This compiler is stored in `compiler/m3compiler.target` and the associated runtime and core library in `runtime/m3run.target.o` and `lib/m3lib.target.a` respectively.

- if all went well, you have a working system for *target*. Otherwise, you have to determine what's wrong and go back to constructing the cross-compiler
- send us (`m3-request@src.dec.com`) your modifications for the *target* architecture, so that we can incorporate them in the next release.

Compiler Hopefully, all the things that the compiler itself needs to know are summarized in the `Target` module. Copy `compiler/VAX/Target.{i,m}3` to `compiler/`*target*. Then modify these files to reflect the architecture of *target*. Copy `compiler/VAX/Imakefile` to `compiler/`*target*.

Runtime routines The file `runtime/`*target*`/M3machine.h` is included in all the C files that are produced by the compiler. You can compare the variations for the existing port to get a flavor of what goes there.

Garbage collector It has to know about the alignment constraints and the start of the data section of compiled programs. There are three places in `runtime/gcalloc/gc.c` where conditional compilation is used to adjust these parameters. Add cases for the *target* architecture.

Threads On `DS3100` systems, thread switching is implemented by standard C code. This code should work on other architectures as well, provided that `_longjmp` does not insist that the new stack pointer should be lower in the stack than the current stack pointer.

VAX/Ultrix 3.1 does not allow this liberal use of `_longjmp`, so there is a piece of assembly code from which you can start if your *target* architecture is also restrictive.

In any case, copy the contents of `runtime/DS3100` or `runtime/VAX` (as appropriate) into `runtime/`*target* and start from there.

Loader The loader (`loader/m3ld2.c`) is also dependent on the system, because it has to rebuild C names from their translation by the C compiler as they appears in object files. For example, the VAX C compiler adds an underscore in front of C names, while the DS3100 compiler doesn't. The proper behaviour is achieved in `loader/m3ld2.c` by conditional compilation according to the system.

Good Luck!

- make a copy of the distribution in a fresh directory; in the following, paths will be relative to that directory and commands should be issued from that directory.
- establish a link to the installed version:

  ```
  (cd driver; ln -s installed/m3 m3c.bootstrap)
  ```

- chose a name for the new system, say *target*
- create the directories `compiler/`*target*, `runtime/`*target* and `lib/`*target*
- create the file `imake/Imake.`*host*`-`*target* with the contents

  ```
  HOST = host
  TARGET = target
  ```

- create a symbolic link from `imake/Imake.machine` to `imake/Imake.`*host*`-`*target*
- add a line to `imake/Imake.definitions`:

  `source_dir(`*target*`)`

  next to the similar lines for other systems.
- modify the compiler and the runtime as described below
- add `.ROOT/imake` to your path (in each subdirectory of the system, there is a link named `.ROOT` to the top of the hierarchy)
- build the cross-compiler, i.e. the compiler that generates code for the *target* system and runs on the *host* system:

  ```
  $ m3make host
  ```

  The cross-compiler is stored in `compiler/m3compiler.host`
- produce the C version of the compiler using the cross-compiler:

  ```
  $ m3make CFILES
  ```

- copy the hierarchy to the *target* system
- on the *target* system, finish the construction of the compiler (it produces code for the *target* system and runs on the *target* system):

  ```
  $ (cd imake; cc -o imake imake.c)
  $ m3make target
  ```

Joel F. Bartlett, "Compacting garbage collection with ambiguous roots," Digital – Western Research Laboratory, WRL Research Report 88/2, February 1988.

Since that paper, we've made a few modifications to support a growing heap and to use extra information that the Modula-3 compiler generates.

Thread switching is implemented with `setjmp` and `longjmp`. A timer interrupt (signal) is used to cause preemptive thread switching. The global variable `ThreadSupport.self` points to the currently running thread. The integer `ThreadSupport.inCritical` is used by the runtime to prevent thread switching during garbage collection and other "atomic" runtime operations.

Exceptions are implemented with `setjmp` and `longjmp`. The jump buffers and scope descriptors are chained together to form a stack. The head of the chain is kept in `ThreadSupport.handlers`. There is a distinct chain for each thread. When an exception is raised, the chain is searched. If a handler for the exception is found, the exception is allowed to unwind the stack, otherwise a runtime error is signaled. To unwind the stack, a `longjmp` is done to the first handler on the stack. It does whatever cleanup is necessary and passes control on up the stack to the next handler until the exception is actually handled.

Reference types are represented at runtime by a "typecell". Due to separate compilation, opaque types and revelations, it is not possible to fully initialize typecells at compile time. Typecell initialization is finished at runtime prior to the execution of any user code. A typecell contains a type's typecode, a pointer to its parent typecell, the size of the types referent and method list if any, the type's brand, the number of open array dimensions, the type's fingerprint, and procedures to initialize the typecell, initialize new instances of the type, and print instances of the type.

Initialization of a Modula-3 address space occurs in several steps. First, all types are registered. That is, a global array that points to all typecells is built. Next, the runtime verifies that all opaque types have been given concrete representations. Then, the initialization of typecells is finished. Then, all types with the same brand and fingerprint are identified with the same typecode. Then, a check is made to ensure that distinct types have distinct brands. Then, all global variables are initialized. And finally the main bodies of the modules are invoked. The skeletal code that ensures that every module is initialized is generated by `m3ld`(1).

7.3 Porting to another machine

Anyone who is interested in porting this compiler is encouraged! We would like to know how it goes.

The primary concerns when doing a port will be the size and alignment constraints of the target machine and the runtime. We tried to avoid suspicious C constructs, but I doubt that we were completely successful.

General. If you want to a port to an unsupported system you should:

- install SRC Modula-3 on some other system that is supported, say *host*. In the following, let `installed/m3` be the pathname of the installed driver (not the compiler per se).

The compilation process retains the usual phases. Symbols are scanned as needed by the parser. A recursive descent parser reads the entire source and builds the internal syntax tree. All remaining passes simply add decorations to this tree. The next phase binds all identifiers to values in scopes. Modula-3 allows arbitrary forward references so it is necessary to accumulate all names within a scope before binding any identifiers to values. The next phase divides the types into structurally equivalent classes. This phase actually occurs in two steps. First, the types are divided into classes such that each class will have a unique C representation. Then, those classes are refined into what Modula-3 defines as structurally equivalent types. After the types have been partitioned, the entire tree is checked for type errors. Finally, the C code is emitted. C's requirement that declarations precede uses means that the code is generated in several passes. First, the types are generated during type checking. Then, the procedure headers are produced. And finally, the procedure bodies are generated.

The compiler implementation is in the `compiler` directory. Within that directory the following directories exist:

builtinOps	`ABS`, `ADR`, `BITSIZE`, ...
builtinTypes	`INTEGER`, `CHAR`, `REFANY`, ...
exprs	`+`, `-`, `[]`, `^`, `AND`, `OR`, ...
misc	main program, scanner, symbol tables, ...
stmts	`:=`, `IF`, `TRY`, `WHILE`, ...
types	`ARRAY`, `BITS FOR`, `RECORD`, ...
values	`MODULE`, `PROCEDURE`, `VAR`, ...
word	`Word.And`, `Word.Or`, ...

7.2 A tour of the runtime

The runtime includes a primitive interface to the operating system and implementations of a garbage collector, threads, text strings, the Modula-3 startup code and a few miscellaneous functions. The runtime exists in the `runtime` directory. Within that directory the following directories exist:

gcalloc	the memory allocator and garbage collector
kernel	basic elements of the runtime
os	interface to the operating system
text	the `Text` module
thread	the `Thread` module
time	time-related functions
word	the `Word` interface

The interface between the compiler and runtime system is embodied (and very sparsely documented) in `M3Runtime.h` and `M3RuntimeDecls.h`. Every C file generated by the compiler includes these interfaces.

The allocator and garbage collector are based on Joel Bartlett's "mostly copying collector". The best description of his collector is

Chapter 7

Internals

This section contains a brief introduction to the internal structure of the compiler and runtime system. This introduction is neither comprehensive nor tutorial; it is merely intended as a stepping stone for the courageous.

7.1 A tour of the compiler

The compiler has undergone much evolution. It started as a project to build a simple and easy to maintain compiler. Somewhere along the way we decided to compile Modula-3. Much later we decided to generate C. In hindsight, Modula-3 was a good choice, C was at best mediocre.

The initial observation was that most compilers' data structures were visible and complex. This situation makes it necessary to understand a compiler in its entirety before attempting non-trivial enhancements or bug fixes. By keeping most of the compiler's primary data structures hidden behind opaque interfaces, we hoped to avoid this pitfall. So far, bugs have been easy to find. During early development, it was relatively easy to track the weekly language changes.

The compiler is decomposed by language feature rather than the more traditional compiler passes. We attempted to confine each language feature to a single module. For example, the parsing, name binding, type checking and code production for each statement is in its own module. This separation means that only the `CaseStmt` module needs to know what data structures exist to implement `CASE` statements. Other parts of the compiler need only know that the `CASE` statement is a statement. This fact is captured by the object subtype hierarchy. A `CaseStmt.T` is a subtype of a `Stmt.T`.

The main object types within the compiler are: values, statements, expressions, and types. "Values" is a misnomer; "bindings" would be better. This object class include anything that can be named: modules, procedures, variables, exceptions, constants, types, enumeration elements, record fields, methods, and procedure formals. Statements include all of the Modula-3 statements. Expressions include all the Modula-3 expression forms that have a special syntax. And finally, types include the Modula-3 types.

The compiler retains the traditional separation of input streams, scanner, symbol table, and output stream.

The key to making Modula-3 successful requires designing, building and sharing libraries. You can send us useful modules or programs and we will include them in the next release as contributed software. You can also announce the availability of your work on the SRC Modula-3 mailing list (see the previous chapter about this mailing list).

Chapter 6

The standard library

SRC Modula-3 includes a set of core library routines. The library exists within the `lib` and `runtime` subdirectories. These directories include:

lib	utility modules forming a core library
autoflushwr	auto-flushing writers
files	access to the files
fingerprint	fingerprinting texts
convert, fmt, scan	conversion of basic types to and from text
formatter	primitives for building pretty-printers
geometry	geometric primitives: points, intervals, rectangles, ...
list	list data structure
tables	and table data structures
math	an interface to the C math library
parseparams	command line parser
random	random number generator
rd	readers (input streams)
wr	writers (output streams)
statistics	simple statistics: mean, variance, ...
textrw	in-memory (`TEXT`) readers and writers
types	interfaces to regularize the builtin types
uid	a generator of unique identifiers
runtime	the runtime system required by the compiler
gcalloc	the memory allocator and garbage collector
kernel	basic elements of the runtime
os	interface to the operating system
text	the required `Text` implementation
thread	the required `Thread` implementation
time	time-related functions
word	the required `Word` implementation
C	the C basic types in Modula-3 syntax; conversion

It is intended that the interfaces within the library be complete and self documenting.

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Needless to say, this implementation probably has many bugs. We are quite happy to receive bug reports. We don't promise to fix them, but we will try. When reporting a bug, please send us a short program that demonstrates the problem.

5.8.1 Count profiling

This type of profiling reports the number of times each procedure has been called and/or the number of times each statement or line of source code has been executed. UNIX provides two tools to gather the number of executions of a procedure, but no tool to measure the number of executions of a statement. However, these tools also gather time-profiling information and are somewhat problematic in our case (see the next section).

We provide an alternate set of programs that collect both kinds of data. To enable collection of data during the execution of programs, give the `-Z` option to the `m3` command. To interpret the result, run `analyze_coverage`(1).

Note that because of the extensive data collection performed by this mode of profiling, the execution time of the program can be significantly larger when collection is enabled; thus, simultaneous time profiling can produce erroneous results. For the same reason, the profiling data file is rather large; furthermore, as it is augmented by each execution of the program, you may want to compress it from time to time (see `analyze_coverage`(1) for more details).

5.8.2 Time profiling

The standard method to construct time profiles uses a UNIX timer to periodically interrupt the execution of the program and collect the current program counter. We have another use for that timer interrupt (to schedule the execution of threads). Hence, it is generally not possible to gather time profiles. But, programs that have only one thread (and thus, do not use `Thread.Fork`, either directly or indirectly via a library routine), have no scheduling to do. On such programs, using the `-pg` compilation option will gather a time profile that can be interpreted using `gprof`(1).

This situation is only temporary; we plan to offer the full time profiling capabilities standard in UNIX in a forthcoming release.

5.9 Pretty printing

SRC Modula-3 includes a pretty-printer for Modula-3 programs. It is accessible as `m3pp`(1). Read its man page to find out how to use it. (This version may not accept some of the programs that the compiler accepts, in particular because of pragmas. A feature release will fix that.)

5.10 Keeping in touch

Mail sent to `m3@src.dec.com` will be forwarded to all registered users of SRC Modula-3. (You're registered if you sent us a note asking to be added to this list or returned a signed copy of the licensing agreement.) We hope that this mailing list will provide a useful forum for the exchange of ideas, problems and solutions when using SRC Modula-3.

You can contact the SRC Modula-3 implementers at the following address:

Despite the fact that all references turn into `char*`, traced references and objects can be examined with the debugger. To print the referent of a reference or object `ref`, call `print_object (ref)`. Note that using this feature requires your debugger to be able to call procedures in the target address space. Examining untraced `REF`s requires loopholing.

5.7.3 Procedures

Modula-3 procedures are mapped as closely as possible into C procedures. Two differences exist: "large" results and nested procedures.

First, procedures that return structured values (i.e. records, arrays or sets) take an extra parameter. The last parameter is a pointer to the memory that will receive the returned result. This parameter was necessary because some C compilers return structured results by momentarily copying them into global memory. The global memory scheme works fine until it's preempted by the Modula-3 thread scheduler.

Second, nested procedures are passed an "extra" parameter. The first parameter to a nested procedure is a pointer to the local variables of the enclosing block. To call a nested procedure from the debugger, pass the address of the enclosing procedure's local variable named `frame`.

When a nested procedure is passed as parameter, the address of the corresponding C procedure and its "extra" parameter are packaged into a small closure record. The address of this record is actually passed. Any call through a formal procedure parameter first checks to see whether the parameter is a closure or not and then makes the appropriate call. Likewise, assignments of formal procedure parameters to variables perform runtime checks for closures.

`<*EXTERNAL*>` procedures have no extra parameters.

5.7.4 File names and line numbers

Due to liberal use of the `#line` mechanism of C, the Modula-3 file names and line numbers are preserved. Your debugger should give you the right names and line numbers and display the correct Modula-3 source code (if it includes facilities to display source code).

5.7.5 Threads

There is no support for debugging threads. That is, there is no mechanism to force the debugger to examine any thread other than the one currently executing. Usually you can get into another thread by setting a breakpoint that it will hit. There is no mechanism to run a single thread while keeping all others stopped.

5.8 Profiling

SRC Modula-3 provides two types of profiling: count profiling and time profiling.

names like t182. The Modula-3 type names are equated to their corresponding C type. The bad news is that variables are declared with the C type names. So, if you ask your debugger "what is the type of v?", it will most likely answer, "t137". But, if you ask "what is t137?" it will most likely give you a useful type description.

The following table indicates the C type corresponding to a Modula-3 type.

Modula-3	C
enumeration	`unsigned char`, `unsigned short` or `unsigned int` depending on the number of elements in the enumeration.
`INTEGER`	`int`
subrange	`char`, `short` or `int`, possibly `unsigned`, depending on the base type of the subrange. Subranges of enumerations are implemented by the same type as the full enumeration. Subranges of `INTEGER` are implemented by the smallest type containing the range. For example, the type `[0..255]` is mapped to `unsigned char` and `[-1000..1000]` is mapped to `short`.
`REAL`	`float`
`LONGREAL`	`double`
`ARRAY I OF T`	`struct { tT elts[n] }`, where `tT` is the C type of `T` and `n` is `NUMBER(I)`.
`ARRAY`^{n} `OF T`	`struct { char* elts; int size[n] }`, where `elts` is a pointer to the first element of the array.
`RECORD ... END`	`struct{ ... }` with the same collection of fields as the original record, except that their names are prefixed by a `_`.
`BITS n FOR T`	Usually `tT` where `tT` is the the C type of `T`. When `T` is an ordinal type and the packed type occurs within a record, it generates a C bit field.
`SET OF T`	`struct { int elts[n] }` where `n` is $\lceil$`NUMBER (T)/sizeof(int)`$\rceil$.

`REF T`
`UNTRACED REF T`
`OBJECT ... END`
	`ADDRESS`, a `typedef` for `char*` defined in `M3RuntimeDecls.h`. Each use of a reference is cast into a pointer of the appropriate type at the point of use.

`PROCEDURE (): T`	Usually `tT *(proc)()` where `tT` is the C type of `T`. If `T` is a record or array, an extra `VAR` parameter is passed to the procedure which it uses to store the return result.

generates the entry code (as C), compiles it and produces the final linked program. At runtime the generated entry code initializes the program's modules.

For every symbol `X.Z` exported or imported by a module, the compiler generates an auxiliary symbol `VS_X__Z__xx`. This extra symbol, `X.Z`'s version stamp, is used to ensure that all modules linked into a single program agree on the type of `X.Z`. The `xx`'s are a string of 16 hexadecimal digits that encode the signature of `X.Z`. Modules that export `X.Z` also define its version stamp. Modules that import `X.Z` also import its version stamp. Modules that import different versions of `X.Z` will require different version stamps. But, since only a single instance of `X.Z` can be linked into the program, only a single version stamp can be defined.

5.6 Garbage Collection

A crucial fact for clients of the garbage collector to know is that *objects in the heap move*. If all references to a traced heap object are from other traced heap objects, the collector may move the referent. Hence, it is a bad idea to hash pointer values. References from the stack or untraced heap into the traced heap are never modified.

5.7 Debugging

Since an intermediate step of the Modula-3 compiler is to produce C code, you may use any debugger for which your C compiler can produce debugging information; in most cases, this means `dbx` or `gdb`.

However, this mechanism has limitations: the C compiler generates source-level information that relates the executable program to the intermediate C code, not to the Modula-3 source code. We attempted to reflect as much as possible of the source-level Modula-3 information into the intermediate C code. But there are still some shortcomings that you should know about.

5.7.1 Names

Every Modula-3 name is prefixed with an underscore. This mutation prevents name clashes between Modula-3 names, names used by the runtime system, and C reserved words.

Global names (i.e. top-level procedures, constants, types, variables, and exceptions) are also prefixed by their module's name. For example, in an interface or module named `X`, the C name of a top-level procedure `P` would be `_X__P`. Note, there is one underscore before `X` and two between `X` and `P`.

Local names (i.e. ones defined within a procedure or block statement) are simply prefixed by an underscore.

5.7.2 Types

Modula-3 is based on structural type equivalence, C is not. For this reason, the compiler maps all structurally equivalent Modula-3 types into a single C type. These C types have meaningless

The character type. The report defines `CHAR` as an enumeration of at least 256 elements that includes the ISO-Latin-1 alphabet. The report gives a lexical method for naming each of the elements of the enumeration (e.g. `'A'` or `'\012'`). Unfortunately the report does not give names to the elements of this enumeration. SRC Modula-3 defines these names:

name	value	name	value	name	value	name	value
NUL	`\000`	SOH	`\001`	STX	`\002`	ETX	`\003`
EOT	`\004`	ENQ	`\005`	ACK	`\006`	BEL	`\007`
BS	`\010`	HT	`\011`	NL	`\012`	VT	`\013`
NP	`\014`	CR	`\015`	SO	`\016`	SI	`\017`
DLE	`\020`	DC1	`\021`	DC2	`\022`	DC3	`\023`
DC4	`\024`	NAK	`\025`	SYN	`\026`	ETB	`\027`
CAN	`\030`	EM	`\031`	SUB	`\032`	ESC	`\033`
FS	`\034`	GS	`\035`	RS	`\036`	US	`\037`
SP	`\040`	DEL	`\177`				

Hence, `CHAR.NL` and `'\n'` denote the same value. Each of the alphabetic characters a-z and A-Z are also defined in the enumeration, so `CHAR.A` and `'A'` denote the same value.

Assertions. SRC Modula-3 implements an `ASSERT` pragma. The pragma may appear anywhere a statement may appear. It has the form `<*ASSERT expr *>` where `expr` is a boolean expression. At runtime the expression is evaluated. It is a checked runtime error if the result is `FALSE`.

Assertion checking can be disabled with the `-A` compiler switch.

Warnings. SRC Modula-3 generates several types of warning messages (e.g. unused variables, incomplete case statements, and use of non-standard features.) Two pragmas are available to control these warning messages: `<*NOWARN*>` and `<*UNUSED*>`. No warning messages are emitted for lines containing `<*NOWARN*>`. No "unused variable" warnings are emitted for variables declared where `VAR` is immediately preceded by `<*UNUSED*>`. The kinds of warnings emitted can also be controlled by the `-w` switch. See the `m3` man page for the full details.

Obsolete. SRC Modula-3 implents an `<*OBSOLETE*>` pragma. `<*OBSOLETE*>` may appear before any declaration (e.g. `<*OBSOLETE*> PROCEDURE P ();`). A warning is emitted in any module that references an obsolete symbol. This feature is used to warn clients of an interface that is evolving that they are using features that will disappear in the future.

5.5 Linking

SRC Modula-3 requires a special two-phase linker. The Modula-3 linker is normally invoked by `m3`, but may be invoked directly as `m3ld`. The `m3ld`(1) man page describes the arguments and options recognized by the linker.

The first phase of the linker invokes the standard UNIX linker to construct a single object containing everything required by the program except a tiny bit of entry code. The second phase

Inlined procedures. The compiler recognizes the `<*INLINE*>` pragma before procedure declarations. The pragma is allowed in interfaces and modules. At the moment, SRC Modula-3 ignores the pragma. Future versions will implement inline procedures.

For example:

```
INTERFACE X;
<*INLINE*> PROCEDURE P (i: INTEGER);
<*INLINE*> PROCEDURE Q ();
END X.
```

declares `X.P` and `X.Q` to be inlined procedures.

External language interface. The compiler also recognizes the `<*EXTERNAL*>` pragma. The pragma may appear immediately prior to a variable or procedure declaration. A variable or procedure that is declared to be external is assumed to be implemented outside the Modula-3 world. The names of external procedures and variables are passed through to the C compiler unchanged. The types of external variables and the formals to external procedures are assumed to be correct and are not checked against their external implementation. Standard calling conventions are used when calling external procedures.

For example:

```
INTERFACE OS;
<*EXTERNAL*> VAR errno: INTEGER;
<*EXTERNAL*> PROCEDURE exit (i: INTEGER);
END OS.
```

allows importers of `OS` to access the standard UNIX symbols `errno` and `exit` through the names `OS.errno` and `OS.exit` respectively.

If several variables are declared within a single `<*EXTERNAL*> VAR` declaration, they are all assumed to be external.

The external pragma may optionally specify a name different from the Modula-3 name. The form `<*EXTERNAL` id`*>` will use "id" as the external name and the form `<*EXTERNAL "s"*>` will use the text literal "s" as the external name. For example:

```
INTERFACE Xt;
  <*EXTERNAL "_XtCheckSubclassFlag" *>
  PROCEDURE CheckSubclassFlag (...);
  ...
```

defines a procedure named `Xt.CheckSubclassFlag` in Modula-3 and named `_XtCheckSubclassFlag` in the generated C.

5.3 Language restrictions

With a few exceptions, SRC Modula-3 implements the Modula-3 language as defined in the revised report of November 1989. Send a note to `m3-request@src.dec.com` to receive paper copies of the report. A PostScript version of the report is available via `ftp`; see section 4.1.

Arithmetic checking. SRC Modula-3 does not generate any special checking for arithmetic overflow or underflow. You get whatever checking your C compiler gives you. We decided that the runtime checking was too expensive in a compiler that was constrained to produce C. Future versions of this compiler that generate native machine code will perform the checking.

Packed types. Packed types are restricted. `BITS n FOR T` is treated as `T` everywhere except when applied to a field of an ordinal type in a record. In that case, the field is implemented by a *field* of width `n` in a C `struct`. Otherwise, a Modula-3 field is implemented as a *member* of a C `struct`. Consequently, the C representation of a packed field cannot span word boundaries and padding may be added by the C compiler to respect this constraint.

Stack overflow checking. SRC Modula-3 does not reliably detect thread stack overflows. Stacks are only checked for overflow on procedure entry. No checking is done on external procedures. Thread stacks are allocated in fixed size chunks. The required `Thread` interface has been augmented with the —SizedClosure— type to allow arbitrary sized stacks. The default size is given by `Thread.DefaultStackSize`,

Exception semantics. SRC Modula-3 uses C's `setjmp/longjmp` mechanism to unwind the stack when raising an exception. A problem can occur: assignments may appear to be undone. For example, consider

```
TRY
  i := 3;
  P ();
EXCEPT E:
  j := i;
END;
```

where `P` raises exception `E`. The compiler generates a `setjmp` at the beginning of the try statement. If the C compiler allocates variable `i` to a register, the assignment of `3` may be lost during the `longjmp` and branch that gets to the handler.

5.4 Language extensions

SRC Modula-3 implements some features not defined in the Modula-3 report.

5.2 An example

Here's a simple program composed of a main module, an imported interface and its implementation. In the file `Main.m3`:

```
MODULE Main;
IMPORT A;
BEGIN
  A.DoIt ();
END Main.
```

In the file `A.i3`:

```
INTERFACE A;
PROCEDURE DoIt ();
END A.
```

In the file `A.m3`:

```
MODULE A;
IMPORT Wr, Stdio;

PROCEDURE DoIt () =
   BEGIN
     Wr.PutText (Stdio.stdout, "Hello world.\n");
     Wr.Close (Stdio.stdout);
   END DoIt;

BEGIN
END A.
```

And finally, in `Makefile`:

```
OBJECTS = Main.mo A.io A.mo
M3FLAGS = -g

program: $(OBJECTS)
       m3 -o program $(OBJECTS)

.SUFFIXES: .m3 .mo .i3 .io
.m3.mo: ; m3 -c $(M3FLAGS) $*.m3
.i3.io: ; m3 -c $(M3FLAGS) $*.i3
```

If SRC Modula-3 is installed properly, running `make` will compile the three compilation units and link them with the standard libraries. The result will be left in the executable file named `program`.

Chapter 5

How to use the system

This section describes each of the tools in the SRC Modula-3 distribution and how to use them. Briefly, the tools include a compiler, linker, pretty printer, and a profiler.

5.1 Compiling

To compile a Modula-3 program, invoke `m3`(1). This driver is much in the style of `cc`(1); the output is an object file or an executable program, according to the options.

`m3` parses the command line and invokes the compiler and linker as required. `m3` tells the compiler where to seek imported interfaces and where to find the Modula-3 runtime library. Arguments ending in `.m3` or `.i3` are assumed to name Modula-3 source files to be compiled. Arguments ending in `.mo`, `.io` or `.o` are assumed to name object files, possibly created by other language processors, that are to be linked with the object files created by `m3`. Arguments ending in `.mc`, `.ic`, or `.c` are assumed to name C source files to be compiled. Arguments ending in `.ms`, `.is`, or `.s` are assumed to name assembly language files to be translated into object files by the assembler. Arguments starting with `-` specify compiler options. Other arguments are assumed to name library files, and are simply passed along to the linker.

The source for a module named `M` is normally in a file named `M.m3`. The source for an interface named `I` must be in a file named `I.i3`. The main program is the module that implements the interface `Main`.

There are options to compile without linking, stop compiling after producing C, emit debugger symbols, generate profiling hooks, retain intermediate files, override search paths, select non-standard executables for the various passes, and pass arguments to individual passes. For the full details, see the `m3`(1) man page.

In a source file, an occurrence of `IMPORT Mumble` causes the compiler to seek an interface named `Mumble`. The compiler will step through a sequence of directories looking for the file `Mumble.i3`. It will parse the first such file that it finds, which is expected to contain an interface named `Mumble`. If no file `Mumble.i3` exists, or if the parse fails, the compiler will generate an error. The particular sequence of directories to be searched is determined by the options passed to `m3`. See the `m3(1)` manual page for full details.

4.2 Installation procedure

1. Configure the system for you machine, by building one of the targets `VAX`, `DS3100` or `SPARC`. For example:

   ```
   $ make VAX
   ```

2. Edit `imake/Imake.Ultrix-install` to select the system directories in which to install the various parts. See the comments at the beginning of this file to know what to change.

3. Compile SRC Modula-3:

   ```
   $ make
   ```

   The table above shows in the "Requirements, build (mn)" column the CPU time (in minutes) needed to compile the corresponding distribution of SRC Modula-3.

4. Install SRC Modula-3:

   ```
   $ make install
   ```

5. Conserve space:

   ```
   $ make clean
   ```

If you need to install on more than one kind of machine, you can restart from the configuration step above, directing the installation to another place.

4.3 What's in the distribution

The distribution hierarchy comprises the following directories:

`compiler`	the Modula-3 to C compiler
`coverage`	a line-based profiler
`depend`	a tool to detect if a file needs to be recompiled
`doc`	source for this document
`driver`	glue for the compiler passes: compile , C-compile, link, ...
`imake`	tools to build and install the system
`lib`	utility modules forming a core library
`loader`	the Modula-3 specific loader
`pp`	pretty-printer
`runtime`	the required runtime system
`tests`	test programs for the Modula-3 system
`X`	interfaces to the X window system
`o.HOST`	objects for the host machine (in case of port)
`o.TARGET`	objects for the target machine

In general, each directory contains a `README` that describes the contents of that directory and an `Imakefile` that rebuilds and installs the contents of that directory.

4. Open an `ftp` connection with `gatekeeper.dec.com` [16.1.0.2]; give `anonymous` for the name and your id for the password:

```
$ ftp gatekeeper.dec.com
Connected to gatekeeper.dec.com.
...
Name (gatekeeper.dec.com):  anonymous
Password (gatekeeper.decom.com:anonymous):  your name@your machine
...
```

5. Change to the proper directory:

```
ftp> cd /pub/DEC/Modula-3
```

6. Set the transmission type to binary and get the distribution:

```
ftp> type binary
ftp> get m3-1.4.tar.Z dist.tar.Z
```

   Other files are also available from the same place; `Report.ps` is the "Modula-3 Report (revised)" in PostScript format. `Report{1,2,3}.ps` is the same, but in pieces.

7. Close the connection:

```
ftp> quit
```

8. Uncompress the file:

```
$ uncompress dist.tar.Z
```

9. Extract the files for this `tar` file:

```
$ tar xpof dist.tar
```

   The `tar` arguments specify the following options:

`x`	extract the files from the `tar` file to the current directory
`p`	restore files to their original modes
`o`	override the original ownership, this makes you the owner of the files
`f`	use the following argument `dist.tar` as the input file

   You can add the `v` option to see what is going on.

10. At this point you may delete the `tar` file to save space (the requirement indicated above assumes that you do delete this file):

```
$ rm dist.tar
```

Chapter 4

Installation

This chapter describes how to get and install the SRC Modula-3 system.

4.1 Getting SRC Modula-3

SRC Modula-3 is distributed through anonymous `ftp` on `gatekeeper.dec.com`, in a compressed `tar` file named `m3-1.4.tar.Z`. This compressed `tar` file is 4.5 Mb. The table below indicates the ressources necessary for the various installations (all three can be made from the same distribution):

System	Requirements			Hardware	Operating system
	build (Mb)	build (mn)	disk (Mb)		
`VAX`	45	30	8	VAX 8800	Ultrix 3.1
`DS3100`	45	25	9	DECstation 3100	Ultrix 3.1
`SPARC`				Sparcstation-1	SunOS 4.0.3

In the following, `$` is the shell prompt and `ftp>` is the `ftp` prompt. To get SRC Modula-3:

1. Make sure that you have enough disk space. The table above, in the column "Requirements, build (Mb)", shows the amount of disk space necessary to build SRC Modula-3, while "Requirements, disk (Mb)" shows the amount of disk space permanently occupied (if you remove the sources).

2. Create a fresh directory for the software. Path names below are relative to that directory:

```
$ mkdir m3
```

3. Change to that directory:

```
$ cd m3
```

It is known to run on VAX Ultrix 3.1. We have not tested the software in any other configurations. The software may function correctly on other versions of Ultrix, and if recompiled, may even work on other machines.

Chapter 3

History

Version 1.4 Version 1.4 is the second public release of SRC Modula-3. It uses the new features of version 1.3 and was alpha-tested by several SRC clients. This version added `<*UNUSED*>` and `<*OBSOLETE*>` pragmas, simplified coverage profiling by having the compiler directly generate the counters, reduced the number of `#line` directives in the generated C, added "map" procedures so that the garbage collector can efficiently locate global references, packed enumerations into smaller C types, and fixed several bugs.

Version 1.3 Version 1.3 was for internal use only. This version served to snapshot the massive editing that had taken place since 1.2. This version fixed the variable renaming problems, made `TEXT` a `REF ARRAY OF CHAR`, converted the text implementation to Modula-3, passed nested procedures as closures, used C initialization where possible for constants and variables, added warning messages, and fixed many bugs.

Version 1.2 Thanks to the new technology introduced in 1.1, porting the compiler to other machines is much easier. We have ported it to DECstation 3100 running Ultrix 3.1. A few bugs have been fixed. The driver processes the options `-D` and `-B` in a slightly different way.

The installation procedure is new, and we no longer furnish executables as the intermediate C files are present on the release. Because the intermediate C files vary according to the target machine, there are separate `tar` files for each of the supported machines. However, each distribution contains all of the sources; only the intermediate C files differ.

Version 1.1 This version is for internal use only. The main difference with Version 1.0 is the use of RCS and the use of `imake` rather than the standard `make`.

Version 1.0 This version is the first public release of the SRC Modula-3 system. It contains a Modula-3 compiler and runtime, a core library, a coverage analyzer, a dependency checker, a Modula-3 pretty printer, and a small test suite of Modula-3 programs. The compiler generates C as an intermediate code.

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Chapter 2

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Chapter 1

Introduction

This document describes the SRC Modula-3 distribution and the terms under which it is distributed.

The distribution contains a Modula-3 compiler and runtime, a core library, a coverage analyzer, a dependency checker, a Modula-3 pretty printer, and a small test suite of Modula-3 programs. The compiler generates C as an intermediate code.

This release is known to run on VAX and DECstation 3100 running Ultrix 3.1, as well as on Sparcstation running SunOS 4.0.3. We have not tested the software in any other configurations. The software may function correctly on other versions of Ultrix, and if recompiled, may even work on other machines.

The compiler and runtime system was designed and implemented by Bill Kalsow and Eric Muller. Neither of us view this as a finished product. Nonetheless, we thought others might like to use it. The system should be of interest to two camps: those interested in trying out Modula-3 and those interested in compiler hacking.

We would like to thank Joel Bartlett (DEC-WRL) for his help with the garbage collector, John Dillon (DEC-SRC) who provided us with the C version of thread switching, Greg Nelson and Mark Manasse (DEC-SRC) for readers and writers, Jérôme Chailloux (DEC-SRC and ILOG) for the X interface, David Goldberg (XEROX PARC) for the SPARC port, Jorge Stolfi (DEC-SRC) and Stephen Harrison (DEC-WSE) for their patience and invaluable examples of bugs, and all the persons, too numerous to name them all, who sent bug reports.

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SRC Modula-3
Version 1.4

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