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**WORKING DRAFT
ISO IEC TECHNICAL REPORT 19767**

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Enhanced Module Facilities

in

Fortran

An extension to IS 1539-1:2004

11 November 2003

THIS PAGE TO BE REPLACED BY ISO-CS

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Foreword

[General part to be provided by ISO CS]

This technical report specifies an extension to the module program unit facilities of the programming language Fortran. Fortran is specified by the international standard ISO/IEC 1539-1:2004. This document has been prepared by ISO/IEC JTC1/SC22/WG5, the technical working group for the Fortran language.

It is the intention of ISO/IEC JTC1/SC22/WG5 that the semantics and syntax specified by this technical report be included in the next revision of the Fortran standard (ISO/IEC 1539-1:2004) without change unless experience in the implementation and use of this feature identifies errors that need to be corrected, or changes are needed to achieve proper integration, in which case every reasonable effort will be made to minimize the impact of such changes on existing implementations.

0 Introduction

The module system of Fortran, as standardized by ISO/IEC 1539-1:2004, while adequate for programs of modest size, has shortcomings that become evident when used for large programs, or programs having large modules. The primary cause of these shortcomings is that modules are monolithic.

This technical report extends the module facility of Fortran so that program developers can optionally encapsulate the implementation details of module procedures in **submodules** that are separate from but dependent on the module in which the interfaces of their procedures are defined. If a module or submodule has submodules, it is the **parent** of those submodules.

The facility specified by this technical report is compatible to the module facility of Fortran as standardized by ISO/IEC 1539-1:2004.

0.1 Shortcomings of Fortran's module system

The shortcomings of the module system of Fortran, as specified by ISO/IEC 1539-1:2004, and solutions offered by this technical report, are as follows.

0.1.1 Decomposing large and interconnected facilities

If an intellectual concept is large and internally interconnected, it requires a large module to implement it. Decomposing such a concept into components of tractable size using modules as specified by ISO/IEC 1539-1:2004 may require one to convert private data to public data. The drawback of this is not primarily that an “unauthorized” procedure or module might access or change these entities, or develop a dependence on their internal details. Rather, during maintenance, one must then answer the question “where is this entity used?”

Using facilities specified in this technical report, such a concept can be decomposed into modules and submodules of tractable size, without exposing private entities to uncontrolled use.

Decomposing a complicated intellectual concept may furthermore require circularly dependent modules, but this is prohibited by ISO/IEC 1539-1:2004. It is frequently the case, however, that the dependence is between the implementation of some parts of the concept and the interface of other parts. Because the module facility defined by ISO/IEC 1539-1:2004 does not distinguish between the implementation and interface, this distinction cannot be exploited to break the circular dependence. Therefore, modules that implement large intellectual concepts tend to become large, and therefore expensive to maintain reliably.

Using facilities specified in this technical report, complicated concepts can be implemented in submodules that access modules, rather than modules that access modules, thus reducing the possibility for circular dependence between modules.

0.1.2 Avoiding recompilation cascades

Once the design of a program is stable, few changes to a module occur in its **interface**, that is, in its public data, public types, the interfaces of its public procedures, and private entities that affect their definitions. We refer to the rest of a module, that is, private entities that do not affect the definitions of public entities, and the bodies of its public procedures, as its **implementation**. Changes in the implementation have no effect on the translation of other program units that access the module. The existing module facility, however, draws no structural distinction between the interface and the implementation. Therefore, if one changes any part of a module, most language translation systems have no alternative but to conclude that a change might have occurred that could affect other modules that access the changed module. This effect cascades into modules that access modules that access the changed module, and so on. This can cause a substantial expense to retranslate and recertify a large program. Recertification can be several orders of magnitude more costly than retranslation.

Using facilities specified in this technical report, implementation details of a module can be encapsulated in submodules. Submodules are not accessible by use association, and they depend on their parent module, not vice-versa. Therefore, submodules can be changed without implying that a program unit accessing the parent module (directly or indirectly) must be retranslated.

It may also be appropriate to replace a set of modules by a set of submodules each of which has access to others of the set through the parent/child relationship instead of USE association. A change in one such submodule requires the retranslation only of its descendant submodules. Thus, compilation and certification cascades caused by changes can be shortened.

0.1.3 Packaging proprietary software

If a module as specified by international standard ISO/IEC 1539-1:2004 is used to package proprietary software, the source text of the module cannot be published as authoritative documentation of the interface of the module, without either exposing trade secrets, or requiring the expense of separating the implementation from the interface every time a revision is published.

Using facilities specified in this technical report, one can easily publish the source text of the module as authoritative documentation of its interface, while withholding publication of the source text of the submodules that contain the implementation details, and the trade secrets embodied within them.

0.1.4 Easier library creation

Most Fortran translator systems produce a single file of computer instructions and data, frequently called an *object file*, for each module. This is easier than producing an object file for the specification part and one for each module procedure. It is also convenient, and conserves space and time, when a program uses all or most of the procedures in each module. It is inconvenient, and results in a larger program, when only a few of the procedures in a general purpose module are needed in a particular program.

Modules can be decomposed using facilities specified in this technical report so that it is easier for each program unit's author to control how module procedures are allocated among object files. One can then collect sets of object files that correspond to a module and its submodules into a library.

0.2 Disadvantage of using this facility

Translator systems will find it more difficult to carry out global inter-procedural optimizations if the program uses the facility specified in this technical report. Interprocedural optimizations involving

procedures in the same module or submodule will not be affected. When translator systems become able to do global inter-procedural optimization in the presence of this facility, it is possible that requesting inter-procedural optimization will cause compilation cascades in the first situation mentioned in subclause 0.1.2, even if this facility is used. Although one advantage of this facility could perhaps be reduced in the case when users request inter-procedural optimization, it would remain if users do not request inter-procedural optimization, and the other advantages remain in any case.

Information technology – Programming Languages – Fortran

Technical Report: Enhanced Module Facilities

1 General

1 1.1 Scope

2 This technical report specifies an extension to the module facilities of the programming language Fortran. The Fortran language is specified by international standard ISO/IEC 1539-1:2004 : Fortran. The extension allows program authors to develop the implementation details of concepts in new program units, called **submodules**, that cannot be accessed directly by use association. In order to support submodules, the module facility of international standard ISO/IEC 1539-1:2004 is changed by this technical report in such a way as to be upwardly compatible with the module facility specified by international standard ISO/IEC 1539-1:2004.

9 Clause 2 of this technical report contains a general and informal but precise description of the extended functionalities. Clause 3 contains detailed instructions for editorial changes to ISO/IEC 1539-1:2004.

11 1.2 Normative References

12 The following standards contain provisions that, through reference in this text, constitute provisions of this technical report. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. Parties to agreements based on this technical report are, however, encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referenced applies. Members of IEC and ISO maintain registers of currently valid International Standards.

18 ISO/IEC 1539-1:2004 : *Information technology – Programming Languages – Fortran; Part 1: Base Language*
19

2 Requirements

The following subclauses contain a general description of the extensions to the syntax and semantics of the Fortran programming language to provide facilities for submodules, and to separate subprograms into interface and implementation parts.

2.1 Summary

This technical report defines a new entity and modifications of two existing entities.

The new entity is a program unit, the *submodule*. As its name implies, a submodule is logically part of a module, and it depends on that module. A new variety of interface body, a *module procedure interface body*, and a new variety of procedure, a *separate module procedure*, are introduced.

By putting a module procedure interface body in a module and its corresponding separate module procedure in a submodule, program units that access the interface body by use association do not depend on the procedure's body. Rather, the procedure's body depends on its interface body.

2.2 Submodules

A **submodule** is a program unit that is dependent on and subsidiary to a module or another submodule. A module or submodule may have several subsidiary submodules. If it has subsidiary submodules, it is the **parent** of those subsidiary submodules, and each of those submodules is a **child** of its parent. A submodule accesses its parent by host association.

An **ancestor** of a submodule is its parent, or an ancestor of its parent. A **descendant** of a module or submodule is one of its children, or a descendant of one of its children.

A submodule is introduced by a statement of the form `SUBMODULE (parent-identifier) submodule-name`, and terminated by a statement of the form `END SUBMODULE submodule-name`. The *parent-identifier* is either the name of the parent module or is of the form *ancestor-module-name* : *submodule-name*, where *submodule-name* is the name of a submodule that is a descendant of the module named *ancestor-module-name*.

Identifiers declared in a submodule are effectively PRIVATE, except for the names of separate module procedures that correspond to public module procedure interface bodies (2.3) in the ancestor module. It is not possible to access entities declared in the specification part of a submodule by use association because a USE statement is required to specify a module, not a submodule. ISO/IEC 1539-1:2004 permits PRIVATE and PUBLIC declarations only in a module, and this technical report does not propose to change this.

Submodule identifiers are global identifiers, but since they consist of a module name and a descendant submodule name, the name of a submodule can be the same as the name of another submodule so long as they do not have the same ancestor module.

In all other respects, a submodule is identical to a module.

2.3 Separate module procedure and its corresponding interface body

A **module procedure interface body** specifies the interface for a separate module procedure. It is different from an interface body defined by ISO/IEC 1539-1:2004 in three respects. First, it is introduced by a *function-stmt* or *subroutine-stmt* that includes MODULE in its *prefix*. Second, it specifies that its corresponding procedure body is in the module or submodule in which it appears, or one of its descendant submodules. Third, it accesses the module or submodule in which it is declared by host association.

1 A **separate module procedure** is a module procedure whose interface is declared in the same module or
 2 submodule, or is declared in one of its ancestors and is accessible from that ancestor by host association.
 3 The module subprogram that defines it may redeclare its characteristics, whether it is recursive, and its
 4 binding label. If any of these are redeclared, the characteristics, corresponding dummy argument names,
 5 whether it is recursive, and its binding label if any, shall be the same as in its module procedure interface
 6 body. The procedure is accessible by use association if and only if its interface body is accessible by
 7 use association. It is accessible by host association if and only if its interface body or procedure body is
 8 accessible by host association.

9 If the procedure is a function and its characteristics are not redeclared, the result variable name is
 10 determined by the FUNCTION statement in the module procedure interface body. Otherwise, the
 11 result variable name is determined by the FUNCTION statement in the module subprogram.

12 2.4 Examples of modules with submodules

13 The example module POINTS below declares a type POINT and a module procedure interface body for
 14 a module function POINT_DIST. Because the interface body includes the MODULE prefix, it accesses
 15 the scoping unit of the module by host association, without needing an IMPORT statement; indeed, an
 16 IMPORT statement is prohibited.

```
17  MODULE POINTS
18      TYPE :: POINT
19          REAL :: X, Y
20      END TYPE POINT
21
22      INTERFACE
23          MODULE FUNCTION POINT_DIST ( A, B ) RESULT ( DISTANCE )
24              TYPE(POINT), INTENT(IN) :: A, B ! POINT is accessed by host association
25              REAL :: DISTANCE
26          END FUNCTION POINT_DIST
27      END INTERFACE
28  END MODULE POINTS
```

29 The example submodule POINTS_A below is a submodule of the POINTS module. The type POINT and
 30 the interface POINT_DIST are accessible in the submodule by host association. The characteristics of the
 31 function POINT_DIST are redeclared in the module function body, and the dummy arguments have the
 32 same names. The function POINT_DIST is accessible by use association because its module procedure
 33 interface body is in the ancestor module and has the PUBLIC attribute.

```
34  SUBMODULE ( POINTS ) POINTS_A
35      CONTAINS
36          REAL MODULE FUNCTION POINT_DIST ( A, B ) RESULT ( DISTANCE )
37              TYPE(POINT), INTENT(IN) :: A, B
38              DISTANCE = SQRT( (A%X-B%X)**2 + (A%Y-B%Y)**2 )
39          END FUNCTION POINT_DIST
40  END SUBMODULE POINTS_A
```

41 An alternative declaration of the example submodule POINTS_A shows that it is not necessary to
 42 redeclare the properties of the module procedure POINT_DIST.

```
43  SUBMODULE ( POINTS ) POINTS_A
```

```
1     CONTAINS
2     MODULE PROCEDURE POINT_DIST
3         DISTANCE = SQRT( (A%X-B%X)**2 + (A%Y-B%Y)**2 )
4     END PROCEDURE POINT_DIST
5     END SUBMODULE POINTS_A
```

3 Required editorial changes to ISO/IEC 1539-1:2004

The following editorial changes, if implemented, would provide the facilities described in foregoing clauses of this report. Descriptions of how and where to place the new material are enclosed between square brackets.

[After the third right-hand-side of syntax rule R202 insert:] 9:12+

or submodule

[After syntax rule R1104 add the following syntax rule. This is a quotation of the “real” syntax rule in subclause 11.2.2.] 9:34+

```
R1115a submodule                is submodule-stmt
                                  [ specification-part ]
                                  [ module-subprogram-part ]
                                  end-submodule-stmt
```

[In the second line of the first paragraph of subclause 2.2 insert “, a submodule” after “module”.] 11:41

[In the fourth line of the first paragraph of subclause 2.2 insert a new sentence:] 11:43

A submodule is an extension of a module; it may contain the definitions of procedures declared in a module or another submodule.

[In the sixth line of the first paragraph of subclause 2.2 insert “, a submodule” after “module”.] 11:45

[In the penultimate line of the first paragraph of subclause 2.2 insert “or submodule” after “module”.] 11:47

[In the second sentence of 2.2.3.2, insert “or submodule” between “module” and “containing”.] 12:28

[Insert a new subclause:] 13:17+

2.2.5 Submodule

A **submodule** is a program unit that extends a module or another submodule. It may provide definitions (12.5) for procedures whose interfaces are declared (12.3.2.1) in an ancestor module or submodule. It may also contain declarations and definitions of other entities, which are accessible in descendant submodules. An entity declared in a submodule is not accessible by use association unless it is a module procedure whose interface is declared in the ancestor module.

NOTE 2.2¹/₂

The scoping unit of a submodule accesses the scoping unit of its parent module or submodule by host association.

[In the second line of the first row of Table 2.1 insert “, SUBMODULE” after “MODULE”.] 14

[Change the heading of the third column of Table 2.2 from “Module” to “Module or Submodule”.] 14

[In the second footnote to Table 2.2 insert “or submodule” after “module” and change “the module” to “it”.] 14

[In the last line of 2.3.3 insert “, *end-submodule-stmt*,” after “*end-module-stmt*”.] 15:2

1	[In the first line of the second paragraph of 2.4.3.1.1 insert “, submodule,” after “module”.]	17:4
2	[At the end of 3.3.1, immediately before 3.3.1.1, add “END PROCEDURE” and “END SUBMODULE”	28
3	into the list of adjacent keywords where blanks are optional, in alphabetical order.]	
4	[In the second line of the third paragraph of 4.5.1.1 after “definition” insert “, and its descendant	46:10
5	submodules”.]	
6	[In the last line of Note 4.18, after “defined” add “, and its descendant submodules”.]	46
7	[In the last line of the fourth paragraph of 4.5.3.6, after “definition”, add “and its descendant submod-	55:10
8	ules”.]	
9	[In the last line of Note 4.40, after “module” add “, and its descendant submodules”.]	55
10	[In the last line of Note 4.41, after “definition” add “and its descendant submodules”.]	56
11	[In the last line of the paragraph before Note 4.44, after “definition” add “, and its descendant submod-	58:8
12	ules”.]	
13	[In the third and fourth lines of the second paragraph of 4.5.5.2 insert “or submodule” after “module”	59:23-24
14	twice.]	
15	[In the second paragraph of Note 4.48, insert “or submodule” after “module” twice.]	60
16	[In the first line of the second paragraph of 5.1.2.12 insert “, or any of its descendant submodules” after	84:3
17	“attribute”.]	
18	[In the first and third lines of the second paragraph of 5.1.2.13 insert “or submodule” after “module”	84:14,16
19	twice.]	
20	[In the third line of the penultimate paragraph of 6.3.1.1 replace “or a subobject thereof” by “or sub-	113:18
21	module, or a subobject thereof”.]	
22	[In the first two lines of the first paragraph after Note 6.23 insert “or submodule” after “module” twice.]	115:9-10
23	[In the second line of the first paragraph of Section 11 insert “, a submodule” after “module”.]	249:3
24	[In the first line of the second paragraph of Section 11 insert “, submodules” after “modules”.]	249:4
25	[Add another alternative to R1108]	250:17+
26	or <i>separate-module-subprogram</i>	
27	[Within the first paragraph of 11.2.1, at its end, insert the following sentence:]	251:8
28	A submodule shall not reference its ancestor module by use association, either directly or indirectly.	
29	[Then insert the following note:]	

NOTE 11.6¹₃

It is possible for submodules with different ancestor modules to access each others' ancestor modules by use association.

1 [After constraint C1109 insert an additional constraint:] 251:30+

2 C1109a (R1109) If the USE statement appears within a submodule, *module-name* shall not be the name

3 of the ancestor module of that submodule (11.2.2).

4 [Insert a new subclass immediately before 11.3:] 253:6-

5 **11.2.2 Submodules**

6 A **submodule** is a program unit that extends a module or another submodule. The program unit

7 that it extends is its **parent**; its parent is specified by the *parent-identifier* in the *submodule-stmt*. A

8 submodule is a **child** of its parent. An **ancestor** of a submodule is its parent or an ancestor of its parent.

9 A **descendant** of a module or submodule is one of its children or a descendant of one of its children.

10 The **submodule identifier** consists of the ancestor module name together with the submodule name.

NOTE 11.6²₃

A module and its submodules stand in a tree-like relationship one to another, with the module at the root. Therefore, a submodule has exactly one ancestor module and may optionally have one or more ancestor submodules.

11 A submodule accesses the scoping unit of its parent by host association.

12 A submodule may provide implementations for module procedures, each of which is declared by a module

13 procedure interface body (12.3.2.1) within that submodule or one of its ancestors, and declarations and

14 definitions of other entities that are accessible by host association in descendant submodules.

15 R1115a *submodule* is *submodule-stmt*

16 [*specification-part*]

17 [*module-subprogram-part*]

18 *end-submodule-stmt*

19 R1115b *submodule-stmt* is SUBMODULE (*parent-identifier*) *submodule-name*

20 R1115c *parent-identifier* is *ancestor-module-name* [: *parent-submodule-name*]

21 R1115d *end-submodule-stmt* is END [SUBMODULE [*submodule-name*]]

22 C1114a (R1115a) An automatic object shall not appear in the *specification-part* of a submodule.

23 C1114b (R1115a) A submodule *specification-part* shall not contain a *format-stmt* or a *stmt-function-stmt*.

24 C1114c (R1115a) If an object of a type for which *component-initialization* is specified (R444) is declared

25 in the *specification-part* of a submodule and does not have the ALLOCATABLE or POINTER

26 attribute, the object shall have the SAVE attribute.

27 C1114d (R1115c) The *ancestor-module-name* shall be the name of a nonintrinsic module; the *parent-*

28 *submodule-name* shall be the name of a descendant of that module.

29 C1114e (R1115e) If a *submodule-name* is specified in the *end-submodule-stmt*, it shall be identical to the

30 *submodule-name* specified in the *submodule-stmt*.

-
- 1 [In the last line of the first paragraph of 12.3 after “units” add “, except that for a separate module 257:13
 2 procedure body (12.5.2.4), the dummy argument names, binding label, and whether it is recursive shall
 3 be the same as in its corresponding module procedure interface body (12.3.2.1)].
-
- 4 [In C1210 insert “that is not a module procedure interface body” after “*interface-body*”.] 259:20
-
- 5 [After the third paragraph after constraint C1211 insert the following paragraphs and constraints.] 259:30+
- 6 A **module procedure interface body** is an interface body in which the *prefix* of the initial *function-*
 7 *stmt* or *subroutine-stmt* includes MODULE. It declares the interface for a separate module procedure
 8 (12.5.2.4). A separate module procedure is accessible by use association if and only if its interface
 9 body is declared in the specification part of a module and its name has the PUBLIC attribute. If a
 10 corresponding (12.5.2.4) separate module procedure is not defined, the interface may be used to specify
 11 an explicit specific interface but the procedure shall not be used in any way.
- 12 A **module procedure interface** is declared by a module procedure interface body.
- 13 C1211a (R1205) A scoping unit in which a module procedure interface body is declared shall be a module
 14 or submodule.
- 15 C1212b (R1205) A module procedure interface body shall not appear in an abstract interface block.
-
- 16 [Add a right-hand-side to R1228:] 280:3+
- 17 **or** MODULE
-
- 18 [Add constraints after C1242:] 280:7+
- 19 C1242a (R1227) MODULE shall appear only within the *function-stmt* or *subroutine-stmt* of an interface
 20 body that is declared in the scoping unit of a module or submodule, or of a module subprogram.
- 21 C1242b (R1227) If MODULE appears within the *prefix* in a module subprogram, a module procedure
 22 interface having the same name as the subprogram shall be declared in the module or submodule
 23 in which the subprogram is defined, or shall be declared in an ancestor of that program unit
 24 and be accessible by host association from that ancestor.
- 25 C1242c (R1227) If MODULE appears within the *prefix* in a module subprogram, the subprogram shall
 26 specify the same characteristics and dummy argument names as its corresponding (12.5.2.4)
 27 module procedure interface body.
- 28 C1242d (R1227) If MODULE appears within the *prefix* in a module subprogram and a binding label
 29 is specified, it shall be the same as the binding label specified in the corresponding module
 30 procedure interface body.
- 31 C1242e (R1227) If MODULE appears within the *prefix* in a module subprogram, RECURSIVE shall
 32 appear if and only if RECURSIVE appears in the *prefix* in the corresponding module procedure
 33 interface body.
-
- 34 [Insert the following new subclause before the existing subclause 12.5.2.4 and renumber succeeding 283:1-
 35 subclauses appropriately:]

36 **12.5.2.4 Separate module procedures**

37 A **separate module procedure** is a module procedure defined by a *separate-module-subprogram*,

1 by a *function-subprogram* in which the *prefix* of the initial *function-stmt* includes MODULE, or by a
 2 *subroutine-subprogram* in which the prefix of the initial *subroutine-stmt* includes MODULE. Its interface
 3 is declared by a module procedure interface body (12.3.2.1) in the *specification-part* of the module or
 4 submodule in which the procedure is defined, or in an ancestor module or submodule.

5 R1234a *separate-module-subprogram* is MODULE PROCEDURE *procedure-name*
 6 [*specification-part*]
 7 [*execution-part*]
 8 [*internal-subprogram-part*]
 9 *end-sep-subprogram-stmt*

10 R1234b *end-sep-subprogram-stmt* is END [PROCEDURE [*procedure-name*]]

11 C1251a (R1234a) The *procedure-name* shall be the same as the name of a module procedure interface
 12 that is declared in the module or submodule in which the *separate-module-subprogram* is defined,
 13 or is declared in an ancestor of that program unit and is accessible by host association from that
 14 ancestor.

15 C1251b (R1234b) If a *procedure-name* appears in the *end-sep-subprogram-stmt*, it shall be identical to
 16 the *procedure-name* in the MODULE PROCEDURE statement.

17 A module procedure interface body and a subprogram that defines a separate module procedure **corre-**
 18 **spond** if they have the same name, and the module procedure interface is declared in the same program
 19 unit as the separate module procedure or is declared in an ancestor of the program unit in which the
 20 separate module procedure is defined and is accessible by host association from that ancestor.

NOTE 12.40¹/₂

A separate module procedure can be accessed by use association if and only if its interface body is declared in the specification part of a module and its name has the PUBLIC attribute. A separate module procedure that is not accessible by use association might still be accessible by way of a procedure pointer, a dummy procedure, or a type-bound procedure.

21 If a procedure is defined by a *separate-module-subprogram*, its characteristics are specified by the corre-
 22 sponding module procedure interface body.

23 If a separate module procedure is a function defined by a *separate-module-subprogram*, the result variable
 24 name is determined by the FUNCTION statement in the module procedure interface body. Otherwise,
 25 the result variable name is determined by the FUNCTION statement in the module subprogram.

26 [In constraint C1253 replace “*module-subprogram*” by “a *module-subprogram* that does not define a
 27 separate module procedure”.] 283:7

28 [In the first line of the first paragraph after syntax rule R1237 in 12.5.2.6 insert “, submodule” after
 29 “module”,] 284:37

30 [In the list in subclause 16.0, add an item after item (1):] 405:9+
 31 (1¹/₂) A submodule identifier (12.5.2.4),

32 [In the second sentence of the first paragraph of 16.1, insert “non-submodule” before “program unit.”] 405:19,22

33 [After the second sentence of the first paragraph of 16.1, insert a new sentence “The submodule identifier
 34 is a global identifier and shall not be the same as any other submodule identifier.”] 405:22

NOTE 16.2 $\frac{1}{2}$

Submodule identifiers are global identifiers, but since they consist of a module name and a descendant submodule name, the name of a submodule can be the same as the name of another submodule so long as they do not have the same ancestor module.

-
- 1 [In item (1) in the first numbered list in 16.2, after “abstract interfaces” insert “, module procedure 406:6
2 interfaces”.]
-
- 3 [In the paragraph immediately before Note 16.3, after “(4.5.9)” insert “, and a separate module procedure 406:20
4 shall have the same name as its corresponding module procedure interface body”.]
-
- 5 [In the first line of the first paragraph of 16.4.1.3 insert “, a module procedure interface body” after 411:2,3
6 “module subprogram”. In the second line, insert “that is not a module procedure interface body” after
7 “interface body”.]
-
- 8 [In the third line of the first paragraph of 16.4.1.3, after the second instance of “interface body”, insert 411:4
9 a new sentence: “A submodule has access to the named entities of its parent by host association.”]
-
- 10 [In the third line after the sixteen-item list in 16.4.1.3 insert “that does not define a separate module 411:33
11 procedure” after the first “subprogram”.]
-
- 12 [In the first line of Note 16.9, after “interface body” insert “that is not a module procedure interface 412:1+2
13 body”.]
-
- 14 [Insert a new item after item (5)(d) in the list in 16.4.2.1.3:] 415:15+
- 15 (d $\frac{1}{2}$) Is in the scoping unit of a submodule if any scoping unit in that submodule or any of its
16 descendant submodules is in execution.
-
- 17 [In item (3)(c) of 16.5.6 insert “or submodule” after “module” twice.] 422:14-15
-
- 18 [Replace Note 16.18 by the following.] 422

NOTE 16.18

A module subprogram inherently references the module or submodule that is its host. Therefore, for processors that keep track of when modules or submodules are in use, one is in use whenever any procedure in it or any of its descendant submodules is active, even if no other active scoping units reference its ancestor module; this situation can arise if a module procedure is invoked via a procedure pointer, a type-bound procedure, or by means other than Fortran.

-
- 19 [In item (3)(d) of 16.5.6 insert “or submodule” after “module” twice.] 422:16-17
-
- 20 [Insert the following definitions into the glossary in alphabetical order:]
- 21 **ancestor** (11.2.2) : Of a submodule, its parent or an ancestor of its parent. 425:15+
- 22 **child** (11.2.2) : A submodule is a child of its parent. 426:43+
- 23 **correspond** (12.5.2.4) : A module procedure interface body and a subprogram that defines a separate 426:29+
24 module procedure correspond if they have the same name, and the module procedure interface is declared
25 in the same program unit as the separate module procedure or is declared in an ancestor of the program
26 unit in which the separate module procedure is defined and is accessible by host association from that

- 1 ancestor.
- 2 **descendant** (11.2.2) : Of a module or submodule, one of its children or a descendant of one of its 428:28+
3 children.
- 4 **module procedure interface** (12.3.2.1) : An interface defined by an interface body in which MODULE 432:9+
5 appears in the *prefix* of the initial *function-stmt* or *subroutine-stmt*. It declares the interface for a separate
6 module procedure.
- 7 **parent** (11.2.2) : Of a submodule, the module or submodule specified by the *parent-identifier* in its 432:36+
8 *submodule-stmt*.
- 9 **separate module procedure** (12.5.2.4) : A module procedure defined by a subprogram in which 434:26+
10 MODULE appears in the *prefix* of the initial *function-stmt* or *subroutine-stmt*.
- 11 **submodule** (2.2.5, 11.2.2) : A program unit that depends on a module or another submodule; it extends 435:15+
12 the program unit on which it depends.
- 13 **submodule identifier** (11.2.2) : Identifier of a submodule, consisting of the ancestor module name
14 together with the submodule name.

15 [Insert a new subclause immediately before C.9:] 477:29+

16 **C.8.3.9 Modules with submodules**

17 Each submodule specifies that it is the child of exactly one parent module or submodule. Therefore, a
18 module and all of its descendant submodules stand in a tree-like relationship one to another.

19 If a module procedure interface body that is specified in a module has public accessibility, and its
20 corresponding separate module procedure is defined in a descendant of that module, the procedure can
21 be accessed by use association. No other entity in a submodule can be accessed by use association. Each
22 program unit that accesses a module by use association depends on it, and each submodule depends on
23 its ancestor module. Therefore, if one changes a separate module procedure body in a submodule but
24 does not change its corresponding module procedure interface, a tool for automatic program translation
25 would not need to reprocess program units that access the module by use association. This is so even if
26 the tool exploits the relative modification times of files as opposed to comparing the result of translating
27 the module to the result of a previous translation.

28 This is not the end of the story. By constructing taller trees, one can put entities at intermediate levels
29 that are shared by submodules at lower levels; changing these entities cannot change the interpretation of
30 anything that is accessible from the module by use association. Developers of modules that embody large
31 complicated concepts can exploit this possibility to organize components of the concept into submodules,
32 while preserving the privacy of entities that are shared by the submodules and that ought not to be
33 exposed to users of the module. Putting these shared entities at an intermediate level also prevents
34 cascades of reprocessing and testing if some of them are changed.

35 The following example illustrates a module, `color_points`, with a submodule, `color_points_a`, that in
36 turn has a submodule, `color_points_b`. Public entities declared within `color_points` can be accessed by
37 use association. The submodules `color_points_a` and `color_points_b` can be changed without causing
38 the appearance that the module `color_points` might have changed.

39 The module `color_points` does not have a *contains-part*, but a *contains-part* is not prohibited. The
40 module could be published as definitive specification of the interface, without revealing trade secrets
41 contained within `color_points_a` or `color_points_b`. Of course, a similar module without the `module`
42 prefix in the interface bodies would serve equally well as documentation – but the procedures would be
43 external procedures. It would make little difference to the consumer, but the developer would forfeit all

1 of the advantages of modules.

```

2  module color_points
3
4      type color_point
5          private
6          real :: x, y
7          integer :: color
8      end type color_point
9
10     interface                ! Interfaces for procedures with separate
11                               ! bodies in the submodule color_points_a
12     module subroutine color_point_del ( p ) ! Destroy a color_point object
13         type(color_point), allocatable :: p
14     end subroutine color_point_del
15     ! Distance between two color_point objects
16     real module function color_point_dist ( a, b )
17         type(color_point), intent(in) :: a, b
18     end function color_point_dist
19     module subroutine color_point_draw ( p ) ! Draw a color_point object
20         type(color_point), intent(in) :: p
21     end subroutine color_point_draw
22     module subroutine color_point_new ( p ) ! Create a color_point object
23         type(color_point), allocatable :: p
24     end subroutine color_point_new
25     end interface
26
27 end module color_points
    
```

28 The only entities within `color_points_a` that can be accessed by use association are separate module
 29 procedures for which corresponding module procedure interface bodies are provided in `color_points`.
 30 If the procedures are changed but their interfaces are not, the interface from program units that access
 31 them by use association is unchanged. If the module and submodule are in separate files, utilities that
 32 examine the time of modification of a file would notice that changes in the module could affect the
 33 translation of its submodules or of program units that access the module by use association, but that
 34 changes in submodules could not affect the translation of the parent module or program units that access
 35 it by use association.

36 The variable `instance_count` is not accessible by use association of `color_points`, but is accessible
 37 within `color_points_a`, and its submodules.

```

38     submodule ( color_points ) color_points_a ! Submodule of color_points
39
40         integer, save :: instance_count = 0
41
42         interface                ! Interface for a procedure with a separate
43                                 ! body in submodule color_points_b
44         module subroutine inquire_palette ( pt, pal )
45             use palette_stuff      ! palette_stuff, especially submodules
46                                 ! thereof, can access color_points by use
47                                 ! association without causing a circular
48                                 ! dependence because this use is not in the
    
```

```

1           ! module. Furthermore, changes in the module
2           ! palette_stuff are not accessible by use
3           ! association of color_points
4       type(color_point), intent(in) :: pt
5       type(palette), intent(out) :: pal
6       end subroutine inquire_palette
7
8       end interface
9
10      contains ! Invisible bodies for public module procedure interfaces
11          ! declared in the module
12
13      module subroutine color_point_del ( p )
14          type(color_point), allocatable :: p
15          instance_count = instance_count - 1
16          deallocate ( p )
17      end subroutine color_point_del
18      real module function color_point_dist ( a, b ) result ( dist )
19          type(color_point), intent(in) :: a, b
20          dist = sqrt( (b%x - a%x)**2 + (b%y - a%y)**2 )
21      end function color_point_dist
22      module subroutine color_point_new ( p )
23          type(color_point), allocatable :: p
24          instance_count = instance_count + 1
25          allocate ( p )
26      end subroutine color_point_new
27
28      end submodule color_points_a

```

29 The subroutine `inquire_palette` is accessible within `color_points_a` because its interface is declared
30 therein. It is not, however, accessible by use association, because its interface is not declared in the
31 module, `color_points`. Since the interface is not declared in the module, changes in the interface
32 cannot affect the translation of program units that access the module by use association.

```

33      submodule ( color_points_a ) color_points_b ! Subsidiary**2 submodule
34
35      contains
36          ! Invisible body for interface declared in the ancestor module
37      module subroutine color_point_draw ( p )
38          use palette_stuff, only: palette
39          type(color_point), intent(in) :: p
40          type(palette) :: MyPalette
41          ...; call inquire_palette ( p, MyPalette ); ...
42      end subroutine color_point_draw
43
44          ! Invisible body for interface declared in the parent submodule
45      module procedure inquire_palette
46          ... implementation of inquire_palette
47      end procedure inquire_palette
48
49      subroutine private_stuff ! not accessible from color_points_a
50          ...
51      end subroutine private_stuff

```

```

1
2   end submodule color_points_b
3
4   module palette_stuff
5     type :: palette ; ... ; end type palette
6   contains
7     subroutine test_palette ( p )
8       ! Draw a color wheel using procedures from the color_points module
9       type(palette), intent(in) :: p
10      use color_points ! This does not cause a circular dependency because
11                    ! the "use palette_stuff" that is logically within
12                    ! color_points is in the color_points_a submodule.
13      ...
14    end subroutine test_palette
15  end module palette_stuff

```

16 There is a use palette_stuff in color_points_a, and a use color_points in palette_stuff. The
 17 use palette_stuff would cause a circular reference if it appeared in color_points. In this case, it
 18 does not cause a circular dependence because it is in a submodule. Submodules are not accessible by use
 19 association, and therefore what would be a circular appearance of use palette_stuff is not accessed.

```

20  program main
21    use color_points
22    ! "instance_count" and "inquire_palette" are not accessible here
23    ! because they are not declared in the "color_points" module.
24    ! "color_points_a" and "color_points_b" cannot be accessed by
25    ! use association.
26    interface draw                ! just to demonstrate it's possible
27      module procedure color_point_draw
28    end interface
29    type(color_point) :: C_1, C_2
30    real :: RC
31    ...
32    call color_point_new (c_1)      ! body in color_points_a, interface in color_points
33    ...
34    call draw (c_1)                ! body in color_points_b, specific interface
35                                ! in color_points, generic interface here.
36    ...
37    rc = color_point_dist (c_1, c_2) ! body in color_points_a, interface in color_points
38    ...
39    call color_point_del (c_1)     ! body in color_points_a, interface in color_points
40    ...
41  end program main

```

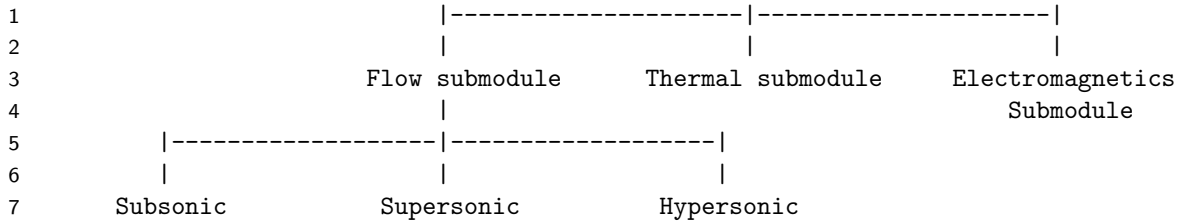
42 A multilevel submodule system can be used to package and organize a large and interconnected concept
 43 without exposing entities of one subsystem to other subsystems.

44 Consider a Plasma module from a Tokamak simulator. A plasma simulation requires attention at least to
 45 fluid flow, thermodynamics, and electromagnetism. Fluid flow simulation requires simulation of subsonic,
 46 supersonic, and hypersonic flow. This problem decomposition can be reflected in the submodule structure
 47 of the Plasma module:

```

48                               Plasma module
49                               |

```



8 Entities can be shared among the **Subsonic**, **Supersonic**, and **Hypersonic** submodules by putting
 9 them within the **Flow** submodule. One then need not worry about accidental use of these entities by
 10 use association or by the **Thermal** or **Electromagnetics** modules, or the development of a dependency
 11 of correct operation of those subsystems upon the representation of entities of the **Flow** subsystem as
 12 a consequence of maintenance. Since these these entities are not accessible by use association, if any
 13 of them are changed, it cannot affect program units that access the **Plasma** module by use association,
 14 and the answer to the question “where are these entities used” is confined to the set of descendant
 15 submodules of the **Flow** submodule.