset:

- Previously, `ltrace` failed to build if you used any version of `elfutils` with the GCC compiler version distributed with DTS. In Red Hat Developer Toolset 9.1, you can build `ltrace` with the provided GCC version.
  This update also fixes some internal errors by using the string "unknown" instead of "(null)" in backtraces.

  BZ#1759532