

2. **Extended Fortran Support** An implementation with this level of Fortran support provides Basic Fortran Support plus additional features that specifically support Fortran 90, as described in Section 16.2.4.

A compliant MPI-2 implementation providing a Fortran interface must provide Extended Fortran Support unless the target compiler does not support modules or KIND-parameterized types.

### 16.2.2 Problems With Fortran Bindings for MPI

This section discusses a number of problems that may arise when using MPI in a Fortran program. It is intended as advice to users, and clarifies how MPI interacts with Fortran. It does not add to the standard, but is intended to clarify the standard.

As noted in the original MPI specification, the interface violates the Fortran standard in several ways. While these cause few problems for Fortran 77 programs, they become more significant for Fortran 90 programs, so that users must exercise care when using new Fortran 90 features. The violations were originally adopted and have been retained because they are important for the usability of MPI. The rest of this section describes the potential problems in detail. It supersedes and replaces the discussion of Fortran bindings in the original MPI specification (for Fortran 90, not Fortran 77).

The following MPI features are inconsistent with Fortran 90.

1. An MPI subroutine with a choice argument may be called with different argument types.
2. An MPI subroutine with an assumed-size dummy argument may be passed an actual scalar argument.
3. Many MPI routines assume that actual arguments are passed by address and that arguments are not copied on entrance to or exit from the subroutine.
4. An MPI implementation may read or modify user data (e.g., communication buffers used by nonblocking communications) concurrently with a user program that is executing outside of MPI calls.
5. Several named “constants,” such as MPI\_BOTTOM, MPI\_IN\_PLACE, MPI\_STATUS\_IGNORE, MPI\_STATUSES\_IGNORE, MPI\_ERRCODES\_IGNORE, MPI\_ARGV\_NULL, and MPI\_ARGVS\_NULL are not ordinary Fortran constants and require a special implementation. See Section 2.5.4 on page 14 for more information.
6. The memory allocation routine MPI\_ALLOC\_MEM can’t be usefully used in Fortran without a language extension that allows the allocated memory to be associated with a Fortran variable.

Additionally, MPI is inconsistent with Fortran 77 in a number of ways, as noted below.

- MPI identifiers exceed 6 characters.
- MPI identifiers may contain underscores after the first character.
- MPI requires an include file, `mpif.h`. On systems that do not support include files, the implementation should specify the values of named constants.

- Many routines in MPI have KIND-parameterized integers (e.g., `MPI_ADDRESS_KIND` and `MPI_OFFSET_KIND`) that hold address information. On systems that do not support Fortran 90-style parameterized types, `INTEGER*8` or `INTEGER` should be used instead.

MPI-1 contained several routines that take address-sized information as input or return address-sized information as output. In C such arguments were of type `MPI_Aint` and in Fortran of type `INTEGER`. On machines where integers are smaller than addresses, these routines can lose information. In MPI-2 the use of these functions has been deprecated and they have been replaced by routines taking `INTEGER` arguments of `KIND=MPI_ADDRESS_KIND`. A number of new MPI-2 functions also take `INTEGER` arguments of non-default `KIND`. See Section 2.6 on page 15 and Section 4.1.1 on page 79 for more information.

### Problems Due to Strong Typing

All MPI functions with choice arguments associate actual arguments of different Fortran datatypes with the same dummy argument. This is not allowed by Fortran 77, and in Fortran 90 is technically only allowed if the function is overloaded with a different function for each type. In C, the use of `void*` formal arguments avoids these problems.

The following code fragment is technically illegal and may generate a compile-time error.

```
integer i(5)
real    x(5)
...
call mpi_send(x, 5, MPI_REAL, ...)
call mpi_send(i, 5, MPI_INTEGER, ...)
```

In practice, it is rare for compilers to do more than issue a warning, though there is concern that Fortran 90 compilers are more likely to return errors.

It is also technically illegal in Fortran to pass a scalar actual argument to an array dummy argument. Thus the following code fragment may generate an error since the `buf` argument to `MPI_SEND` is declared as an assumed-size array `<type> buf(*)`.

```
integer a
call mpi_send(a, 1, MPI_INTEGER, ...)
```

*Advice to users.* In the event that you run into one of the problems related to type checking, you may be able to work around it by using a compiler flag, by compiling separately, or by using an MPI implementation with Extended Fortran Support as described in Section 16.2.4. An alternative that will usually work with variables local to a routine but not with arguments to a function or subroutine is to use the `EQUIVALENCE` statement to create another variable with a type accepted by the compiler. (*End of advice to users.*)

### Problems Due to Data Copying and Sequence Association

Implicit in MPI is the idea of a contiguous chunk of memory accessible through a linear address space. MPI copies data to and from this memory. An MPI program specifies the

location of data by providing memory addresses and offsets. In the C language, sequence association rules plus pointers provide all the necessary low-level structure.

In Fortran 90, user data is not necessarily stored contiguously. For example, the array section `A(1:N:2)` involves only the elements of `A` with indices 1, 3, 5, ... . The same is true for a pointer array whose target is such a section. Most compilers ensure that an array that is a dummy argument is held in contiguous memory if it is declared with an explicit shape (e.g., `B(N)`) or is of assumed size (e.g., `B(*)`). If necessary, they do this by making a copy of the array into contiguous memory. Both Fortran 77 and Fortran 90 are carefully worded to allow such copying to occur, but few Fortran 77 compilers do it.<sup>1</sup>

Because MPI dummy buffer arguments are assumed-size arrays, this leads to a serious problem for a non-blocking call: the compiler copies the temporary array back on return but MPI continues to copy data to the memory that held it. For example, consider the following code fragment:

```
real a(100)
call MPI_Irecv(a(1:100:2), MPI_REAL, 50, ...)
```

Since the first dummy argument to `MPI_Irecv` is an assumed-size array (`<type> buf(*)`), the array section `a(1:100:2)` is copied to a temporary before being passed to `MPI_Irecv`, so that it is contiguous in memory. `MPI_Irecv` returns immediately, and data is copied from the temporary back into the array `a`. Sometime later, MPI may write to the address of the deallocated temporary. Copying is also a problem for `MPI_Isend` since the temporary array may be deallocated before the data has all been sent from it.

Most Fortran 90 compilers do not make a copy if the actual argument is the whole of an explicit-shape or assumed-size array or is a ‘simple’ section such as `A(1:N)` of such an array. (We define ‘simple’ more fully in the next paragraph.) Also, many compilers treat allocatable arrays the same as they treat explicit-shape arrays in this regard (though we know of one that does not). However, the same is not true for assumed-shape and pointer arrays; since they may be discontinuous, copying is often done. It is this copying that causes problems for MPI as described in the previous paragraph.

Our formal definition of a ‘simple’ array section is

```
name ( [:,]... [<subscript>]:[<subscript>] [,<subscript>]... )
```

That is, there are zero or more dimensions that are selected in full, then one dimension selected without a stride, then zero or more dimensions that are selected with a simple subscript. Examples are

```
A(1:N), A(:,N), A(:,1:N,1), A(1:6,N), A(:, :, 1:N)
```

Because of Fortran’s column-major ordering, where the first index varies fastest, a simple section of a contiguous array will also be contiguous.<sup>2</sup>

The same problem can occur with a scalar argument. Some compilers, even for Fortran 77, make a copy of some scalar dummy arguments within a called procedure. That this can cause a problem is illustrated by the example

<sup>1</sup>Technically, the Fortran standards are worded to allow non-contiguous storage of any array data.

<sup>2</sup>To keep the definition of ‘simple’ simple, we have chosen to require all but one of the section subscripts to be without bounds. A colon without bounds makes it obvious both to the compiler and to the reader that the whole of the dimension is selected. It would have been possible to allow cases where the whole dimension is selected with one or two bounds, but this means for the reader that the array declaration or most recent allocation has to be consulted and for the compiler that a run-time check may be required.

```

call user1(a,rq)
call MPI_WAIT(rq,status,ierr)
write (*,*) a

subroutine user1(buf,request)
call MPI_IRecv(buf,...,request,...)
end

```

If `a` is copied, `MPI_IRecv` will alter the copy when it completes the communication and will not alter `a` itself.

Note that copying will almost certainly occur for an argument that is a non-trivial expression (one with at least one operator or function call), a section that does not select a contiguous part of its parent (e.g., `A(1:n:2)`), a pointer whose target is such a section, or an assumed-shape array that is (directly or indirectly) associated with such a section.

If there is a compiler option that inhibits copying of arguments, in either the calling or called procedure, this should be employed.

If a compiler makes copies in the calling procedure of arguments that are explicit-shape or assumed-size arrays, simple array sections of such arrays, or scalars, and if there is no compiler option to inhibit this, then the compiler cannot be used for applications that use `MPI_GET_ADDRESS`, or any non-blocking MPI routine. If a compiler copies scalar arguments in the called procedure and there is no compiler option to inhibit this, then this compiler cannot be used for applications that use memory references across subroutine calls as in the example above.

### Special Constants

MPI requires a number of special “constants” that cannot be implemented as normal Fortran constants, including `MPI_BOTTOM`, `MPI_STATUS_IGNORE`, `MPI_IN_PLACE`, `MPI_STATUSES_IGNORE` and `MPI_ERRCODES_IGNORE`. In C, these are implemented as constant pointers, usually as `NULL` and are used where the function prototype calls for a pointer to a variable, not the variable itself.

In Fortran the implementation of these special constants may require the use of language constructs that are outside the Fortran standard. Using special values for the constants (e.g., by defining them through `parameter` statements) is not possible because an implementation cannot distinguish these values from legal data. Typically these constants are implemented as predefined static variables (e.g., a variable in an MPI-declared `COMMON` block), relying on the fact that the target compiler passes data by address. Inside the subroutine, this address can be extracted by some mechanism outside the Fortran standard (e.g., by Fortran extensions or by implementing the function in C).

### Fortran 90 Derived Types

MPI does not explicitly support passing Fortran 90 derived types to choice dummy arguments. Indeed, for MPI implementations that provide explicit interfaces through the `mpi` module a compiler will reject derived type actual arguments at compile time. Even when no explicit interfaces are given, users should be aware that Fortran 90 provides no guarantee of sequence association for derived types or arrays of derived types. For instance, an array of a derived type consisting of two elements may be implemented as an array of the first

elements followed by an array of the second. Use of the `SEQUENCE` attribute may help here, somewhat.

The following code fragment shows one possible way to send a derived type in Fortran. The example assumes that all data is passed by address.

```

type mytype
  integer i
  real x
  double precision d
end type mytype

type(mytype) foo
integer blocklen(3), type(3)
integer(MPI_ADDRESS_KIND) disp(3), base

call MPI_GET_ADDRESS(foo%i, disp(1), ierr)
call MPI_GET_ADDRESS(foo%x, disp(2), ierr)
call MPI_GET_ADDRESS(foo%d, disp(3), ierr)

base = disp(1)
disp(1) = disp(1) - base
disp(2) = disp(2) - base
disp(3) = disp(3) - base

blocklen(1) = 1
blocklen(2) = 1
blocklen(3) = 1

type(1) = MPI_INTEGER
type(2) = MPI_REAL
type(3) = MPI_DOUBLE_PRECISION

call MPI_TYPE_CREATE_STRUCT(3, blocklen, disp, type, newtype, ierr)
call MPI_TYPE_COMMIT(newtype, ierr)

! unpleasant to send foo%i instead of foo, but it works for scalar
! entities of type mytype
call MPI_SEND(foo%i, 1, newtype, ...)
```

#### A Problem with Register Optimization

MPI provides operations that may be hidden from the user code and run concurrently with it, accessing the same memory as user code. Examples include the data transfer for an `MPI_IRECV`. The optimizer of a compiler will assume that it can recognize periods when a copy of a variable can be kept in a register without reloading from or storing to memory. When the user code is working with a register copy of some variable while the hidden operation reads or writes the memory copy, problems occur. This section discusses register optimization pitfalls.

When a variable is local to a Fortran subroutine (i.e., not in a module or **COMMON block**), the compiler will assume that it cannot be modified by a called subroutine unless it is an actual argument of the call. In the most common linkage convention, the subroutine is expected to save and restore certain registers. Thus, the optimizer will assume that a register which held a valid copy of such a variable before the call will still hold a valid copy on return.

Normally users are not afflicted with this. But the user should pay attention to this section if in his/her program a buffer argument to an **MPI\_SEND**, **MPI\_RECV** etc., uses a name which hides the actual variables involved. **MPI\_BOTTOM** with an **MPI\_Datatype** containing absolute addresses is one example. Creating a datatype which uses one variable as an anchor and brings along others by using **MPI\_GET\_ADDRESS** to determine their offsets from the anchor is another. The anchor variable would be the only one mentioned in the call. Also attention must be paid if MPI operations are used that run in parallel with the user's application.

Example 16.11 shows what Fortran compilers are allowed to do.

**Example 16.11** Fortran 90 register optimization.

This source ...	can be compiled as:
call MPI_GET_ADDRESS(buf,bufaddr, ierror)	call MPI_GET_ADDRESS(buf,...)
call MPI_TYPE_CREATE_STRUCT(1,1, bufaddr, MPI_REAL,type,ierror)	call MPI_TYPE_CREATE_STRUCT(...)
call MPI_TYPE_COMMIT(type,ierror)	call MPI_TYPE_COMMIT(...)
val_old = buf	register = buf
	val_old = register
call MPI_RECV(MPI_BOTTOM,1,type,...)	call MPI_RECV(MPI_BOTTOM,...)
val_new = buf	val_new = register

The compiler does not invalidate the register because it cannot see that **MPI\_RECV** changes the value of **buf**. The access of **buf** is hidden by the use of **MPI\_GET\_ADDRESS** and **MPI\_BOTTOM**.

Example 16.12 shows extreme, but allowed, possibilities.

**Example 16.12** Fortran 90 register optimization – extreme.

Source	compiled as	or compiled as
call MPI_Irecv(buf,..req)	call MPI_Irecv(buf,..req)	call MPI_Irecv(buf,..req)
	register = buf	b1 = buf
call MPI_WAIT(req,..)	call MPI_WAIT(req,..)	call MPI_WAIT(req,..)
b1 = buf	b1 := register	

**MPI\_WAIT** on a concurrent thread modifies **buf** between the invocation of **MPI\_Irecv** and the finish of **MPI\_WAIT**. But the compiler cannot see any possibility that **buf** can be changed after **MPI\_Irecv** has returned, and may schedule the load of **buf** earlier than

typed in the source. It has no reason to avoid using a register to hold `buf` across the call to `MPI_WAIT`. It also may reorder the instructions as in the case on the right.

To prevent instruction reordering or the allocation of a buffer in a register there are two possibilities in portable Fortran code:

- The compiler may be prevented from moving a reference to a buffer across a call to an MPI subroutine by surrounding the call by calls to an external subroutine with the buffer as an actual argument. Note that if the intent is declared in the external subroutine, it must be `OUT` or `INOUT`. The subroutine itself may have an empty body, but the compiler does not know this and has to assume that the buffer may be altered. For example, the above call of `MPI_RECV` might be replaced by

```
call DD(buf)
call MPI_RECV(MPI_BOTTOM,...)
call DD(buf)
```

with the separately compiled

```
subroutine DD(buf)
  integer buf
end
```

(assuming that `buf` has type `INTEGER`). The compiler may be similarly prevented from moving a reference to a variable across a call to an MPI subroutine.

In the case of a non-blocking call, as in the above call of `MPI_WAIT`, no reference to the buffer is permitted until it has been verified that the transfer has been completed. Therefore, in this case, the extra call ahead of the MPI call is not necessary, i.e., the call of `MPI_WAIT` in the example might be replaced by

```
call MPI_WAIT(req,...)
call DD(buf)
```

- An alternative is to put the buffer or variable into a module or a common block and access it through a `USE` or `COMMON` statement in each scope where it is referenced, defined or appears as an actual argument in a call to an MPI routine. The compiler will then have to assume that the MPI procedure (`MPI_RECV` in the above example) may alter the buffer or variable, provided that the compiler cannot analyze that the MPI procedure does not reference the module or common block.

The `VOLATILE` attribute, available in later versions of Fortran, gives the buffer or variable the properties needed, but it may inhibit optimization of any code containing the buffer or variable.

In C, subroutines which modify variables that are not in the argument list will not cause register optimization problems. This is because taking pointers to storage objects by using the `&` operator and later referencing the objects by way of the pointer is an integral part of the language. A C compiler understands the implications, so that the problem should not occur, in general. However, some compilers do offer optional aggressive optimization levels which may not be safe.

### 16.2.3 Basic Fortran Support

Because Fortran 90 is (for all practical purposes) a superset of Fortran 77, Fortran 90 (and future) programs can use the original Fortran interface. The following additional requirements are added:

1. Implementations are required to provide the file `mpif.h`, as described in the original MPI-1 specification.
2. `mpif.h` must be valid and equivalent for both fixed- and free- source form.

*Advice to implementors.* To make `mpif.h` compatible with both fixed- and free-source forms, to allow automatic inclusion by preprocessors, and to allow extended fixed-form line length, it is recommended that requirement two be met by constructing `mpif.h` without any continuation lines. This should be possible because `mpif.h` contains only declarations, and because common block declarations can be split among several lines. To support Fortran 77 as well as Fortran 90, it may be necessary to eliminate all comments from `mpif.h`. (*End of advice to implementors.*)

### 16.2.4 Extended Fortran Support

Implementations with Extended Fortran support must provide:

1. An `mpi` module
2. A new set of functions to provide additional support for Fortran intrinsic numeric types, including parameterized types: `MPI_SIZEOF`, `MPI_TYPE_MATCH_SIZE`, `MPI_TYPE_CREATE_F90_INTEGER`, `MPI_TYPE_CREATE_F90_REAL` and `MPI_TYPE_CREATE_F90_COMPLEX`. Parameterized types are Fortran intrinsic types which are specified using `KIND` type parameters. These routines are described in detail in Section 16.2.5.

Additionally, high-quality implementations should provide a mechanism to prevent fatal type mismatch errors for MPI routines with choice arguments.

#### The `mpi` Module

An MPI implementation must provide a module named `mpi` that can be `USED` in a Fortran 90 program. This module must:

- Define all named MPI constants
- Declare MPI functions that return a value.

An MPI implementation may provide in the `mpi` module other features that enhance the usability of MPI while maintaining adherence to the standard. For example, it may:

- Provide interfaces for all or for a subset of MPI routines.
- Provide `INTENT` information in these interface blocks.

*Advice to implementors.* The appropriate `INTENT` may be different from what is given in the MPI generic interface. Implementations must choose `INTENT` so that the function adheres to the MPI standard. (*End of advice to implementors.*)



*Rationale.* The intent given by the MPI generic interface is not precisely defined and does not in all cases correspond to the correct Fortran `INTENT`. For instance, receiving into a buffer specified by a datatype with absolute addresses may require associating `MPI_BOTTOM` with a dummy `OUT` argument. Moreover, “constants” such as `MPI_BOTTOM` and `MPI_STATUS_IGNORE` are not constants as defined by Fortran, but “special addresses” used in a nonstandard way. Finally, the MPI-1 generic intent is changed in several places by MPI-2. For instance, `MPI_IN_PLACE` changes the sense of an `OUT` argument to be `INOUT`. (*End of rationale.*)

Applications may use either the `mpi` module or the `mpif.h` include file. An implementation may require use of the module to prevent type mismatch errors (see below).

*Advice to users.* It is recommended to use the `mpi` module even if it is not necessary to use it to avoid type mismatch errors on a particular system. Using a module provides several potential advantages over using an include file. (*End of advice to users.*)

It must be possible to link together routines some of which `USE mpi` and others of which `INCLUDE mpif.h`.

### No Type Mismatch Problems for Subroutines with Choice Arguments

A high-quality MPI implementation should provide a mechanism to ensure that MPI choice arguments do not cause fatal compile-time or run-time errors due to type mismatch. An MPI implementation may require applications to use the `mpi` module, or require that it be compiled with a particular compiler flag, in order to avoid type mismatch problems.

*Advice to implementors.* In the case where the compiler does not generate errors, nothing needs to be done to the existing interface. In the case where the compiler may generate errors, a set of overloaded functions may be used. See the paper of M. Hennecke [26]. Even if the compiler does not generate errors, explicit interfaces for all routines would be useful for detecting errors in the argument list. Also, explicit interfaces which give `INTENT` information can reduce the amount of copying for `BUF(*)` arguments. (*End of advice to implementors.*)

### 16.2.5 Additional Support for Fortran Numeric Intrinsic Types

The routines in this section are part of Extended Fortran Support described in Section 16.2.4.

MPI provides a small number of named datatypes that correspond to named intrinsic types supported by C and Fortran. These include `MPI_INTEGER`, `MPI_REAL`, `MPI_INT`, `MPI_DOUBLE`, etc., as well as the optional types `MPI_REAL4`, `MPI_REAL8`, etc. There is a one-to-one correspondence between language declarations and MPI types.

Fortran (starting with Fortran 90) provides so-called `KIND`-parameterized types. These types are declared using an intrinsic type (one of `INTEGER`, `REAL`, `COMPLEX`, `LOGICAL` and `CHARACTER`) with an optional integer `KIND` parameter that selects from among one or more variants. The specific meaning of different `KIND` values themselves are implementation dependent and not specified by the language. Fortran provides the `KIND` selection functions `selected_real_kind` for `REAL` and `COMPLEX` types, and `selected_int_kind` for `INTEGER` types that allow users to declare variables with a minimum precision or number of digits. These functions provide a portable way to declare `KIND`-parameterized `REAL`, `COMPLEX` and

INTEGER variables in Fortran. This scheme is backward compatible with Fortran 77. REAL and INTEGER Fortran variables have a default KIND if none is specified. Fortran DOUBLE PRECISION variables are of intrinsic type REAL with a non-default KIND. The following two declarations are equivalent:

```
double precision x
real(KIND(0.0d0)) x
```

MPI provides two orthogonal methods to communicate using numeric intrinsic types. The first method can be used when variables have been declared in a portable way — using default KIND or using KIND parameters obtained with the `selected_int_kind` or `selected_real_kind` functions. With this method, MPI automatically selects the correct data size (e.g., 4 or 8 bytes) and provides representation conversion in heterogeneous environments. The second method gives the user complete control over communication by exposing machine representations.

#### Parameterized Datatypes with Specified Precision and Exponent Range

MPI provides named datatypes corresponding to standard Fortran 77 numeric types — MPI\_INTEGER, MPI\_COMPLEX, MPI\_REAL, MPI\_DOUBLE\_PRECISION and MPI\_DOUBLE\_COMPLEX. MPI automatically selects the correct data size and provides representation conversion in heterogeneous environments. The mechanism described in this section extends this model to support portable parameterized numeric types.

The model for supporting portable parameterized types is as follows. Real variables are declared (perhaps indirectly) using `selected_real_kind(p, r)` to determine the KIND parameter, where `p` is decimal digits of precision and `r` is an exponent range. Implicitly MPI maintains a two-dimensional array of predefined MPI datatypes `D(p, r)`. `D(p, r)` is defined for each value of `(p, r)` supported by the compiler, including pairs for which one value is unspecified. Attempting to access an element of the array with an index `(p, r)` not supported by the compiler is erroneous. MPI implicitly maintains a similar array of COMPLEX datatypes. For integers, there is a similar implicit array related to `selected_int_kind` and indexed by the requested number of digits `r`. Note that the predefined datatypes contained in these implicit arrays are not the same as the named MPI datatypes MPI\_REAL, etc., but a new set.

*Advice to implementors.* The above description is for explanatory purposes only. It is not expected that implementations will have such internal arrays. (*End of advice to implementors.*)

*Advice to users.* `selected_real_kind()` maps a large number of `(p,r)` pairs to a much smaller number of KIND parameters supported by the compiler. KIND parameters are not specified by the language and are not portable. From the language point of view intrinsic types of the same base type and KIND parameter are of the same type. In order to allow interoperability in a heterogeneous environment, MPI is more stringent. The corresponding MPI datatypes match if and only if they have the same `(p,r)` value (REAL and COMPLEX) or `r` value (INTEGER). Thus MPI has many more datatypes than there are fundamental language types. (*End of advice to users.*)

```

1 MPI_TYPE_CREATE_F90_REAL(p, r, newtype)
2
3     IN      p                precision, in decimal digits (integer)
4     IN      r                decimal exponent range (integer)
5     OUT     newtype          the requested MPI datatype (handle)
6

```

```

7 int MPI_Type_create_f90_real(int p, int r, MPI_Datatype *newtype)
8

```

```

9 MPI_TYPE_CREATE_F90_REAL(P, R, NEWTYPE, IERROR)
10     INTEGER P, R, NEWTYPE, IERROR
11

```

```

12 static MPI::Datatype MPI::Datatype::Create_f90_real(int p, int r)
13

```

This function returns a predefined MPI datatype that matches a **REAL** variable of **KIND selected\_real\_kind(p, r)**. In the model described above it returns a handle for the element **D(p, r)**. Either **p** or **r** may be omitted from calls to **selected\_real\_kind(p, r)** (but not both). Analogously, either **p** or **r** may be set to **MPI\_UNDEFINED**. In communication, an MPI datatype **A** returned by **MPI\_TYPE\_CREATE\_F90\_REAL** matches a datatype **B** if and only if **B** was returned by **MPI\_TYPE\_CREATE\_F90\_REAL** called with the same values for **p** and **r** or **B** is a duplicate of such a datatype. Restrictions on using the returned datatype with the “external32” data representation are given on page [474](#).

It is erroneous to supply values for **p** and **r** not supported by the compiler.

```

22
23 MPI_TYPE_CREATE_F90_COMPLEX(p, r, newtype)
24
25     IN      p                precision, in decimal digits (integer)
26     IN      r                decimal exponent range (integer)
27     OUT     newtype          the requested MPI datatype (handle)
28
29

```

```

30 int MPI_Type_create_f90_complex(int p, int r, MPI_Datatype *newtype)
31

```

```

32 MPI_TYPE_CREATE_F90_COMPLEX(P, R, NEWTYPE, IERROR)
33     INTEGER P, R, NEWTYPE, IERROR
34

```

```

35 static MPI::Datatype MPI::Datatype::Create_f90_complex(int p, int r)
36

```

This function returns a predefined MPI datatype that matches a **COMPLEX** variable of **KIND selected\_real\_kind(p, r)**. Either **p** or **r** may be omitted from calls to **selected\_real\_kind(p, r)** (but not both). Analogously, either **p** or **r** may be set to **MPI\_UNDEFINED**. Matching rules for datatypes created by this function are analogous to the matching rules for datatypes created by **MPI\_TYPE\_CREATE\_F90\_REAL**. Restrictions on using the returned datatype with the “external32” data representation are given on page [474](#).

It is erroneous to supply values for **p** and **r** not supported by the compiler.

```

MPI_TYPE_CREATE_F90_INTEGER(r, newtype)
IN      r                      decimal exponent range, i.e., number of decimal digits
                                (integer)
OUT     newtype                the requested MPI datatype (handle)

```

```
int MPI_Type_create_f90_integer(int r, MPI_Datatype *newtype)
```

```

MPI_TYPE_CREATE_F90_INTEGER(R, NEWTYPE, IERROR)
    INTEGER R, NEWTYPE, IERROR

```

```
static MPI::Datatype MPI::Datatype::Create_f90_integer(int r)
```

This function returns a predefined MPI datatype that matches a `INTEGER` variable of `KIND selected_int_kind(r)`. Matching rules for datatypes created by this function are analogous to the matching rules for datatypes created by `MPI_TYPE_CREATE_F90_REAL`. Restrictions on using the returned datatype with the “external32” data representation are given on page 474.

It is erroneous to supply a value for `r` that is not supported by the compiler.

Example:

```

integer      longtype, quadtype
integer, parameter :: long = selected_int_kind(15)
integer(long) ii(10)
real(selected_real_kind(30)) x(10)
call MPI_TYPE_CREATE_F90_INTEGER(15, longtype, ierror)
call MPI_TYPE_CREATE_F90_REAL(30, MPI_UNDEFINED, quadtype, ierror)
...

call MPI_SEND(ii, 10, longtype, ...)
call MPI_SEND(x, 10, quadtype, ...)

```

*Advice to users.* The datatypes returned by the above functions are predefined datatypes. They cannot be freed; they do not need to be committed; they can be used with predefined reduction operations. There are two situations in which they behave differently syntactically, but not semantically, from the `MPI` named predefined datatypes.

1. `MPI_TYPE_GET_ENVELOPE` returns special combinators that allow a program to retrieve the values of `p` and `r`.
2. Because the datatypes are not named, they cannot be used as compile-time initializers or otherwise accessed before a call to one of the `MPI_TYPE_CREATE_F90_` routines.

If a variable was declared specifying a non-default `KIND` value that was not obtained with `selected_real_kind()` or `selected_int_kind()`, the only way to obtain a matching MPI datatype is to use the size-based mechanism described in the next section.

*(End of advice to users.)*

*Advice to implementors.* An application may often repeat a call to `MPI_TYPE_CREATE_F90_xxxx` with the same combination of `(xxx,p,r)`. The application is not allowed to free the returned predefined, unnamed datatype handles. To prevent the creation of a potentially huge amount of handles, a high quality MPI implementation should return the same datatype handle for the same `(REAL/COMPLEX/INTEGER,p,r)` combination. Checking for the combination `(p,r)` in the preceding call to `MPI_TYPE_CREATE_F90_xxxx` and using a hash-table to find formerly generated handles should limit the overhead of finding a previously generated datatype with same combination of `(xxx,p,r)`. (*End of advice to implementors.*)

*Rationale.* The `MPI_TYPE_CREATE_F90_REAL/COMPLEX/INTEGER` interface needs as input the original range and precision values to be able to define useful and compiler-independent external (Section 13.5.2 on page 414) or user-defined (Section 13.5.3 on page 415) data representations, and in order to be able to perform automatic and efficient data conversions in a heterogeneous environment. (*End of rationale.*)

We now specify how the datatypes described in this section behave when used with the “external32” external data representation described in Section 13.5.2 on page 414.

The external32 representation specifies data formats for integer and floating point values. Integer values are represented in two’s complement big-endian format. Floating point values are represented by one of three IEEE formats. These are the IEEE “Single,” “Double” and “Double Extended” formats, requiring 4, 8 and 16 bytes of storage, respectively. For the IEEE “Double Extended” formats, MPI specifies a Format Width of 16 bytes, with 15 exponent bits, bias = +10383, 112 fraction bits, and an encoding analogous to the “Double” format.

The external32 representations of the datatypes returned by `MPI_TYPE_CREATE_F90_REAL/COMPLEX/INTEGER` are given by the following rules.

For `MPI_TYPE_CREATE_F90_REAL`:

```

if      (p > 33) or (r > 4931) then  external32 representation
                                     is undefined
else if (p > 15) or (r > 307) then  external32_size = 16
else if (p > 6) or (r > 37) then   external32_size = 8
else                                external32_size = 4

```

For `MPI_TYPE_CREATE_F90_COMPLEX`: twice the size as for `MPI_TYPE_CREATE_F90_REAL`.

For `MPI_TYPE_CREATE_F90_INTEGER`:

```

if      (r > 38) then  external32 representation is undefined
else if (r > 18) then  external32_size = 16
else if (r > 9) then   external32_size = 8
else if (r > 4) then   external32_size = 4
else if (r > 2) then   external32_size = 2
else                  external32_size = 1

```

If the external32 representation of a datatype is undefined, the result of using the datatype directly or indirectly (i.e., as part of another datatype or through a duplicated datatype) in operations that require the external32 representation is undefined. These operations

include `MPI_PACK_EXTERNAL`, `MPI_UNPACK_EXTERNAL` and many `MPI_FILE` functions, when the “external32” data representation is used. The ranges for which the external32 representation is undefined are reserved for future standardization.

### Support for Size-specific MPI Datatypes

MPI provides named datatypes corresponding to optional Fortran 77 numeric types that contain explicit byte lengths — `MPI_REAL4`, `MPI_INTEGER8`, etc. This section describes a mechanism that generalizes this model to support all Fortran numeric intrinsic types.

We assume that for each **typeclass** (integer, real, complex) and each word size there is a unique machine representation. For every pair (**typeclass**, **n**) supported by a compiler, MPI must provide a named size-specific datatype. The name of this datatype is of the form `MPI_<TYPE>n` in C and Fortran and of the form `MPI::<TYPE>n` in C++ where `<TYPE>` is one of `REAL`, `INTEGER` and `COMPLEX`, and **n** is the length in bytes of the machine representation. This datatype locally matches all variables of type (**typeclass**, **n**). The list of names for such types includes:

```
MPI_REAL4
MPI_REAL8
MPI_REAL16
MPI_COMPLEX8
MPI_COMPLEX16
MPI_COMPLEX32
MPI_INTEGER1
MPI_INTEGER2
MPI_INTEGER4
MPI_INTEGER8
MPI_INTEGER16
```

One datatype is required for each representation supported by the compiler. To be backward compatible with the interpretation of these types in MPI-1, we assume that the nonstandard declarations `REAL*n`, `INTEGER*n`, always create a variable whose representation is of size **n**. All these datatypes are predefined.

The following functions allow a user to obtain a size-specific MPI datatype for any intrinsic Fortran type.

`MPI_SIZEOF(x, size)`

IN	x	a Fortran variable of numeric intrinsic type (choice)
OUT	size	size of machine representation of that type (integer)

`MPI_SIZEOF(X, SIZE, IERROR)`

```
<type> X
INTEGER SIZE, IERROR
```

This function returns the size in bytes of the machine representation of the given variable. It is a generic Fortran routine and has a Fortran binding only.

*Advice to users.* This function is similar to the C and C++ *sizeof* operator but behaves slightly differently. If given an array argument, it returns the size of the base element, not the size of the whole array. (*End of advice to users.*)

*Rationale.* This function is not available in other languages because it would not be useful. (*End of rationale.*)

`MPI_TYPE_MATCH_SIZE(typeclass, size, type)`

IN	typeclass	generic type specifier (integer)
IN	size	size, in bytes, of representation (integer)
OUT	type	datatype with correct type, size (handle)

`int MPI_Type_match_size(int typeclass, int size, MPI_Datatype *type)`

`MPI_TYPE_MATCH_SIZE(TYPECLASS, SIZE, TYPE, IERROR)`

`INTEGER TYPECLASS, SIZE, TYPE, IERROR`

`static MPI::Datatype MPI::Datatype::Match_size(int typeclass, int size)`

`typeclass` is one of `MPI_TYPECLASS_REAL`, `MPI_TYPECLASS_INTEGER` and `MPI_TYPECLASS_COMPLEX`, corresponding to the desired **typeclass**. The function returns an MPI datatype matching a local variable of type (**typeclass**, **size**).

This function returns a reference (handle) to one of the predefined named datatypes, not a duplicate. This type cannot be freed. `MPI_TYPE_MATCH_SIZE` can be used to obtain a size-specific type that matches a Fortran numeric intrinsic type by first calling `MPI_SIZEOF` in order to compute the variable size, and then calling `MPI_TYPE_MATCH_SIZE` to find a suitable datatype. In C and C++, one can use the C function `sizeof()`, instead of `MPI_SIZEOF`. In addition, for variables of default kind the variable's size can be computed by a call to `MPI_TYPE_GET_EXTENT`, if the `typeclass` is known. It is erroneous to specify a size not supported by the compiler.

*Rationale.* This is a convenience function. Without it, it can be tedious to find the correct named type. See note to implementors below. (*End of rationale.*)

*Advice to implementors.* This function could be implemented as a series of tests.

```
int MPI_Type_match_size(int typeclass, int size, MPI_Datatype *rtype)
{
```

```
    switch(typeclass) {
        case MPI_TYPECLASS_REAL: switch(size) {
            case 4: *rtype = MPI_REAL4; return MPI_SUCCESS;
            case 8: *rtype = MPI_REAL8; return MPI_SUCCESS;
            default: error(...);
        }
        case MPI_TYPECLASS_INTEGER: switch(size) {
            case 4: *rtype = MPI_INTEGER4; return MPI_SUCCESS;
            case 8: *rtype = MPI_INTEGER8; return MPI_SUCCESS;
```

```

        default: error(...);      }
    ... etc. ...
}

```

*(End of advice to implementors.)*

### Communication With Size-specific Types

The usual type matching rules apply to size-specific datatypes: a value sent with datatype `MPI_<TYPE>n` can be received with this same datatype on another process. Most modern computers use 2's complement for integers and IEEE format for floating point. Thus, communication using these size-specific datatypes will not entail loss of precision or truncation errors.

*Advice to users.* Care is required when communicating in a heterogeneous environment. Consider the following code:

```

real(selected_real_kind(5)) x(100)
call MPI_SIZEOF(x, size, ierror)
call MPI_TYPE_MATCH_SIZE(MPI_TYPECLASS_REAL, size, xtype, ierror)
if (myrank .eq. 0) then
    ... initialize x ...
    call MPI_SEND(x, xtype, 100, 1, ...)
else if (myrank .eq. 1) then
    call MPI_RECV(x, xtype, 100, 0, ...)
endif

```

This may not work in a heterogeneous environment if the value of `size` is not the same on process 1 and process 0. There should be no problem in a homogeneous environment. To communicate in a heterogeneous environment, there are at least four options. The first is to declare variables of default type and use the MPI datatypes for these types, e.g., declare a variable of type `REAL` and use `MPI_REAL`. The second is to use `selected_real_kind` or `selected_int_kind` and with the functions of the previous section. The third is to declare a variable that is known to be the same size on all architectures (e.g., `selected_real_kind(12)` on almost all compilers will result in an 8-byte representation). The fourth is to carefully check representation size before communication. This may require explicit conversion to a variable of size that can be communicated and handshaking between sender and receiver to agree on a size.

Note finally that using the “external32” representation for I/O requires explicit attention to the representation sizes. Consider the following code:

```

real(selected_real_kind(5)) x(100)
call MPI_SIZEOF(x, size, ierror)
call MPI_TYPE_MATCH_SIZE(MPI_TYPECLASS_REAL, size, xtype, ierror)

if (myrank .eq. 0) then

```



```

1      call MPI_FILE_OPEN(MPI_COMM_SELF, 'foo',          &
2                          MPI_MODE_CREATE+MPI_MODE_WRONLY, &
3                          MPI_INFO_NULL, fh, ierror)
4      call MPI_FILE_SET_VIEW(fh, 0, xtype, xtype, 'external32', &
5                              MPI_INFO_NULL, ierror)
6      call MPI_FILE_WRITE(fh, x, 100, xtype, status, ierror)
7      call MPI_FILE_CLOSE(fh, ierror)
8  endif
9
10     call MPI_BARRIER(MPI_COMM_WORLD, ierror)
11
12     if (myrank .eq. 1) then
13         call MPI_FILE_OPEN(MPI_COMM_SELF, 'foo', MPI_MODE_RDONLY, &
14                             MPI_INFO_NULL, fh, ierror)
15         call MPI_FILE_SET_VIEW(fh, 0, xtype, xtype, 'external32', &
16                                 MPI_INFO_NULL, ierror)
17         call MPI_FILE_WRITE(fh, x, 100, xtype, status, ierror)
18         call MPI_FILE_CLOSE(fh, ierror)
19     endif
20
21
22
23
24
25
26
27
28
29
30
31
32
33
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39
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43
44
45
46
47
48

```

If processes 0 and 1 are on different machines, this code may not work as expected if the size is different on the two machines. (*End of advice to users.*)

## 16.3 Language Interoperability

### 16.3.1 Introduction

It is not uncommon for library developers to use one language to develop an applications library that may be called by an application program written in a different language. MPI currently supports ISO (previously ANSI) C, C++, and Fortran bindings. It should be possible for applications in any of the supported languages to call MPI-related functions in another language.

Moreover, MPI allows the development of client-server code, with MPI communication used between a parallel client and a parallel server. It should be possible to code the server in one language and the clients in another language. To do so, communications should be possible between applications written in different languages.

There are several issues that need to be addressed in order to achieve interoperability.

**Initialization** We need to specify how the MPI environment is initialized for all languages.

**Interlanguage passing of MPI opaque objects** We need to specify how MPI object handles are passed between languages. We also need to specify what happens when an MPI object is accessed in one language, to retrieve information (e.g., attributes) set in another language.

**Interlanguage communication** We need to specify how messages sent in one language can be received in another language.

It is highly desirable that the solution for interlanguage interoperability be extendable to new languages, should MPI bindings be defined for such languages.

### 16.3.2 Assumptions

We assume that conventions exist for programs written in one language to call routines written in another language. These conventions specify how to link routines in different languages into one program, how to call functions in a different language, how to pass arguments between languages, and the correspondence between basic data types in different languages. In general, these conventions will be implementation dependent. Furthermore, not every basic datatype may have a matching type in other languages. For example, C/C++ character strings may not be compatible with Fortran `CHARACTER` variables. However, we assume that a Fortran `INTEGER`, as well as a (sequence associated) Fortran array of `INTEGER`s, can be passed to a C or C++ program. We also assume that Fortran, C, and C++ have address-sized integers. This does not mean that the default-size integers are the same size as default-sized pointers, but only that there is some way to hold (and pass) a C address in a Fortran integer. It is also assumed that `INTEGER(KIND=MPI_OFFSET_KIND)` can be passed from Fortran to C as `MPI_Offset`.

### 16.3.3 Initialization

A call to `MPI_INIT` or `MPI_INIT_THREAD`, from any language, initializes MPI for execution in all languages.

*Advice to users.* Certain implementations use the (inout) `argc`, `argv` arguments of the C/C++ version of `MPI_INIT` in order to propagate values for `argc` and `argv` to all executing processes. Use of the Fortran version of `MPI_INIT` to initialize MPI may result in a loss of this ability. (*End of advice to users.*)

The function `MPI_INITIALIZED` returns the same answer in all languages.

The function `MPI_FINALIZE` finalizes the MPI environments for all languages.

The function `MPI_FINALIZED` returns the same answer in all languages.

The function `MPI_ABORT` kills processes, irrespective of the language used by the caller or by the processes killed.

The MPI environment is initialized in the same manner for all languages by `MPI_INIT`. E.g., `MPI_COMM_WORLD` carries the same information regardless of language: same processes, same environmental attributes, same error handlers.

Information can be added to info objects in one language and retrieved in another.

*Advice to users.* The use of several languages in one MPI program may require the use of special options at compile and/or link time. (*End of advice to users.*)

*Advice to implementors.* Implementations may selectively link language specific MPI libraries only to codes that need them, so as not to increase the size of binaries for codes that use only one language. The MPI initialization code need perform initialization for a language only if that language library is loaded. (*End of advice to implementors.*)

### 16.3.4 Transfer of Handles

Handles are passed between Fortran and C or C++ by using an explicit C wrapper to convert Fortran handles to C handles. There is no direct access to C or C++ handles in Fortran. Handles are passed between C and C++ using overloaded C++ operators called from C++ code. There is no direct access to C++ objects from C.

The type definition `MPI_Fint` is provided in C/C++ for an integer of the size that matches a Fortran `INTEGER`; usually, `MPI_Fint` will be equivalent to `int`.

The following functions are provided in C to convert from a Fortran communicator handle (which is an integer) to a C communicator handle, and vice versa. See also Section 2.6.5 on page 21.

```
MPI_Comm MPI_Comm_f2c(MPI_Fint comm)
```

If `comm` is a valid Fortran handle to a communicator, then `MPI_Comm_f2c` returns a valid C handle to that same communicator; if `comm = MPI_COMM_NULL` (Fortran value), then `MPI_Comm_f2c` returns a null C handle; if `comm` is an invalid Fortran handle, then `MPI_Comm_f2c` returns an invalid C handle.

```
MPI_Fint MPI_Comm_c2f(MPI_Comm comm)
```

The function `MPI_Comm_c2f` translates a C communicator handle into a Fortran handle to the same communicator; it maps a null handle into a null handle and an invalid handle into an invalid handle.

Similar functions are provided for the other types of opaque objects.

```
MPI_Datatype MPI_Type_f2c(MPI_Fint datatype)
```

```
MPI_Fint MPI_Type_c2f(MPI_Datatype datatype)
```

```
MPI_Group MPI_Group_f2c(MPI_Fint group)
```

```
MPI_Fint MPI_Group_c2f(MPI_Group group)
```

```
MPI_Request MPI_Request_f2c(MPI_Fint request)
```

```
MPI_Fint MPI_Request_c2f(MPI_Request request)
```

```
MPI_File MPI_File_f2c(MPI_Fint file)
```

```
MPI_Fint MPI_File_c2f(MPI_File file)
```

```
MPI_Win MPI_Win_f2c(MPI_Fint win)
```

```
MPI_Fint MPI_Win_c2f(MPI_Win win)
```

```
MPI_Op MPI_Op_f2c(MPI_Fint op)
```

```
MPI_Fint MPI_Op_c2f(MPI_Op op)
```

```
MPI_Info MPI_Info_f2c(MPI_Fint info)
```

```
MPI_Fint MPI_Info_c2f(MPI_Info info)
```

```
MPI_Errhandler MPI_Errhandler_f2c(MPI_Fint errhandler)
```

```
MPI_Fint MPI_Errhandler_c2f(MPI_Errhandler errhandler)
```

**Example 16.13** The example below illustrates how the Fortran MPI function `MPI_TYPE_COMMIT` can be implemented by wrapping the C MPI function `MPI_Type_commit` with a C wrapper to do handle conversions. In this example a Fortran-C interface is assumed where a Fortran function is all upper case when referred to from C and arguments are passed by addresses.

```

! FORTRAN PROCEDURE
SUBROUTINE MPI_TYPE_COMMIT( DATATYPE, IERR)
INTEGER DATATYPE, IERR
CALL MPI_X_TYPE_COMMIT(DATATYPE, IERR)
RETURN
END

/* C wrapper */

void MPI_X_TYPE_COMMIT( MPI_Fint *f_handle, MPI_Fint *ierr)
{
    MPI_Datatype datatype;

    datatype = MPI_Type_f2c( *f_handle);
    *ierr = (MPI_Fint)MPI_Type_commit( &datatype);
    *f_handle = MPI_Type_c2f(datatype);
    return;
}

```

The same approach can be used for all other MPI functions. The call to `MPI_xxx_f2c` (resp. `MPI_xxx_c2f`) can be omitted when the handle is an OUT (resp. IN) argument, rather than INOUT.

*Rationale.* The design here provides a convenient solution for the prevalent case, where a C wrapper is used to allow Fortran code to call a C library, or C code to call a Fortran library. The use of C wrappers is much more likely than the use of Fortran wrappers, because it is much more likely that a variable of type `INTEGER` can be passed to C, than a C handle can be passed to Fortran.

Returning the converted value as a function value rather than through the argument list allows the generation of efficient inlined code when these functions are simple (e.g., the identity). The conversion function in the wrapper does not catch an invalid handle argument. Instead, an invalid handle is passed below to the library function, which, presumably, checks its input arguments. (*End of rationale.*)

**C and C++** The C++ language interface provides the functions listed below for mixed-language interoperability. The token `<CLASS>` is used below to indicate any valid MPI opaque handle name (e.g., `Group`), except where noted. For the case where the C++ class corresponding to `<CLASS>` has derived classes, functions are also provided for converting between the derived classes and the C `MPI_<CLASS>`.

The following function allows assignment from a C MPI handle to a C++ MPI handle.

```
MPI::<CLASS>& MPI::<CLASS>::operator=(const MPI_<CLASS>& data)
```

The constructor below creates a C++ MPI object from a C MPI handle. This allows the automatic promotion of a C MPI handle to a C++ MPI handle.

```
MPI::<CLASS>::<CLASS>(const MPI_<CLASS>& data)
```

**Example 16.14** In order for a C program to use a C++ library, the C++ library must export a C interface that provides appropriate conversions before invoking the underlying C++ library call. This example shows a C interface function that invokes a C++ library call with a C communicator; the communicator is automatically promoted to a C++ handle when the underlying C++ function is invoked.

```
// C++ library function prototype
void cpp_lib_call(MPI::Comm cpp_comm);

// Exported C function prototype
extern "C" {
    void c_interface(MPI_Comm c_comm);
}

void c_interface(MPI_Comm c_comm)
{
    // the MPI_Comm (c_comm) is automatically promoted to MPI::Comm
    cpp_lib_call(c_comm);
}
```

The following function allows conversion from C++ objects to C MPI handles. In this case, the casting operator is overloaded to provide the functionality.

```
MPI::<CLASS>::operator MPI_<CLASS>() const
```

**Example 16.15** A C library routine is called from a C++ program. The C library routine is prototyped to take an MPI\_Comm as an argument.

```
// C function prototype
extern "C" {
    void c_lib_call(MPI_Comm c_comm);
}

void cpp_function()
{
    // Create a C++ communicator, and initialize it with a dup of
    // MPI::COMM_WORLD
    MPI::Intracomm cpp_comm(MPI::COMM_WORLD.Dup());
    c_lib_call(cpp_comm);
}
```

*Rationale.* Providing conversion from C to C++ via constructors and from C++ to C via casting allows the compiler to make automatic conversions. Calling C from C++ becomes trivial, as does the provision of a C or Fortran interface to a C++ library. (*End of rationale.*)

*Advice to users.* Note that the casting and promotion operators return new handles by value. Using these new handles as INOUT parameters will affect the internal MPI object, but will *not* affect the original handle from which it was cast. (*End of advice to users.*)

It is important to note that all C++ objects with corresponding C handles can be used interchangeably by an application. For example, an application can cache an attribute on `MPI_COMM_WORLD` and later retrieve it from `MPI::COMM_WORLD`.

### 16.3.5 Status

The following two procedures are provided in C to convert from a Fortran status (which is an array of integers) to a C status (which is a structure), and vice versa. The conversion occurs on all the information in status, including that which is hidden. That is, no status information is lost in the conversion.

```
int MPI_Status_f2c(MPI_Fint *f_status, MPI_Status *c_status)
```

If `f_status` is a valid Fortran status, but not the Fortran value of `MPI_STATUS_IGNORE` or `MPI_STATUSES_IGNORE`, then `MPI_Status_f2c` returns in `c_status` a valid C status with the same content. If `f_status` is the Fortran value of `MPI_STATUS_IGNORE` or `MPI_STATUSES_IGNORE`, or if `f_status` is not a valid Fortran status, then the call is erroneous.

The C status has the same source, tag and error code values as the Fortran status, and returns the same answers when queried for count, elements, and cancellation. The conversion function may be called with a Fortran status argument that has an undefined error field, in which case the value of the error field in the C status argument is undefined.

Two global variables of type `MPI_Fint*`, `MPI_F_STATUS_IGNORE` and `MPI_F_STATUSES_IGNORE` are declared in `mpi.h`. They can be used to test, in C, whether `f_status` is the Fortran value of `MPI_STATUS_IGNORE` or `MPI_STATUSES_IGNORE`, respectively. These are global variables, not C constant expressions and cannot be used in places where C requires constant expressions. Their value is defined only between the calls to `MPI_INIT` and `MPI_FINALIZE` and should not be changed by user code.

To do the conversion in the other direction, we have the following:

```
int MPI_Status_c2f(MPI_Status *c_status, MPI_Fint *f_status)
```

This call converts a C status into a Fortran status, and has a behavior similar to `MPI_Status_f2c`. That is, the value of `c_status` must not be either `MPI_STATUS_IGNORE` or `MPI_STATUSES_IGNORE`.

*Advice to users.* There is not a separate conversion function for arrays of statuses, since one can simply loop through the array, converting each status. (*End of advice to users.*)

*Rationale.* The handling of `MPI_STATUS_IGNORE` is required in order to layer libraries with only a C wrapper: if the Fortran call has passed `MPI_STATUS_IGNORE`, then the C wrapper must handle this correctly. Note that this constant need not have the same value in Fortran and C. If `MPI_Status_f2c` were to handle `MPI_STATUS_IGNORE`, then the type of its result would have to be `MPI_Status**`, which was considered an inferior solution. (*End of rationale.*)