GNU Mes Reference Manual

Full Source Bootstrapping for the GNU system

Jan (janneke) Nieuwenhuizen

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GNU Mes

This document describes GNU Mes version 0.22, a bootstrappable Scheme interpreter and C compiler written for bootstrapping the GNU system.

1 Introduction

> These were "Maxwell's Equations of Software!"
> —*Alan Kay*

The purpose of GNU Mes[1] is to help create a computer operating system that we can trust.

Mes consists of a mutual self-hosting Scheme interpreter written in C and a Nyacc-based (see see Section "NYACC User's Guide" in *NYACC User's Guide*) C compiler written in Scheme. The Scheme interpreter `mes.c` is about 5,000LOC of restricted C, to be compiled with M2-Planet[2], a very simple C compiler.

If we want to trust our computers to do what we instructed them to do then we need to be able to inspect all instructions—all softwares—that we have given it to run.

1.1 Software Freedom

The four essential Freedoms of Software are at the core of our GNU community. Quoting the GNU philosophy[3]

> A program is free software if the program's users have the four essential freedoms:
>
> 0. The freedom to run the program as you wish, for any purpose (freedom 0).
> 1. The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1). Access to the source code is a precondition for this.
> 2. The freedom to redistribute copies so you can help others (freedom 2).
> 3. The freedom to distribute copies of your modified versions to others (freedom 3). By doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.

A computer operating system that respects the user's freedom is one essential ingredient for building a reliable, trustable computing system. There are about a dozen general purpose operating systems that can be trusted in this way, see Free Distributions (`https://www.gnu.org/distros/free-distros.html`). For all softwares on such a system we have the full source code and build recipes available.

So we have access to all the software, we have studied it, possibly modified it, then we built it and we installed it on a computer or some device or appliance. How can we trust that when we run the program we are indeed running the untainted product of the source code that we studied? Unless we are certain of this we cannot really enjoy Freedom 1.

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[1] "Mes" is an acronym for the Maxwell Equations of Software.

[2] See `https://github.com/oriansj/m2-planet`

[3] The four essential freedoms `https://www.gnu.org/philosophy/free-sw.html`

1.2 Reproducible Builds

The current Reproducible Builds effort incubated in the Debian project[4] and was organized by Lunar. Quoting the Reproducible Builds website[5]

> A build is reproducible if given the same source code, build environment and build instructions, any party can recreate bit-by-bit identical copies of all specified artifacts.

1.2.1 Can we trust our freedom?

Now consider the opposite, that a second build of a piece of source code produces a different binary program. Upon further investigation we might find that the only difference is probably harmless: a timestamp that was embedded in the binary, or perhaps the name of the user that built it or directory it was built in. Such investigations can be nontrivial and are highly unpractical. And what if the binary difference is not so trivial, cannot be easily accounted for?

A piece of software that cannot be built bit-by-bit reproducible is probably not a good community member in the world of software freedom. We think the importance of reproducibility should not be underestimated largely because failing that precondition makes justifable trust in binaries provided suspect at best and downright dangerous in reality.

It becomes clear that a bit-by-bit reproducible build of all our sofwares is essential if we value our Freedom 1.

1.2.2 An Old Idea

The idea of reproducible builds is not very new. It was implemented for GNU tools in the early 1990s (which we learned, much later in 2017). In the Debian world it was mentioned first in 2000 and then more explicitly in 2007 on debian-devel[6]

> I think it would be really cool if the Debian policy required that packages could be rebuild bit-identical from source.
>
> —*Martin Uecker*

1.3 Bootstrappable Builds

Software distributions that take reproducible builds seriously are currently shipping well over 90% reproducible packages.

That a package builds bit-by-bit reproducibly however is not enough to guarantee Freedom 1. There is another factor that is often overlooked: opaque ascii or binary *seeds* that are injected during build time. Yes, a package may build reproduciblly from all inspectable sourcess...but what functionality is programmed in the opaque seed?

1.3.1 Bootstrap Binary Seed

Possibly one of the most harmless, but certainly by far the biggest binary seed that all software distributions inject are the so called *bootstrap binary seed*. Bootstrap binaries are the initial binary seeds that are used to start building the distribution.

[4] The Debian Project (`http://debian.org`)

[5] Reproducible Builds (`https://reproducible-builds.org/`)

[6] Martin Uecker on debian-devel on bit-reproducibility (`https://lists.debian.org/debian-devel/2007/09/msg00746.html`)

The GNU Guix operating system, version 1.0 had a relatively small closure of bootstrap binary seed: GNU binutils, GNU gcc, GNU Libc, GNU Guile, and "Static binaries" (think: bash, bzip2, coreutils, gawk, grep, gzip, patch, sed, tar, xz).

```
$ du -schx $(readlink $(guix build bootstrap-tarballs)/*)
2.1M /gnu/store/9623n4bq6iq5c8cwwdq99qb7d0xj93ym-binutils-static-stripped-tarball-2.28
18M /gnu/store/437xwygmmwwpkddcyy1qvjcv4hak89pb-gcc-stripped-tarball-5.5.0/gcc-strippe
1.8M /gnu/store/55ccx18a0d1x5y6a575jf1yr0ywizvdg-glibc-stripped-tarball-2.26.105-g0890
5.7M /gnu/store/bqf0ajclbvnbm0a46819f30804y3ilx0-guile-static-stripped-tarball-2.2.3/g
5.8M /gnu/store/j8yzjmh9sy4gbdfwjrhw46zca43aah6x-static-binaries-tarball-0/static-bina
33M total
```

only a 33MB download that unpacks to a 252MB *seed* of opaque binary code.

```
$ for i in $(readlink $(guix build bootstrap-tarballs)/*);\
  do sudo tar xf $i; done
$ du -schx *
130M bin
13M include
54M lib
51M libexec
5.2M share
252M total
```

During the Guix 1.1 development series we managed to create the first reduction by 50% of the Guix *bootstrap binary seed*[7]. This was a very important step because the ~250MB *seed* of binary code was practically non-auditable, which makes it hard to establish what source code produced them.

1.4 Full Source Bootstrap

There is an obvious solution: we cannot allow any binary seeds in our software stack. Not even in the bootstrap binary seed. Maybe that is a bit too strong: we want to have the absolute minimum of binary seeds and all binary seeds need to be inspectable and must be reviewed. How big would the absolute minimal set be?

1.4.1 The Magical Self-Hosting Hex Assembler

June 2016 I learnt about Stage0 (`https://github.com/oriansj/stage0/`). Jeremiah Orians created `hex0` a ~500 byte self-hosting hex assembler. The source code is well documented and the binary is the exact mirror of the source code. I was inspired.

Here is an example of what the `hex0` program looks like; the start of the *hex* function

```
00000060: 4883 f830 7c6f 4883 f83a 7c5a 4883 f841  H..0|oH..:|ZH..A
...
000000d0: 48c7 c0ff ffff ffc3 0000 0000 0000 0000  H...............
000000e0: 4883 e830 c300 0000 0000 0000 0000 0000  H..0............
```

All computer programs look like this: an opaque list of computer codes. The initial programs that we take for granted—the bootstrap binary seed—are about 250MB of such numbers: think 250,000 pages full of numbers.

[7] See `https://guix.gnu.org/blog/2019/guix-reduces-bootstrap-seed-by-50/`

Most computers work pretty well so apparently there is not a pressing need to inspect and study all of these codes. At the same time it is tricky to fully trust[8] a computer that was bootstrapped in this way.

Here is what the source code of the `hex0` assembler looks like

```
## function: hex
48 83 f8 30                # cmp $0x30,%rax
7c 6f                      # jl 6000f3 <ascii_other>
48 83 f8 3a                # cmp $0x3a,%rax
7c 5a                      # jl 6000e4 <ascii_num>
48 83 f8 41                # cmp $0x41,%rax
...
## function: ascii_other
48 c7 c0 ff ff ff ff       # mov $0xffffffffffffffff,%rax
c3                         # ret
...
## function: ascii_num
48 83 e8 30                # sub $0x30,%rax
c3                         # ret
```

While it may be hard to understand what this piece of the program does, it should be possible for anyone to verify that the computer codes above correspond to the source code with comments.

One step beyond these annotated codes is Assembly language. To write a program in Assembly, you only need to provide the instructions; the codes are computed by the `assembler` program.

```
hex:
# deal all ascii less than 0
cmp $48, %rax
jl ascii_other
# deal with 0-9
cmp $58, %rax
jl ascii_num
...
ascii_other:
mov $-1, %rax
ret
ascii_num:
sub $48, %rax
ret
```

More readable still, a similar program text in the C programming language.

```
int
hex (int c)
{
  if (c >= '0' && c <= '9')
```

[8] Ken Thompson's 1984 Turing award acceptance speech Reflections on Trusting Tust (`http://www.ece.cmu.edu/~ganger/712.fall02/papers/p761-thompson.pdf`).

```
        return c - 48;
    ...
    }
```

What if we could bootstrap our entire system from only this one `hex0` assembler binary seed? We would only ever need to inspect these 500 bytes of computer codes. Every[9] later program is written in a more friendly programming language: Assembly, C, ... Scheme.

Inspecting all these programs is a lot of work, but it can certainly be done. We might be able to create a fully inspectable path from almost nothing to all of the programs that our computer runs. Something that seemed to be an impossible dream is suddenly starting to look like "just a couple years of work".

1.5 LISP as Maxwell's Equations of Software

As fate would have it, I stumbled upon this interview with Alan Kay (`https://queue.acm.org/detail.cfm?id=1039523`), where he shares a revelation he had when reading John McCarthy's LISP-1.5 (`http://www.softwarepreservation.org/projects/LISP/book/LISP%201.5%20Programmers%20Manual.pdf`) manual:

> that was the big revelation to me ... when I finally understood that the half page of code on the bottom of page 13 of the Lisp 1.5 manual was Lisp in itself. These were "Maxwell's Equations of Software!" This is the whole world of programming in a few lines that I can put my hand over.
>
> —*Alan Kay*

Our starting point is `hex0`, a 500 byte hex assembler and we need to somehow close the gap to building the bootstrap binary seed, esp. GNU Gcc and the GNU C Library. What better way to do that than by leveraging the powers of LISP?

GNU Mes is a Scheme[10] interpreter that will be indirectly bootstrapped from `hex0` and that wields the magical powers of LISP to close the bootstrap gap, asserting we can enjoy software Freedom 1.

1.5.1 Auditable Elegance

`eval` and `apply` are mutual recursing functions that—using a few helper functions—describe the core of the universe of computing.

```
(define (apply fn x a)
  (cond
   ((atom fn)
    (cond
     ((eq fn CAR)  (caar x))
     ((eq fn CDR)  (cdar x))
     ((eq fn CONS) (cons (car x) (cadr x)))
     ((eq fn ATOM) (atom (car x)))
```

[9] Some program languages have become very hard or practically impossible to bootstrap. Instead of depending on a simple language such as C, they depend on a recent version of itself, or on other binary or ASCII seeds, on other recent programs written in that language, or even on manual intervention. Programs written in a language that cannot be bootstrapped can still run on our systems, but cannot enjoy any of the trust we intend to create.

[10] Scheme is a modern LISP

```
      ((eq fn EQ)   (eq (car x) (cadr x)))
      (#t           (apply (eval fn a) x a))))
    ((eq (car fn) LAMBDA)
                  (eval (caddr fn) (pairlis (cadr fn) x a)))
    ((eq (car fn) LABEL)
                  (apply (caddr fn) x
                         (cons (cons (cadr fn) (caddr fn)) a)))))
(define (eval e a)
  (cond
    ((atom e) (cdr (assoc e a)))
    ((atom (car e))
     (cond ((eq (car e) QUOTE) (cadr e))
           ((eq (car e) COND)  (evcon (cdr e) a))
           (#t                 (apply (car e) (evlis (cdr e) a) a))))
    (#t       (apply (car e) (evlis (cdr e) a) a))))
```

It will be a big day when our computers are fully bootstrapped from source. It would be nice if that source code were readable, auditable and elegant. To be honest, the elegance displayed above that we achieved at the very start of the Mes project is currently hard to find. It is our sincerest hope to bring back this level of quality and elegance..

2 Installation

Mes is available for download from its website at `https://www.gnu.org/pub/gnu/mes/`. This section describes the software requirements of Mes, as well as how to install it and get ready to use it.

2.1 Regular Requirements

This section lists requirements when building Mes from source. The build procedure for Mes is the same as for other GNU software, and is not covered here. Please see the files `README` and `INSTALL` in the Mes source tree for additional details.

GNU Mes depends on the following packages:

- GNU Guile (`http://gnu.org/software/guile/`), version 2.0.13 or later, including 2.2.x;
- GNU Make (`http://www.gnu.org/software/make/`).
- NYACC (`https://savannah.gnu.org/projects/nyacc/`), 0.93.0 or later, including 0.99.0.
- GCC's gcc (`http://gcc.gnu.org`), version 2.95.3 or later.
- mescc-tools (`https://savannah.gnu.org/projects/mescc-tools/`), version 0.6.1 or later,

Mes is compatible with GNU Guile, so it is possible to share the same Scheme code between both. Currently Mes only supports the minimal subset of R5RS and Guile extensions to run MesCC.

2.2 Bootstrap Requirements

This section lists requirements when building Mes as a bootstrap package. The bootstrap build procedure for Mes is similar to building GNU software and goes like this

```
sh configure.sh --prefix=/your/prefix/here
sh bootstrap.sh
sh check.sh
sh install.sh
```

See `configure.sh` and `bootstrap.sh` for inspiration on what environment variables to set.

Bootstrapping Mes depends on the following packages:

- a POSIX-compatible shell
- mescc-tools (`https://github.com/oriansj/mescc-tools/`), version 0.6.1 or later.
- NYACC (`https://savannah.gnu.org/projects/nyacc/`), 0.93.0 or later, including 0.99.0.

2.3 Running the Test Suites

After a successful `configure` and `make` run, it is a good idea to run the test suites.

```
make check
```

Run Mes Scheme language semantics tests (`scaffold/boot`) only

```
build-aux/check-boot.sh
```

Run a single Mes boot test

```
MES_BOOT=scaffold/boot/00-zero.scm bin/mes
```

Run a single Mes Scheme test

```
./pre-inst-env tests/boot.test
MES=guile ./pre-inst-env tests/boot.test
```

Run MesCC tests only

```
build-aux/check-mescc.sh
```

Run a single MesCC test

```
CC=gcc CC32=i686-unknown-linux-gnu-gcc MES=guile \
  build-aux/test.sh scaffold/tests/00-exit-0
```

3 Bootstrapping

> Recipe for yogurt: Add yogurt to milk.
> —*Anonymous*

The bootstrap problem we have set out to solve is that none of our modern software distributions, and Guix in particular, can be created all from source code. In addition to the carefully signed source code of all the programs (the 'milk') an opaque binary seed (the 'yogurt') is injected as an essential dependency.

Why would this be a problem, I hear you ask? This is how it is done, we always did it this way, everyone does it like this! Indeed, a popular way of handling the bootstrapping issue is by ignoring it.

> Your compiler becoming self-hosting. . . a language creator's wet dream.
> —*PFH*

It seems that writing a self-hosting compiler is considered to be a language creator's ultimate goal. It means that their language and compiler have become powerful enough to not depend on a pre-exising language that possibly is—but certainly was until now—more powerful; it feels like passing the rite to adulthood.

When you see the irony, you grasp what our bootstrapping effort means in practice. Creating bootstrappable software is not hard; actually most softwares' first releases are bootstrappable. The problem of bootstrapping is not a technical one, it is a lack of awareness and responsibility.

3.1 The Mes Bootstrap Process

The Reduced Binary Seed bootstrap currently adopted by Guix[1]. In its intiial form it is only available for x86-linux.

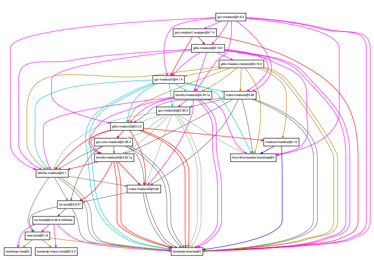
Currently, it goes like this:

```
 gcc-mesboot (4.9.4)
        ^
        |
glibc-mesboot (2.16.0)
        ^
        |
 gcc-mesboot1 (4.7.4)
        ^
        |
binutils-mesboot (2.20.1a)
        ^
        |
 gcc-mesboot0 (2.95.3)
        ^
        |
 glibc-mesboot0 (2.2.5)
```

[1] See `gnu/packages/commencement.scm` in the *master* branch in Guix git `http://git.savannah.gnu.org/cgit/guix.git/tree/gnu/packages/commencement.scm`

```
                              ^
                              |
                      gcc-core-mesboot (2.95.3)
                              ^
                              |
   make-mesboot0, diffutils-mesboot, binutils-mesboot0 (2.20.1a)
                              ^
                              |
                          tcc-boot
                              ^
                              |
                          tcc-boot0
                              ^
                              |
                          mes-boot
                              ^
                              |
                              *
             bootstrap-mescc-tools, bootstrap-mes (~10MB)
     bootstrap-bash, bootstrap-coreutils&co, bootstrap-guile (~120MB)
```

Here's a generated dependency diagram to for the final bootstrap gcc that builds the rest of Guix.



Work is ongoing to remove these binary seeds that were intentionally injected by our own doing as temporary shortcut

```
bootstrap-mescc-tools (seed), bootstrap-mes (seed)
```

For now, these additional non-bootstrapped dependencies (i.e., binary seeds) are taken for granted

```
bootstrap-guile, bash, bzip2, coreutils, gawk, grep, gzip, patch, sed,
tar, xz
```

Although we think these are less essential and thus less interesting than the GNU toolchain triplet that we focussed on initially, our next priority is to eleminate these one by one.

3.2 Invoking mes

The `mes` command is the Scheme interpreter whose prime directive is to run the `MesCC` program.

For convenience and testing purposes, `mes` tries to mimic guile.

```
mes option... FILE...
```

The *options* can be among the following:

`-s` *script arg...*
: By default, mes will read a file named on the command line as a script. Any command-line arguments *arg*... following *script* become the script's arguments; the `command-line` function returns a list of strings of the form `(script arg...)`.

  Scripts are read and evaluated as Scheme source code just as the `load` function would. After loading *script*, mes exits.

`-c` *expr arg...*
: Evaluate *expr* as Scheme code, and then exit. Any command-line arguments *arg*...) following *expr* become command-line arguments; the `command-line` function returns a list of strings of the form `(guile arg...)`, where *mes* is the path of the mes executable.

`--` *arg...*
: Run interactively, prompting the user for expressions and evaluating them. Any command-line arguments *arg*... following the `--` become command-line arguments for the interactive session; the `command-line` function returns a list of strings of the form `(guile arg...)`, where *mes* is the path of the mes executable.

`-L,--load-path=`*directory*
: Add *directory* to the front of Mes module load path. The given directories are searched in the order given on the command line and before any directories in the `GUILE_LOAD_PATH` environment variable.

`-C,--compiled-path=`*directory*
: Accepted and ignored for Guile compatibility.

`-l` *file*
: Load Scheme source code from *file*, and continue processing the command line.

`-e,--main=`*function*
: Make *function* the *entry point* of the script. After loading the script file (with `-s`) or evaluating the expression (with `-c`), apply *function* to a list containing the program name and the command-line arguments—the list provided by the `command-line` function.

`-h`, `--help`
: Display help on invoking mes, and then exit.

`-v`, `--version`
: Display the current version of mes%, and then exit.

3.2.1 Environment Variables

Here are the environment variables (see see Section "Environment Variables" in *Guile Reference*) that affect the run-time behavior of mes:

`MES_BOOT`
: Set `MES_BOOT` to change the initial Scheme program that mes runs.

`MES_ARENA`
: The initial size of the arena see Section "5.3" in *SICP* in cells. Default: 20,000.

`MES_MAX_ARENA`
: The maximum size of the arena in cells. Default: 100,000,000.

`MES_MAX_STRING`
: The maximum size of a string. Default: 524,288.

`MES_DEBUG`

1. Informational:
   - MODULEDIR
   - included SCM modules and sources
   - result of program
   - gc stats at exit
2. opened files
3. runtime gc stats
4. detailed info
   - parsed, expanded program
   - list of builtins
   - list of symbol
   - opened input strings
   - gc details
5. usage of opened input strings

`GUILE_LOAD_PATH`
: This variable may be used to augment the path that is searched for Scheme files when loading. Its value should be a colon-separated list of directories. If it contains the special path component `...` (ellipsis), then the default path is put in place of the ellipsis, otherwise the default path is placed at the end. The result is stored in `%load-path`.

Mes uses **GUILE**_*LOAD_PATH* for compatibility with Guile.

3.3 Invoking mescc

```
mescc option... FILE...
```

The *option*s can be among the following:

`--align`
: align globals

`--base-address=ADRRESS`
: use BaseAddress ADDRESS [0x1000000]

`-c`
: preprocess, compile and assemble only; do not link

`-D DEFINE[=VALUE]`

`-dumpmachine`
: display the compiler's target processor

`-E` preprocess only; do not compile, assemble or link

`-g` add `blood-elf` debug info

This enables GDB setting breakpoints on function names, and to have the GDB backtrace command to show the function call stack.

`-h, --help`
display this help and exit

`-I DIR` append DIR to include path

`-L DIR` append DIR to library path

`-l LIBNAME`
link with LIBNAME

`-m BITS` compile for BITS bits [32]

`-O LEVEL` use optimizing LEVEL

`-o FILE` write output to FILE

`-S` preprocess and compile only; do not assemble or link

`--std=STANDARD`
assume that the input sources are for STANDARD

`-V,--version`
display version and exit

`-w,--write=TYPE`
dump Nyacc AST using TYPE {pretty-print,write}

`-x LANGUAGE`
specify LANGUAGE of the following input files

3.3.1 MesCC Environment Variables

`MES`

Setting `MES` to a mes-compatible Scheme will run mescc using that

```
MES=guile mescc -c scaffold/main.c
```

See, now Guile has become compatible with Mes, instead of the other way around ;-)

`C_INCLUDE_PATH`
`LIBRARY_PATH`
`NYACC_DEBUG`
Setting `NYACC_DEBUG` makes nyacc print names of function during the parsing phase.

3.4 Invoking mesar

```
mesar option... command ARCHIVE-FILE FILE...
```

The *command* is ignored for compatibility with `ar`

```
r[ab][f][u]  - replace existing or insert new file(s) into the archive
[c]          - do not warn if the library had to be created
[D]          - use zero for timestamps and uids/gids (default)
```

and assumed to be *crD*.

The *option*s can be among the following:

`-h, --help`
: display this help and exit

`-V,--version`
: display version and exit

4 Contributing

4.1 Building from Git

If you want to hack GNU Mes itself, it is recommended to use the latest version from the Git repository:

```
git clone git://git.savannah.gnu.org/mes.git
```

The easiest way to set up a development environment for Mes is, of course, by using Guix! The following command starts a new shell where all the dependencies and appropriate environment variables are set up to hack on Mes:

```
guix environment -l .guix.scm
```

Finally, you have to invoke `make check` to run tests (see Section 2.3 [Running the Test Suites], page 9). If anything fails, take a look at installation instructions (see Chapter 2 [Installation], page 8) or send a message to the `bug-mes@gnu.org` mailing list.

4.2 Running Mes From the Source Tree

First, you need to have an environment with all the dependencies available (see Section 4.1 [Building from Git], page 16), and then simply prefix each command by `./pre-inst-env` (the `pre-inst-env` script lives in the top build tree of Mes).

4.3 Porting GNU Mes

Mes was written for x86-linux. A 64 bit (x86_64) is almost done, only a few bugs remain. The Guix bootstrap for x86_64 uses x86 mes and that is not expected to change.

An ARM (armv4/armv7l) linux port is underway. A port to GNU/Hurd (x86-gnu) is also underway.

Initial scaffold, built by `build-aux/build-scaffold.sh`:

```
lib/linux/x86-mes-gcc/exit-42.S
lib/linux/x86-mes/elf32-0exit-42.hex2
lib/linux/x86-mes/elf32-body-exit-42.hex2

lib/linux/x86-mes-gcc/hello-mes.S
lib/linux/x86-mes/elf32-0hello-mes.hex2
lib/linux/x86-mes/elf32-body-hello-mes.hex2
```

Porting MesCC:

```
lib/x86-mes/x86.M1

module/mescc/mescc.scm
module/mescc/i386/as.scm
module/mescc/i386/info.scm

mes/module/mescc/i386/as.mes
mes/module/mescc/i386/info.mes
```

4.4 The Perfect Setup

The Perfect Setup to hack on Mes is basically the perfect setup used for Guile hacking (see Section "Using Guile in Emacs" in *Guile Reference Manual*). First, you need more than an editor, you need Emacs (`http://www.gnu.org/software/emacs`), empowered by the wonderful Geiser (`http://nongnu.org/geiser/`).

Geiser allows for interactive and incremental development from within Emacs: code compilation and evaluation from within buffers, access to on-line documentation (docstrings), context-sensitive completion, `M-.` to jump to an object definition, a REPL to try out your code, and more (see Section "Introduction" in *Geiser User Manual*).

4.5 Coding Style

In general our code follows the GNU Coding Standards (see *GNU Coding Standards*). However, they do not say much about Scheme, so here are some additional rules.

4.5.1 Programming Paradigm

Scheme code in Mes is written in a purely functional style.

4.5.2 Formatting Code

When writing Scheme code, we follow common wisdom among Scheme programmers. In general, we follow the Riastradh's Lisp Style Rules (`http://mumble.net/~campbell/scheme/style.txt`). This document happens to describe the conventions mostly used in Guile's code too. It is very thoughtful and well written, so please do read it.

If you do not use Emacs, please make sure to let your editor knows these rules.

Additionally, in Mes we prefer to format `if` statements like this

```
(if foo? trivial-then
    (let ((bar (the-longer ...)))
      more-complicated
      ...
      else))
```

4.6 Submitting Patches

Development is done using the Git distributed version control system. Thus, access to the repository is not strictly necessary. We welcome contributions in the form of patches as produced by `git format-patch` sent to the `guix-patches@gnu.org` mailing list.

Please write commit logs in the ChangeLog format (see Section "Change Logs" in *GNU Coding Standards*); you can check the commit history for examples.

4.6.1 Reporting Bugs

Encountering a problem or bug can be very frustrating for you as a user or potential contributor. For us as Mes maintainers, the preferred bug report includes a beautiful and tested patch that we can integrate without any effort.

However, please don't let our preference stop you from reporting a bug. There's one thing *much* worse for us than getting a bug report without a patch: Reading a complaint or rant online about your frustrations and how our work sucks, without having heard directly what you experienced.

So if you report a problem, will it be fixed? And **when**? The most honest answer is: It depends. Let's curry that informationless honesty with a more helpful and more blunt reminder of a mantra of free software:

Q: When will it be finished?

A: It will be ready sooner if you help.

—*Richard Stallman*

Join us on `#bootstrappable` on the Freenode IRC network or on `guix-devel@gnu.org` to share your experience—good or bad.

Please send bug reports with full details to `bug-mes@gnu.org`.

5 Acknowledgments

We would like to thank the following people for their help: Jeremiah Orians, Peter de Wachter, rain1, Ricardo Wurmus, Rutger van Beusekom.

We also thank Ludovic Courtès for creating GNU Guix and making the bootstrap problem so painfully visible, John McCarthy for creating LISP-1.5 and Alan Kay for their inspiring comment on Page 13 (`https://queue.acm.org/detail.cfm?id=1039523`).

6 Resources

- Bootstrappable Builds (`https://bootstrappable.org`) Minimize the amount and size of opaque binary seeds we need to swallow.
- Reproducible Builds (`https://reproducible-builds.org`) Provide a verifiable path from source code to binary.
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