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DEBUT OF THE

ADA PROGRAMMING LANGUAGE

4-5 SEPTEMBER 1980

U.S. DEPARTMENT OF COMMERCE AUDITORIUM

A

THURSDAY SEPTEMBER 4TH

9:00-10:30	Opening Session	
	Welcome	Dr. Robert R. Fossum Director Defense Advanced Research Projects Agency
	Remarks	Hon William J. Perry Undersecretary of Defense for Research and Engineering
	Introduction to Ada	Dr. Jean D. Ichbiah Principal Language Designer
	Coffee Break	
10:50-12:30	Types	Dr. Ichbiah
	Lunch	
1:45-3:15	Program Structure	Dr. Ichbiah
	Coffee Break	
3:35-5:00	Algorithmic Features	Dr. Ichbiah

Wine and Cheese Party
Hotel Washington

FRIDAY SEPTEMBER 5TH

9:00-10:30	Tasking	Dr. Ichbiah
	Coffee Break	
10:50-12:30	Exception Handling Generic Program Units	Dr. Ichbiah
	Lunch	
1:45-2:45	Other Ada Features	Dr. Ichbiah
	Conclusion	
2:45-3:45	Question/Answer Session	
3:45	Closing Remarks	William E. Carlson Ada Program Manager

SPEECH
BY
DR. ROBERT R. FOSSUM
DIRECTOR
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
AT THE ADA DEBUT 4-5 SEPTEMBER, 1980
WASHINGTON, D.C.

I'm really very happy to be here today. I enjoy coming to convocations of this type and seeing old friends, and I'm especially glad to see Bill Whitaker. I can remember working late at night but I never worked any later at night at ARPA than my colleague Bill, when he was in his office working at a terminal on the various things he had to do as Chairman of the High Order Language Working Group.

I asked Bill Perry why in the world he wasn't able to be here this morning and he said, "Well, I have difficulty with accountants; I have a hearing on the Capital Hill that I have to go to". Then he told me a little story related to the accountant syndrome. He said, "Do you know, Bob, about 100 years ago during the Civil War, when R&D was in its infancy in the U.S. Army, the problem of surveillance was severe. The Army was testing a balloon borne observation system up northwest of Washington. A bright young Army officer was the pilot of the balloon, 'Areostat', it was called in those days. He took off one afternoon on a test flight. These balloons are teathered, except on this day the teather broke loose, he drifted through thunder clouds of great magnitude doing his best to land in some sort of controlled crash. He finally succeeded, drifting down and landing on the White House lawn. It turns out that Mr. Lincoln at the time was having a Cabinet meeting. Seeing the balloon come down and crashed, they ran out. The first person to arrive at the gondola of the balloon was a very distinguished looking gentlemen. The balloon pilot looked up and said (he was rather dazed),"for goodness sake where am I?" The gentleman answered, "Why you're on a green grassy lawn, of course". This took the pilot by some surprise, and after a few minutes of absorbing that profound statement, he said," Are you an accountant?" The fellow said, "Why yes, how in the world did you know?" And the pilot replied, "Because the information you have given me is perfectly accurate but utterly useless".

This little story, I think, reflects Bill's frustrations at not being able to be here today, and I bring with me today his best wishes. He is very much interested in this program, as you all know. He is interested in joint programs with NATO, with the Western Alliance, and he feels this language is one of the successes that is coming about in our increasing efforts at joint programs.

I want to extend my personal congratulations and the congratulations of Dr. Perry to Jean Ichbiah and the Ada Design Team for a job well done.

We at ARPA are very happy to have been part of the DoD effort to develop this language. As most of you know, the programming language modernization and convergence effort is coordinated by the High Order Language Working Group, or HOLWG, which includes representatives of all three Services and the Defense Agencies. The German and United Kingdom Ministries of Defense have sent liaison members to the HOLWG. The Services have provided the money for the Ada development, and full time participation by some of their best people.

The Ada program has benefitted from international cooperation beginning with the requirements definition process, and continuing throughout design, test and evaluation. I note that at least nine countries are represented in the audience here today. Experts from the U.S., United Kingdom, Germany, France, and other nations including Japan have contributed to the design effort. By working together, it is my opinion we have developed a much higher quality product for our common use than any of us could have developed. Such cooperative development programs are an effective way to counter what we in the Department of Defense believe (and we believe it is a mutual perception), to be a massive Warsaw Pact investment strategy which constitutes a real threat today.

Achieving more effective armaments cooperation within the Western Alliance is a major goal of this administration, especially the Undersecretary and the Secretary of Defense. The Ada language is certainly one of the significant accomplishments in this major thrust.

Today I would like to share with you my view of the significance of Ada to the Western Alliance, highlight some of the factors which have made this program a success, and summarize DoD's plans for the Ada phase-in period.

WHAT IS THE SIGNIFICANCE OF ADA?

We in this Alliance must take advantage of our lead in various technologies, in particular computer technology, to maintain the balance of power. The Soviets have historically held a quantitative advantage in deployed weapons. In the past, we have had a qualitative advantage, but that advantage is now eroding in the face of massive Eastern Block R&D investments.

These challenges are formidable. But we have some distinct advantages as well: we have a superior technological base, we have a highly competitive industry with greater productivity, and a substantial industrial base necessary to capitalize on the technology base investments.

Our approach is to expedite the development of systems based on technology in which we lead. We have an asymmetric advantage which can produce a distinct military advantage. Two such obvious technologies in the tech base today in this country and all through the west are micro circuit technology and computer technology, which are, of course, closely related and mutually reenforcing.

Military systems of the future will incorporate much more flexible and intelligent control logic. For example, new surveillance systems will have sophisticated algorithms for detecting, identifying, and locating targets; command and control systems will be able to pass target information to fire units very rapidly, essentially in real-time. We will have even more capable precision guided weapons than we have today. We will also be upgrading existing tanks, aircraft and other weapons with intelligent digital control systems to extend their useful life.

Thus, the Ada program has been an effort to provide a high quality common programming language for these critically important military systems of the future.

Our goal, however, has gone beyond merely designing a quality programming language. The usefulness of a language is determined as much by the stability of its specification and the size of its user population as by its detailed technical characteristics.

It takes several years to accumulate a significant collection of software tools to enhance the productivity of programmers using a language. Developers of applications software cannot afford the time or the money to develop large tool kits, so they are for the most part constrained to use existing tools. Quality tool kits are only available for the most popular languages.

Even in very primitive environments with almost no tools, there must be a compiler for every high order language. The benefits of using proven compilers for applications developments are especially compelling. It takes a while for compiler implementors to refine their products, find the most efficient algorithms, and eliminate residual errors.

Our approach to training is also greatly influenced by how widely the programming language is used. With a widely used common language, experienced programmers are available to work on new projects. Hence, development projects do not have to pay for training and for the mistakes which are inevitably made by inexperienced programmers. Furthermore, training can be viewed as a long term investment in future productivity; since during the course of their careers, programmers will work on a variety of systems in the common language.

The goal, then, is to have a language which is both of high technical quality and widely used. The military has been a successful catalyst for new standards in the past, most notably with the COBOL language in the early 1960's. In the Ada effort, we have tried to involve the widest possible community from throughout the Western alliance so that technical requirements of all our real-time and large systems applications would be provided for in the language design.

WHAT ARE THE HIGHLIGHTS OF THE ADA DEVELOPMENT?

The Ada development has been both a modernization and a convergence effort. The research and development community had developed important new software techniques in the late 60's and early 70's which DoD project managers wanted to use. Among these ideas were: structured programming, the ability for users to define their own data types and have compilers enforce type consistency, various high level and structured approaches to parallel processing which reduced the risk of deadlocks and improved system reliability, and the separation of external interfaces from implementation details to enforce modularity. The separate specification of external interfaces is especially important for standard reusable software components.

In 1975 and 1976, each of the Services was proposing to develop a new programming language incorporating these advances. In discussions with our allies, we learned that these pressures were not unique to the U.S. The IFIP Working Group 2.4 and the Long-Term Procedural Language-Europe Group, among others, had already begun the process of consolidating the advances so that a new common and widely adopted standard language could be developed.

Given the benefits from language commonality which we just discussed, we decided to establish a single joint program to develop a common language. The U.K. Ministry of Defense assigned a liaison officer to work full time with us in the United States formulating language requirements.

We could not afford the risk of having this language designed by anyone other than the best designers in the whole world. Who that should be, however, was not immediately obvious. There were several strong candidates.

The solution was to hold an international design competition based on widely reviewed and agreed upon requirements. Our objective has been to have the widest possible participation in the identification of requirements and the review of interim products, but to have a single designer responsible for the internal consistency and integrity of the language design. As you know, the team headed by Jean Ichbiah, of CII Honeywell Bull in Paris in cooperation with the Honeywell Systems and Research Center in Minneapolis won the competition.

The debut today and tomorrow marks the succesful completion of extensive test and evaluation of the language design. During the past year, a signficant number of applications algorithms have been recoded in Ada. We have received more than 900 language issues, reports and comments. Jean has refined the language based on the results of these inputs, and will be presenting the proposed Ada Standard in a few minutes.

HOW ABOUT THE FUTURE

We are now entering the language phase-in period. A DoD joint project office is being established to maintain the Ada Standard and to coordinate service implementation and training efforts.

We want to begin using Ada in exploratory development applications as soon as possible. Hence, test compilers are being developed for these pilot applications. New York University will deliver an interpreter for the complete Ada language and submit it for validation testing early in 1981. Carnegie-Mellon and Intermetrics are working together to deliver a complete test compiler by the summer of 1981.

The Army and Air Force have already begun to develop advanced development models for Ada compilers. The Army has chosen SofTech to develop its compiler, and they have started work. The Army has a particularly pressing need to begin using Ada to develop battlefield systems, so everything possible is being done to complete an implementation with code generators for the battlefield computers by mid-1982. Capabilities of the existing operating system environment are being used to expedite the development of the required minimal set of programming tools.

The Air Force effort aims to produce a compiler which is embedded in a self-contained, vendor independent, portable environment in accordance with DoD's STONEMAN specification. There will be a competitive design phase involving two or three contractors who are being selected at the present time. The designs will be delivered in Spring 1981 and the system in 1983.

Both the Air Force and Army compilers will be written in Ada, and will be delivered with the essential programming tools. When the initial designs are delivered to DoD in Spring 1981, DoD will select and specify standard interfaces between the environment and the programming tools. Contracts will then be renegotiated to insure compliance with the interface standards, and to achieve the maximum amount of practical commonality between Army and Air Force efforts.

The Navy is waiting for these activities to stabilize before developing a compiler which is unique to Navy systems. They expect to make substantial use of software developed by the Army and Air Force.

Elsewhere, there are a number of compilers already under development in Europe, Japan, and as proprietary ventures by industry. In particular, the German Ministry of Defense, the United Kingdom Ministry of Defense and the Council of the European Communities have compiler procurements already underway. We in DoD will coordinate closely with these efforts.

At the present time, we are assuming that Ada will be used in a variety of diverse environments, and that our goal in standardizing internal interfaces for initial DoD compilers and tools is simply to make the most efficient use of our development resources.

We intend to establish policies which encourage the private sector to innovate in Ada software and in computer hardware to run Ada programs. An important step towards that end is to provide the stability necessary for private industry investment and non-defense use of the language.

The proposed standard document is being reviewed under American National Standards Institute canvass ballot procedures, and we hope that there will be an ANSI standard for Ada in the near future. ANSI will be submitting the Ada standard to the International Standards Organization to establish an international standard for the language.

We intend to take a variety of steps to encourage the widespread use of Ada. The compiler validation test sets will be available to other governments and standards organizations, with appropriate safeguards to insure that the standard is rigidly and uniformly enforced. Source code and documentation for the initial DoD developed compilers will be made available, to provide an early baseline capability. The contracts have been written so that DoD can give the software to anyone in the world, and the recipients will be free to use it for commercial as well as defense purposes.

As soon as possible, we would like to begin competitively procuring Ada compilers and software tools as products, rather than funding their development on a cost reimbursable basis. For example, we will be using Ada programs as benchmarks when buying commercial hardware so that the performance competition is based on the combined performance of the hardware and the compiler. The Ada compiler validation policies will allow Ada interfaces and special functions to be implemented in hardware, and we will encourage such hardware optimizations for some applications.

These steps are part of DoD's overall strategy of using commercial products wherever possible for defense, so that we can benefit from the industrial base that I described earlier and the economies of scale associated with participating in such a large commercial market place.

CONCLUSION

In summary, I would like to emphasize that the Ada language is extremely important to the U.S. Department of Defense and the Western Alliance. In our opinion, Ada will be used to develop our most important systems in the future. We expect Ada will be widely used throughout the U.S. and the European countries for commercial use as well as defense software, and that the Department of Defense in the U.S. will benefit significantly from the resulting availability of trained personnel and privately developed software.

Dr. Perry shares these views, and very much wishes that he could be with us today. He asked me to emphasize his strong support for this program and his desire to see Ada rapidly implemented and used throughout the Services.

Thank you very much ladies and gentlemen. It is indeed a pleasure to be with you today.

VIEWGRAPH'S

FOR

JEAN ICHBIAH'S PRESENTATION

A SIMPLE PROGRAM

- A simple program
- Textual structure
- Lexical structure
- Execution
- Visibility and Separate Compilation
- Relation to other topics

A SIMPLE PROGRAM

```
with SIMPLE_IO;
procedure COUNT_YOUR_CHANGE is
   use SIMPLE_IO;

   -- This program reads 6 integers
   -- and prints the total value
   COUNT, CHANGE, CENTS, DOLLARS : INTEGER;
   VALUE : constant array (1..6) of INTEGER :=
               (01, 05, 10, 25, 50, 100);
begin
   CHANGE := 0;
   for N in 1 .. 6 loop
      GET(COUNT);
      CHANGE := CHANGE + VALUE(N) * COUNT;
   end loop;
   if CHANGE = 0 then
      PUT( "NO CHANGE" );
   else
      DOLLARS := CHANGE / 100 ;
      CENTS   := CHANGE mod 100;
      PUT (" DOLLARS : "); PUT(DOLLARS);
      PUT (" CENTS   : "); PUT(CENTS);
   end if;
end COUNT_YOUR_CHANGE;
```

TEXTUAL STRUCTURE

```
with SIMPLE_IO;
procedure COUNT_YOUR_CHANGE is
|
|   ...
|
|
begin
|   ...
|   for    ...     loop
|   |  ...
|   end loop;
|
|   if    ...    then
|   |  ...
|   else
|   |  ...
|   end if;
|   ...
end COUNT_YOUR_CHANGE;
```

EXECUTION OF A PROCEDURE

```
procedure COUNT_YOUR_CHANGE is
   COUNTS, CHANGE,
   CENTS, DOLLARS : INTEGER;
begin
   CHANGE := 0;
   ...
   CENTS := CHANGE mod 100;
end COUNT_YOUR_CHANGE;
```

elaborate

declarative part

execute

sequence of statements

elaborate declarations :

give an existence to corresponding objects

VISIBILITY and SEPARATE COMPILATION

a main program :

```
with SIMPLE_IO;
procedure COUNT_YOUR_CHANGE is
   use SIMPLE_IO;
   COUNT, CHANGE,
   CENTS, DOLLARS : INTEGER;

begin
   CHANGE := 0;
   GET (COUNT);
   PUT ("NO CHANGE");
   CENTS := CHANGE mod 100;
end COUNT_YOUR_CHANGE;
```

-- predefined identifiers
-- identifiers from the package
-- local identifiers

POINTS RAISED BY THE EXAMPLE

DECLARATIVE PART

- object declarations
- types
- type declarations

SEQUENCE OF STATEMENTS

- expressions
- statements

PACKAGES and COMPILATION UNITS

VISIBILITY

Points not raised

TASKING, GENERIC UNITS,
EXCEPTIONS, REPRESENTATION

The way by which we impose

structure on data objects

- Need to describe objects
  Factorization of properties
  maintainability

- Need to be able to say something about the properties of objects
  readability

- Need to guarantee that properties of objects are not violated
  reliability

- Need to hide implementation details

1

TYPES

MOTIVATION FOR TYPES

WHAT IS A TYPE

ENUMERATION TYPES

CONSTRAINTS and SUBTYPES

- NUMERIC TYPES
- ARRAY TYPES
- RECORD TYPES
- ACCESS TYPES

TYPE EQUIVALENCE

WHAT IS A TYPE

A type characterizes :

- a set of *values*
- a set of *operations* applicable to the values

WHAT IS A TYPE

Classes of types:

scalar types — values have no components

- enumeration types
- numeric types

composite types — values consist of component values

- array types
- record types

access types — values provide access to other objects

private types — values are not known to the users: only the set of operations is known

RULES

All objects must be declared

objects can be { variables / constants }

Each object gets a type in its declaration — step 1

Any operation on an object must preserve its type — step 2

The type of any object is invariant during program execution :
it is the type given in the object declaration

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CHARACTERISTICS OF ENUMERATION TYPES

```
type DAY is (MON, TUE, WED, THU, FRI, SAT, SUN);
```

Set of values:

MON TUE WED THU FRI SAT SUN

Set of operations applicable to these values:

= /=	test for (in)equality
> >= < <=	test for order

```
MON < FRI
if TODAY >= TUE then
```

:=	assignment

attributes

```
DAY'FIRST        --  MON
DAY'LAST         --  SUN
DAY'SUCC(D)      --  e.g. DAY'SUCC(MON) = TUE
```

ENUMERATION TYPES

enumeration type declarations:

```
type DIRECTION is (NORTH, EAST, SOUTH, WEST);

type DAY is (MON, TUE, WED, THU, FRI, SAT, SUN);
```

object declarations:

```
GOAL   : DIRECTION;
TODAY  : DAY;
MIDDLE : constant DAY := THU;
```

correct assignments:

```
GOAL  := WEST;
TODAY := MON;
TODAY := MIDDLE;
```

incorrect assignments:

```
GOAL   := SUN;
TODAY  := 8;
GOAL   := TODAY;
GOAL   := GOAL + NORTH;
MIDDLE := WED;
```

} compiler detectable

EXAMPLES

type definition :

(MON, TUE, WED, THU, FRI, SAT, SUN)

type declaration :

```
type DAY is (MON, TUE, WED, THU, FRI, SAT, SUN);
```

object declarations :

```
TODAY : DAY;                          -- a variable

START : DAY := MON;                   -- initialized

MIDDLE : constant DAY := THU;         -- a constant

YESTERDAY, TOMORROW : DAY;            -- two variables
```

OTHER FORMS of ENUMERATION TYPES

Character types

```
type DIGIT is
    ('0', '1', '2', '3', '4',
     '5', '6', '7', '8', '9');

type HEX_LETTER is ('A', 'B', 'C', 'D', 'E', 'F');

type MIXT is (START, 'A', STOP, 'B');
```

enumeration literals can be either identifiers or character literals

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CONSTRAINTS

- a constraint restricts the set of possible values of a type
- a constraint does not change the set of applicable operations

range constraints :

```
D : DAY range MON .. FRI;

L : DAY range THU .. FRI;
```

range lower_bound .. upper_bound

SUBTYPES

motivation : factorization for readability and maintainability

```
D : DAY range MON .. FRI;
E : DAY range MON .. FRI;
F : DAY range MON .. FRI;
```

a subtype indication

factorize by a subtype :

```
subtype WEEKDAY is DAY range MON .. FRI;

D : WEEKDAY;
E : WEEKDAY;
F : WEEKDAY;
```

equivalent to the former declaration

a subtype name is an abbreviation for a subtype indication

WHAT HAVE WE SEEN SO FAR ?

- what is a type
- enumeration types
- what is a constraint
- subtypes

Similar notions exist for other types :

array types	:	index constraints
record types	:	discriminant constraints
real types	:	accuracy constraints

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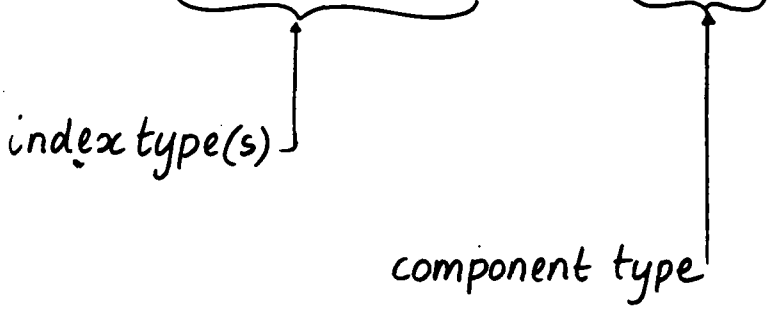
ARRAY TYPES

```
type VECTOR is
   array(INTEGER range <>) of   REAL ;
```



set of values

each VECTOR

- has components of type REAL
- is indexed by values of type INTEGER.
  In particular the
  index bounds
  are of type INTEGER

two VECTORs need not have the same bounds

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EXAMPLES OF ARRAY TYPES

```
type MATRIX is
     array (INTEGER range <>,
            INTEGER range <>) of REAL;
```

two-dimensional

```
subtype NATURAL is INTEGER range 1 .. INTEGER'LAST;
```

```
type STRING is array(NATURAL range <>)
                    of CHARACTER;
```

strings are arrays of characters indexed by natural numbers

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INDEX CONSTRAINTS

An *index constraint* serves to specify the *index bounds* of an array object

```
V : VECTOR (-10 .. 10);
W : VECTOR (1   .. 1000);
```

Array subtype

```
subtype VECT is VECTOR (0 .. N);
```


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INDEX BOUNDS

the index bounds of a constant are obtained from its initial value

```
MESSAGE : constant STRING :=
        "how many characters";
```

A formal parameter is constrained by the index bounds of the corresponding actual parameter

```
procedure PUT(S : STRING);

PUT(MESSAGE);
```


22

ARRAY TYPES

set of operations

= /=	test for (in) equality
:=	assignment possible if same number of components (but bounds need not be the same)
indexing	indexed component: V(I)
slices	for one-dimensional arrays V(I .. J) (a slice is an array value)

notation for array values : aggregates

```
A : VECTOR(1..10) := (1..10 => 0.0);

A := (1..3 => 1.5, 4..7 => X, others => Y);

A(2..4) := (1.0, 5.0, 3.0);
```

RECORD TYPES

```
type DATE is
    record
        MONTH   :   MONTH_NAME;
        DAY     :   INTEGER range 1..31;
        YEAR    :   INTEGER range 0..3000;
    end record;
```

RECORD TYPES WITH DISCRIMINANTS

```
type PERSON (SEX : GENDER := F) is
    record
        BIRTH :  DATE;
        case SEX is
            when M =>  BEARDED: BOOLEAN;
            when F =>  CHILDREN: INTEGER;
        end case;
    end record;
```

set of values

triples of the form { SEX = M, BIRTH, BEARDED }

(M, (MAR, 25, 1940), FALSE)

triples of the form { SEX = F, BIRTH, CHILDREN }

(F, (JAN, 23, 1943), 3)

DISCRIMINANTS

set of operations

- discriminants may only be changed by global record assignments

```
P   :  PERSON;      -- P.SEX = F

P := (M, SOME_DATE, TRUE); -- P.SEX = M

P.SEX := ...        -- Illegal !
```

- access to a component of a variant part depends on the value of the discriminant

```
P.BEARDED
P.CHILDREN    raises CONSTRAINT_ERROR
              if P.SEX = M
```

RECORD SUBTYPES

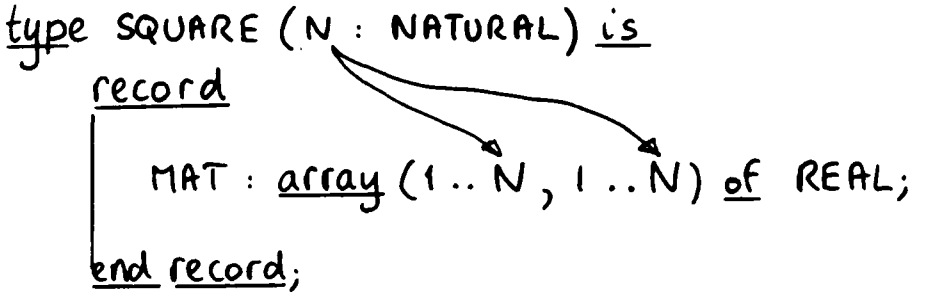
discriminant constraint

```
JOHN  :  PERSON (SEX => M);

MARY  :  PERSON(F) := (F, (MAR, 3, 1970), 0);
```

record subtypes

```
subtype MALE is   PERSON (SEX => M);

subtype FEMALE is  PERSON(SEX => F);
```

ANOTHER EXAMPLE



bounds may depend on a discriminant

- An object declaration must give the discriminant value

```
A, B : SQUARE (8);      -- 8 x 8 matrix
```

-- the size of the matrices cannot be changed

-- it is impossible to create a rectangular matrix using the type SQUARE

TYPE EQUIVALENCE

when do two objects have the same type?

each <u>type definition</u> defines a distinct type

⇒

each type name denotes a distinct type

⇒

two objects have the same type if their declarations refer to the same type name

name equivalence

TYPE EQUIVALENCE

X and Y are not of the same type

```
X : array (1..10) of INTEGER;
Y : array (1..10) of INTEGER;
```

two type definitions hence TWO distinct types

U and V are of the same type

```
U,V : array (1..10) of INTEGER;
```

one single type definition

Or better even: name the type

```
type TABLE_10 is array (1..10) of INTEGER;
A,B : TABLE_10;
C   : TABLE_10;
```

EXPLICIT CONVERSIONS BETWEEN ARRAY TYPES

```
type VECTOR is array (INTEGER range <>) of REAL;
procedure SORT ( X : in out VECTOR);

type TABLE is array (INTEGER range <>) of REAL;
procedure LIST (X : in TABLE);

A : TABLE (1 .. 100);
B : VECTOR(0 .. 1000);
C : array (1 .. 2000) of REAL;

LIST(A);                    SORT(B);

SORT(VECTOR(A));            LIST (TABLE (B))

SORT (VECTOR(C));           LIST (TABLE (C));
```

SUMMARY

Notion of type

- set of values
- set of operations

motivated by reliability

Classes of types

- scalar: enumeration, numeric
- composite: array, record

access

private types

Constraints and subtypes for all classes

Name equivalence

SOFTWARE COMPONENTS

M.D. MacIlroy, 1963

> "I would like to see components become a dignified branch of software engineering.
>
> I would like to see standard catalogs of routines classified by precision, robustness, time-space requirements and binding time of parameters."

- manufacturers of standard components
- catalogs of components
- parameterized components

GENERAL PROGRAM STRUCTURE

how to organize text
    compilation units

scope and visibility
    Algol like visibility rules
    and extensions

Packages
    for better control of visibility
    for logical modularity

private types

separate compilation
    for physical modularity

methodological impact

PROGRAM UNITS

three forms

- subprograms
- packages
- tasks

program units may be nested

- classical Algol-like block structure

program units may be separately compiled

- library units
- context specifications

SCOPE AND VISIBILITY

declared identifiers have a scope

the scope of a declaration is the region of text where the declaration has an effect

different identifiers may be visible at different points of text

the declaration of an entity is visible at a given point if an occurrence of the corresponding identifier at this point denotes the entity

BASIC VISIBILITY RULES

Algol-like rules: direct visibility

- identifier from outer contexts are visible
- an inner identifier may hide an outer homonym

Dot notation : selected component

unit_name.identifier

Named record components in aggregates

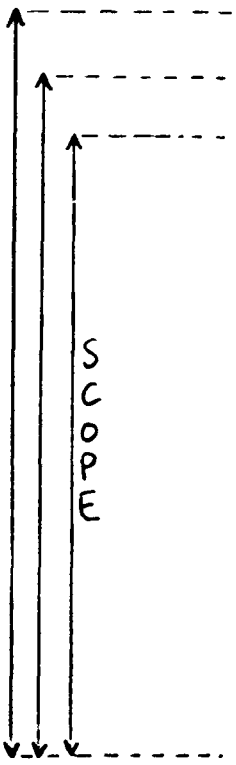
Named parameter associations

SELECTED COMPONENTS

```
procedure OUTER is
   A : BOOLEAN;
   B : BOOLEAN;
   procedure INNER is
      B : BOOLEAN;    --hides OUTER.B
      C : BOOLEAN;
   begin
      B := A;    -- INNER.B := OUTER.A
      C := OUTER.B; -- INNER.C := OUTER.B
   end;
begin
   ...
end OUTER;
```

selected components are also used to denote record components and items declared in packages

VISIBILITY OF RECORD COMPONENTS




```
procedure P is
   ...
   type DATE is
      record
         MONTH : MONTH_NAME;
         DAY   : INTEGER range 1 .. 31;
         YEAR  : INTEGER range 0 .. 3000;
      end record;

   TODAY : DAY;
begin
   TODAY.DAY := 10;        -- selected
                           -- component

   TODAY :=

      (YEAR => 1980, MONTH => SEP, DAY => 10);
                           -- named aggregate
end P;
```

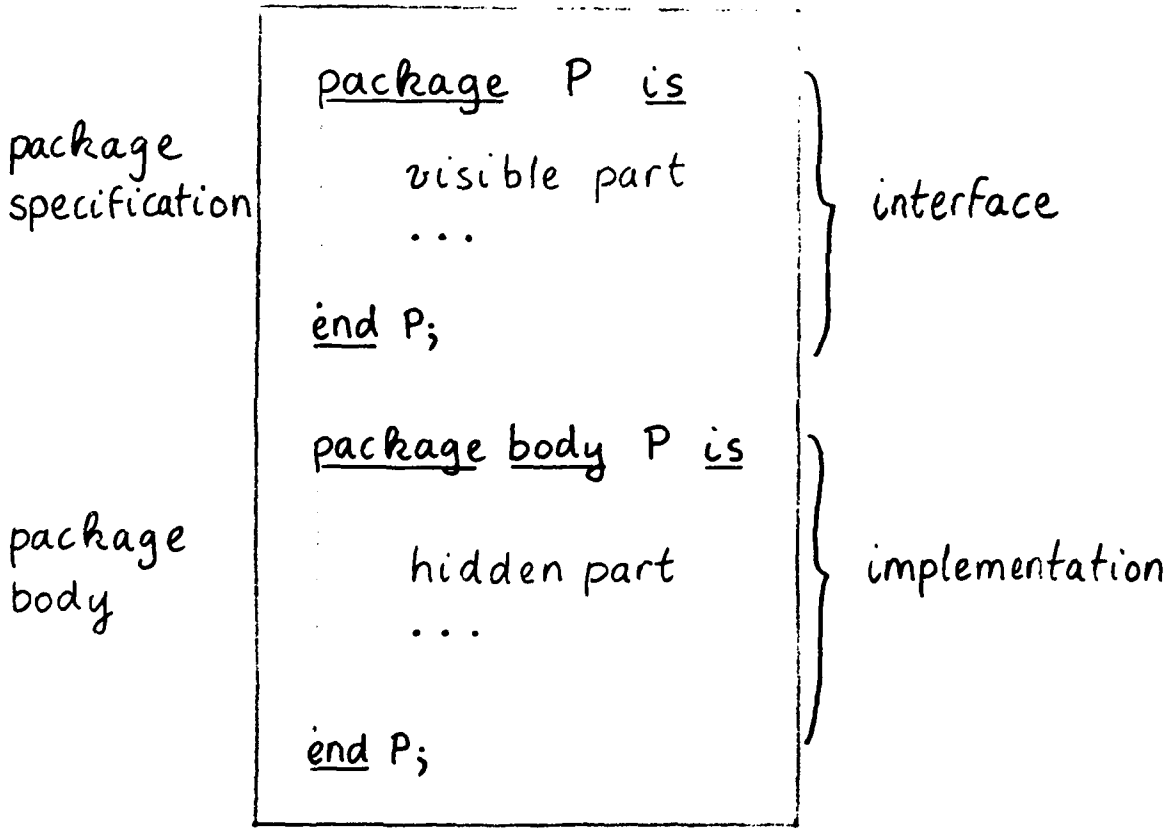
of course, only possible within scope

PACKAGES

Packages are used to formulate

- named collections of declarations
- groups of related subprograms
- private data types

PACKAGE SPECIFICATION AND BODY



A Package

TEXTUAL SEPARATION

procedure specification :

```
procedure SORT ( V : in out VECTOR);
```

procedure body :

```
procedure SORT (V : in out VECTOR) is
begin
    ...
    ...
end SORT;
```

FORMS OF PACKAGES

```
package WORK_DATA is

    type DAY is (MON, TUE, WED, THU, FRI, SAT, SUN);
    type TIME is delta 0.01 range 0.0 .. 24.0;
    type TIME_TABLE is
        array (DAY) of TIME;

    WORK_HOURS   : TIME_TABLE;
    NORMAL_HOURS : constant TIME_TABLE :=
          (MON .. FRI => 8.0, SAT | SUN => 0.0);


end WORK_DATA;
```

PACKAGE EXAMPLE: RANDOM

```
package RANDOM is

   type REAL is digits 7;

   procedure SET_SEED (START : INTEGER);
   function RAND_INT(L,H: INTEGER) return INTEGER;
   function UNIFORM(L,H : REAL) return REAL;
end RANDOM;
```

```
package body RANDOM is

   SEED    : INTEGER;                    -- local data
   CO_SEED : REAL;

   procedure CONGRUENCE is               -- local procedure
   begin
      SEED := ... ; CO_SEED := ... ;
   end;

   procedure SET_SEED(START : INTEGER) is
   begin
      ...
   end;
   Function RAND_INT ... end;
   Function UNIFORM ... end;
begin
   SET_SEED(1); -- initialization
end RANDOM;
```

INFORMATION HIDING

Textual separation of the interface

- the visible part defines the logical interface

- the implementation may be both

  protected and

  physically hidden

PRIVATE TYPES

```
package SIMPLE_INPUT_OUTPUT is

    type FILE is private;
    NO_FILE : constant FILE;

    procedure ASSIGN ( F : out FILE);
    procedure READ  ( F : in FILE; ...);
    procedure WRITE ( F : in FILE; ...);

private

    type FILE is new INTEGER range 0 ..50;
    NO_FILE : constant FILE := 0;

end SIMPLE_INPUT_OUTPUT;
```

```
package body SIMPLE_INPUT_OUTPUT is

    type FILE_DESCRIPTOR is record ... end record;

    DIRECTORY : array (FILE) of FILE_DESCRIPTOR;

    procedure ASSIGN (F : out FILE) is
    begin
        ...
    end ASSIGN;
    ...

begin
    -- initialization of DIRECTORY
end SIMPLE_INPUT_OUTPUT;
```

LIMITED PRIVATE TYPES

```
package INPUT_OUTPUT is

   type IN_FILE is limited private;

   procedure OPEN  (F : in out IN_FILE; ...);
   procedure CLOSE (F : in out IN_FILE; ...);
   procedure READ  (F : in     IN_FILE; ...);

   FILE_OPEN_ERROR : exception;
private

   type IN_FILE is
      record
         FILE_INDEX : INTEGER := 0;
      end record;
end INPUT_OUTPUT;
```

SUMMARY ON PRIVATE TYPES

- values are not known outside the package

- the only operations available are

  those of the visible part

- `:=`, `=`, `/=` } unless limited

ACCESS TO THE VISIBLE PART

dot notation : selected components

```
F : INPUT_OUTPUT.IN_FILE;

INPUT_OUTPUT.OPEN(F);

INPUT_OUTPUT.READ(F, X);
```

collectively : use clause

```
declare
    use INPUT_OUTPUT;
    F : IN_FILE;
begin
    ...
    OPEN(F);
    ...
    READ(F, X);
end;
```

SUMMARY ON PACKAGES

uses of packages cover

- named collections of declarations
- groups of subprograms
- private types

textual separation of

- package specification
- package body

packages support information hiding

packages serve to show

private types
- values are not known outside

access to the visible part
- selected component
- use clause

SEPARATE COMPILATION

- same degree of type checking across separately compiled units as within a compilation unit

- supports program construction

  top down development:
  separate compilation of the parts of a program: subunits

  bottom up development:
  reusing program modules: library units

- grain of change:
  recompilation of a unit

COMPILATION UNITS

several possible forms

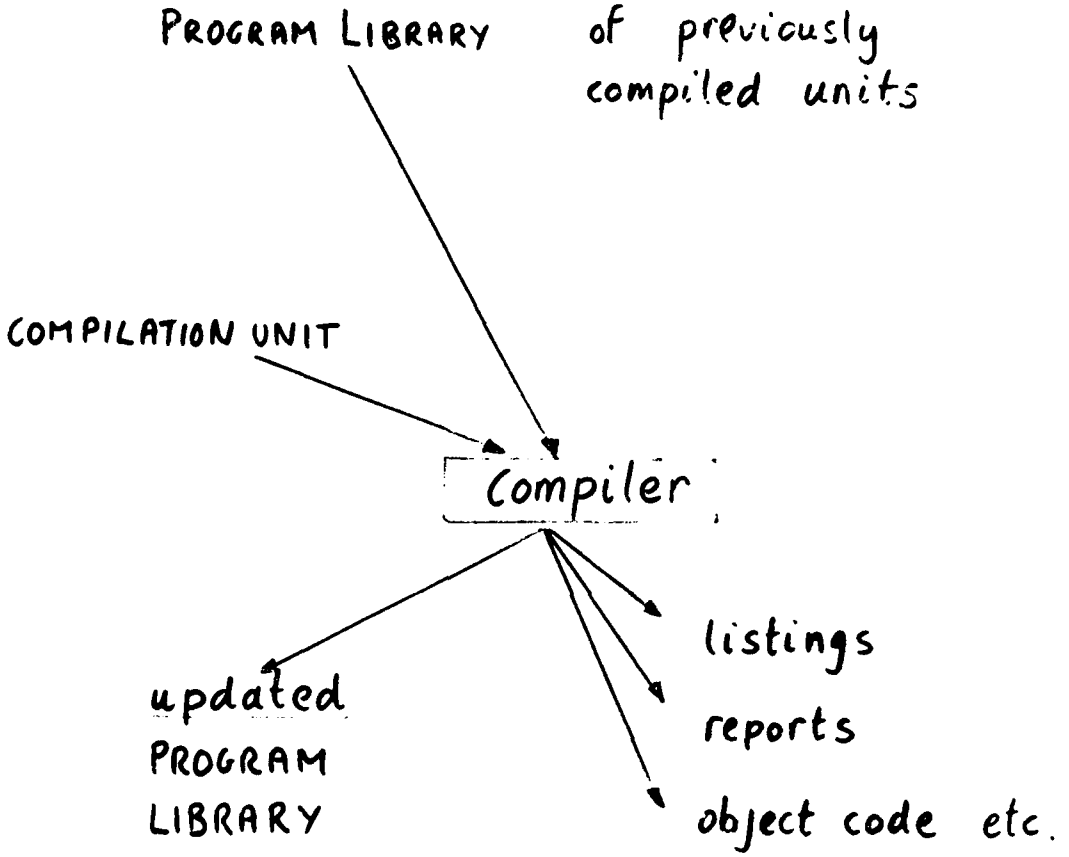
library units

- package declaration or body
- subprogram declaration or body
- subunits

context specification : with clause

```
with TEXT_IO, REAL_OPERATIONS;
procedure QUADRATIC_EQUATION is
   ...

end QUADRATIC_EQUATION;
```

COMPILATION MODEL



either addition of a new unit or update of an old unit

"BOTTOM UP" PROGRAM DEVELOPMENT

GENERALLY USABLE PACKAGES

no with clause

```
package MATH_FUNCTIONS is
    ...
end MATH_FUNCTIONS;
```

some dependence

```
with MATH_CONST;
package SURVEYING is
    ...
end SURVEYING;
```

```
with MATH_CONST, MATH_FUNCTIONS;
package body SURVEYING is
    ...
end SURVEYING;
```

ANY MAIN PROGRAM

"TOP DOWN" PROGRAM DEVELOPMENT

```
with MATH_FUNCTIONS;
procedure TOP is
   use MATH_FUNCTIONS;

   type REAL is digits 10;
   R, S : REAL;

   package D is
      PI : constant := 3.14159_26536;
      Function F(X : REAL) return REAL;
      procedure G(Y, Z : REAL);
   end D;

   package body D is separate;                    BODY
   procedure Q(U : REAL) is separate;             STUBS

begin
   ...

   Q(R);
   ...

   D.G(R, S);
   ...
end TOP;
```

COMPILATION SUBUNITS

SUBUNITS

A SUBUNIT

```
separate (TOP)
procedure Q(U : REAL) is
   use D;
begin
   ...
   U := F(U);
   ...
end Q;
```

ANOTHER SUBUNIT

```
with INPUT_OUTPUT;
separate (TOP)
package body D is
   -- local declarations

   function F(X: REAL) return REAL is
   begin

   end F;
   procedure G(Y,Z : REAL) is separate;
begin
   ...
end D;
```

BODY STUB

NOTE ON VISIBILITY

which identifiers are visible at the start of a compilation unit ?

- For a library unit
  - all identifiers of the predefined environment :
    the package STANDARD
  - all the names listed in the with clauses
  - the name of the unit itself

```
with A,B,C;
package P is ... end P;
```

- For a subunit
  same as at the stub, plus with clauses

METHODOLOGICAL IMPACT

- bottom up development

  libraries of packages

  once the interface is defined,
  the body can be redefined independently
  of the using units

  need for operations on libraries

- top down development

  agree on interface then develop subunits

- physical modularity

- physical information hiding

towards an industry of software components

ALGORITHMIC ASPECTS

NAMES and EXPRESSIONS

STATEMENTS

SUBPROGRAMS

procedures, functions,
and operators

overloading

SOME DECLARATIONS

```
type DATE is
   record
      MONTH : MONTH_NAME;
      DAY   : INTEGER range 1 .. 31;
      YEAR  : INTEGER range 0 .. 3000;
   end record;

type PERSON (SEX : GENDER) is
   record
      BIRTH, DEATH : DATE;
      ADDRESS : STRING (1 .. 30);
      ...
   end record;

subtype KING is PERSON(M);

LOUIS : array (1 .. 18) of KING;

JOHN  : KING :=
          (SEX => M,
           BIRTH => (DEC, 24, 1167),
           DEATH => (OCT, 18, 1216), ...);
```

NAMES

identifiers

```
LOUIS
MONTH_NAME
KING
```

indexed component

```
LOUIS(16)
```

selected component

```
JOHN.BIRTH
```

attribute

```
MONTH_NAME'FIRST    -- JAN
MONTH_NAME'LAST     -- DEC
```

function call

```
HEIR(JOHN)
```

slice

```
LOUIS(11 .. 18)
```

NAMES

combinations of the previous forms are also names

```
LOUIS(11).BIRTH

LOUIS(11).BIRTH.YEAR

JOHN.ADDRESS(12)

LOUIS(14).ADDRESS(1)

HEIR(JOHN).BIRTH.DAY


LOUIS(9..12)(10)      -- LOUIS(10)
```

OPERATORS and EXPRESSIONS

Six precedence levels

lowest	logical operators	and or xor and then or else
	relational operators	= /= < <= > >= in not in
	adding operators	+ - &
	unary operators	+ -
	multiplying operators	* / rem mod
highest	exponentiating operator	**

EVALUATION OF EXPRESSIONS

operators of higher precedence are applied first

parentheses to impose a specific order

the order of evaluation of the two operands of an operator is not defined (except for short circuit control forms)

All operands of an expression are evaluated (unless it contains short circuit control forms)

SUNNY and WARM

```
NEXT_CAR.OWNER /= null and then NEXT_CAR.OWNER.AGE > 25
```

STATEMENTS

Simple assignment statement

or compound statements

```
if ... then          case ... is          loop
   ...                  ...                  ...
end if;              end case;            end loop;
```

also accept and select statements and

```
declare
   ...
begin
   ...
end;
```

SUBPROGRAMS

Conventional parameterized program units

Two forms of subprograms:

Procedures

a procedure call
is a statement

Functions

- called in expressions
- return a value

Operators are defined as functions

SUBPROGRAM BODIES

```
procedure identifier formal_part is
    declarative part
begin
    sequence of statements
end identifier ;
```

```
function designator formal_part return subtype_indication is
    declarative part
begin
    sequence of statements
end designator;
```

a designator is either an identifier or an operator symbol, for exampe "*"

SUBPROGRAM DECLARATIONS

subprogram declarations may be introduced for readability considerations

```
procedure QUADRATIC_EQUATION
          (A,B,C : in REAL;
           ROOT_1, ROOT_2 : out REAL;
           OK : out BOOLEAN);

function INNER (X, Y : VECTOR) return VECTOR;
```

they are necessary in the following cases:

- packages
- mutual recursion

(subprogram specifications also appear in generic declarations and renaming declarations)

PARAMETER MODES

three possible modes

in — the parameter acts as a local constant whose value is provided by the corresponding actual parameter.

out — the parameter acts as a local variable whose value is assigned to the actual parameter as a result of the execution of the subprogram.

in out — the parameter acts as a local variable and permits access and assignment to the actual parameter.

in is the default

For scalar and access types, effect achieved by copy. For array, record, or private types: either by copy or by reference.

FUNCTIONS AND OPERATORS

```
function INNER(X,Y : VECTOR) return VECTOR is
    ...
begin
    ...
    return SUM;
end INNER;
```

```
function "*" (X,Y : VECTOR) return VECTOR is
    ...
begin
    ...
    return SUM;
end "*";
```

```
A, B : VECTOR(1 ..N);
R    : REAL;

R := INNER(A, B);
R := A * B;
```

Only in parameters

PROCEDURE AND FUNCTION CALLS

POSITIONAL CALLS

```
INNER( A, B)

QUADRATIC_EQUATIONS(L,M,N,P,Q,STATUS);
```

NAMED PARAMETER ASSOCIATIONS

formal => actual

```
QUADRATIC_EQUATIONS (L, M, N,
      ROOT_1 => P,   ROOT_2 => Q,
      OK => STATUS);
```

- positional associations must precede named associations
- the order of named associations is immaterial

DEFAULT PARAMETERS

A default value may be given for an in parameter in a subprogram specification

```
type STEAK_TYPE is (RARE, MEDIUM, WELL_DONE);
type POTATO_STYLE is (BAKED, CREAMED, FRIES);
type DRESSING_KIND is ( BLUE_CHEESE,
    THOUSAND_ISLAND, OIL_AND_VINEGAR , FRENCH);

procedure ORDER_DINNER
    (STEAK    : in STEAK_TYPE    := MEDIUM,
     POTATO   : in POTATO_STYLE  := BAKED,
     DRESSING : in DRESSING_KIND := FRENCH);

ORDER_DINNER(STEAK => RARE);

ORDER_DINNER(MEDIUM, CREAMED);

ORDER_DINNER(RARE, DRESSING => BLUE_CHEESE);

ORDER_DINNER;
```

OVERLOADING

- Overloading does not hide
- The identification uses the context
- IF the context does not suffice use <u>qualification</u>

```
procedure REGISTER ( D : DAY);
procedure REGISTER( S : OBJECT);
```

```
REGISTER (TODAY);
REGISTER (NEXT_PLANET);
```
} no problem with variables

```
REGISTER (TUE);
REGISTER(EARTH);
```
} no problem with non-overloaded literals

```
REGISTER (SUN);

REGISTER ( DAY'(SUN));
```
} the solution is to qualify

SUBPROGRAM SUMMARY

Procedures and Functions

Specification may precede body
- must match

Three possible modes
in out inout

Positional and Named calls

Default in parameters

Overloaded subprograms

TASKING CONCEPTS

TASKS and TASK TYPES
- task body, specification, objects

TASK EXECUTION
- activation termination

COMMUNICATION
- entry calls } rendezvous
- accept statements }

TIMING
- delay

SELECT STATEMENT
- multiple wait
- timed and conditional calls

SCHEDULING
- priorities, interrupt

Classification of tasks

TASK TYPES

task specification

```
task type T is
   {entry declaration}
end T;
```

} the interface to other tasks

task body

```
task body T is
   declarative part
begin
   sequence of statements
end T;
```

} the actions of the tasks of the type

task object declarations

```
V, W : T;
```

morphology similar to packages

TASK TYPES

a task type is a limited private type

no assignment

no (in) equality

task objects can be in parameters

an access type can refer to a task type

```
task type KEYBOARD_DRIVER is
   entry READ(C : out CHARACTER);
   entry WRITE(C : in  CHARACTER);
end;

type KEYBOARD is access KEYBOARD_DRIVER;

TERMINAL : KEYBOARD := new KEYBOARD_DRIVER;

--KEYBOARD is not a limited private type
```

A SIMPLE EXAMPLE

```
procedure ARRIVE_AT_AIRPORT is

    task CLAIM_BAGGAGE;

    task RENT_A_CAR;

    task body CLAIM_BAGGAGE is
        ...
    end;

    task body RENT_A_CAR is
        ...
    end;
begin    -- CLAIM_BAGGAGE and RENT_A_CAR
         -- become active

     BOOK_HOTEL;

end; -- await termination of
     -- CLAIM_BAGGAGE and RENT_A_CAR
```

COMMUNICATION BETWEEN TASKS

task specification: the interface

```
task LINE_TO_CHAR is
   entry PUT_LINE ( L : in LINE);
   entry GET_CHAR( C : out CHARACTER);
end;
```

task body:

```
task body LINE_TO_CHAR is
   BUFFER : LINE;
begin
   -- statements describing the actions
   -- performed by the task
end LINE_TO_CHAR;
```

```
type LINE is array (1 .. 80) of CHARACTER;
```

ENTRIES AND ACCEPT STATEMENTS

entry declaration

```
entry PUT_LINE (L : in LINE);
```

similar to a procedure declaration

entry call

```
LINE_TO_CHAR.PUT_LINE (MY_LINE);
```

similar to a procedure call

accept statement

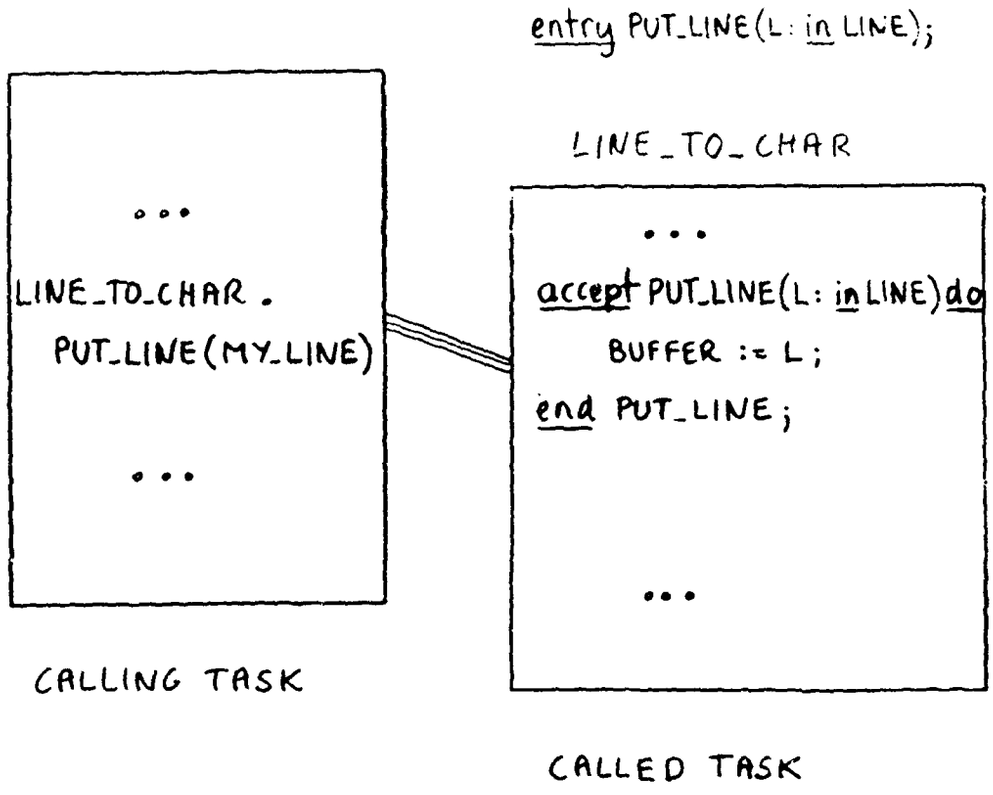
```
accept PUT_LINE (L : in LINE) do
   BUFFER := L;
end PUT_LINE;
```

similar to an inline procedure body

RENDEZVOUS :
between entry call and accept statement

QUEUES :
several tasks may be waiting on an entry

RENDEZVOUS



- whoever is there first waits for the other
- when both are there, the accept is executed
- thereafter, the calling and the called task continue in parallel

A SERVER TASK

```
task LINE_TO_CHAR is
   entry PUT_LINE (L : in LINE);
   entry GET_CHAR (C : out CHARACTER);
end;

task body LINE_TO_CHAR is
   BUFFER : LINE;
begin
   loop
      accept PUT_LINE (L: in LINE) do
         BUFFER := L;
      end PUT_LINE;
      for I in BUFFER'RANGE loop
         accept GET_CHAR(C : out CHARACTER) do
            C := BUFFER(I);
         end GET_CHAR;
      end loop;
   end loop;
end LINE_TO_CHAR;
```

USER TASKS

```
task  PRODUCE_LINE;

task  CONSUME_CHAR;


task body PRODUCE_LINE is
    MY_LINE : LINE;
begin
   loop
      -- fill MY_LINE from somewhere
      LINE_TO_CHAR . PUT_LINE(MY_LINE);
   end loop;
end;

task body CONSUME_CHAR is
   MY_CHAR : CHARACTER;
begin
   loop
      LINE_TO_CHAR.GET_CHAR(MY_CHAR);
      -- dispose of MY_CHAR;
   end loop;
end;
```

DELAY STATEMENT

```
delay 3.5;
```

suspends the task for at least the duration indicated

units are seconds

the expression is of the predefined fixed point type DURATION

For clarity one may write

```
SECONDS : constant := 1.0;
MINUTES : constant := 60.0;
```

and then

```
delay 2.0 * MINUTES + 45.0 * SECONDS;
```

SELECT STATEMENT

waiting for one of several alternatives

```
task PROTECTED_VARIABLE is
   entry READ(V : out ELEM);
   entry WRITE(E : in  ELEM);
end;

task body PROTECTED_VARIABLE is
   VARIABLE : ELEM := INITIAL_VALUE;
begin
   loop
      select
         accept READ(V : out ELEM) do
            V := VARIABLE;
         end;
      or
         accept WRITE(E : in ELEM) do
            VARIABLE := E;
         end;
      end select;
   end loop;
end PROTECTED_VARIABLE;
```

SELECT WITH GUARDS

```
task BUFFERING is
   entry READ (V : out ELEM);
   entry WRITE (E : in ELEM);
end;

task body BUFFERING is
   BUFFER : array (1..N) of ELEM;
   I,J    : INTEGER range 1..N := 1;
   COUNT  : INTEGER range 0..N := 0;
begin
   loop
      select
         when COUNT > 0 =>
            accept READ(V: out ELEM) do
               V := BUFFER(J);
            end;
            J := (J mod N)+1; COUNT := COUNT - 1;
      or
         when COUNT < N =>
            accept WRITE( E : in ELEM) do
               BUFFER(I) := E;
            end;
            I := (I mod N)+1; COUNT := COUNT + 1;
      end select;
   end loop;
end BUFFERING;
```

PACKAGING A TASK

```
package READER_WRITER is
   procedure READ( X : out ELEM);
   procedure WRITE( X : in ELEM);
end;

package body READER_WRITER is
   VARIABLE : ELEM := INITIAL_VALUE;

   task CONTROL is
      entry START; entry STOP;
      entry WRITE (X : in ELEM)
   end;
   ...
   procedure READ(X : out ELEM) is
   begin
      CONTROL.START; X := VARIABLE;
      CONTROL.STOP;
   end;

   procedure WRITE (X : in ELEM) is
   begin
      CONTROL.WRITE(X);
   end;
end;
```

enforcing a protocol

CONTROLLING READERS AND WRITERS

```
task body CONTROL is
    READERS : INTEGER := 0;
begin
    loop
        select
            accept START;
            READERS := READERS + 1;
        or
            accept STOP;
            READERS := READERS - 1;
        or
            when READERS = 0 =>
                accept WRITE(E: in ELEM) do
                    VARIABLE := E;
                end;
        end select;
    end loop;
end;
```

SELECT WITH ELSE PART

```
select
   when WRITE'COUNT = 0  =>
      accept START;
      READERS := READERS + 1;
or
      accept STOP;
      READERS := READERS - 1;
or when READERS = 0  =>
      accept WRITE (E : in ELEM) do
         VARIABLE := E;
      end;
      loop
         select
            accept START;
            READERS := READERS + 1;
         else
            exit;
         end select;
      end loop;
end select;
```

-- new reader only accepted in the absence of writer
-- after a writer, accept any waiting readers

TIMED AND CONDITIONAL ENTRY CALLS

timed entry call

```
select
    SERVER.REQUEST(SOME_DATA);
or
    delay 45.0 * SECONDS;
    -- what to do if service has
    -- not started within delay (server
    -- too busy)
end select;
```

conditional entry call

```
select
    SERVER.REQUEST(SOME_DATA);
else
    -- do something else if busy
    -- server cannot accept request
    -- immediately
end select;
```

load control

TERMINATE ALTERNATIVE

```
task type RESOURCE is
    entry SEIZE;
    entry RELEASE;
end;


task body RESOURCE is
   BUSY : BOOLEAN := FALSE;
begin
   loop
      select
         when not BUSY =>
            accept SEIZE do BUSY := TRUE; end;
      or
         accept RELEASE do BUSY := FALSE; end;
      or
         when not BUSY => terminate;
      end select;
   end loop;
end;
```

TASK CLASSIFICATION

two extremes

the server

calls no other task

its body is often of the form

```
loop
   select
      ...
   end select;
end loop;
```

READER_WRITER

the user

has no entries PRODUCE_LINE

intermediate cases

TASK CLASSIFICATION

when a server supports several users:

- no special requirement because the services do not interact
  use a package look up table

- mutual exclusion between services because of possible interference
  PROTECTED_VARIABLE
  use a select statement

- mutual exclusion + temporary unavailability because conditions cannot be met
  BUFFERING
  use guards

- mutual exclusion + temporary unavailability + control of order (server is a scheduler)
  CONTROLLER
  use families of entries

EXCEPTION HANDLING

concept of an exception

- what can be terminated by an exception
- how are exceptions declared
- what are handlers
- how are exceptions raised
- semantics of exceptions their uses
- scope and exceptions

suppressing checks

exceptions and tasking

summary of use

CONCEPT OF AN EXCEPTION

situations that prevent completion of an action

violation of a constraint

a matrix is singular

an exception names such a situation

CONSTRAINT_ERROR

SINGULAR

Raising an exception means telling the invoker of an action that this situation has occured

Handling an exception means executing some actions in response

EXCEPTION DECLARATIONS

```
SINGULAR : exception;
ERROR    : exception;
```

Some exceptions are predefined:

declared in STANDARD

```
CONSTRAINT_ERROR,
NUMERIC_ERROR,
SELECT_ERROR,
STORAGE_ERROR,
TASKING_ERROR : exception;
```

tasks have an attribute that is an exception

MULTIPLEXER'FAILURE

EXCEPTION HANDLERS

exception handlers may appear at the end of a sequence of statements enclosed by begin and end

```
begin
    sequence of statements
exception
    when CONSTRAINT_ERROR =>
        sequence of statements
    when SINGULAR =>
        sequence of statements
    when others =>
        sequence of statements
end;
```

exception handlers

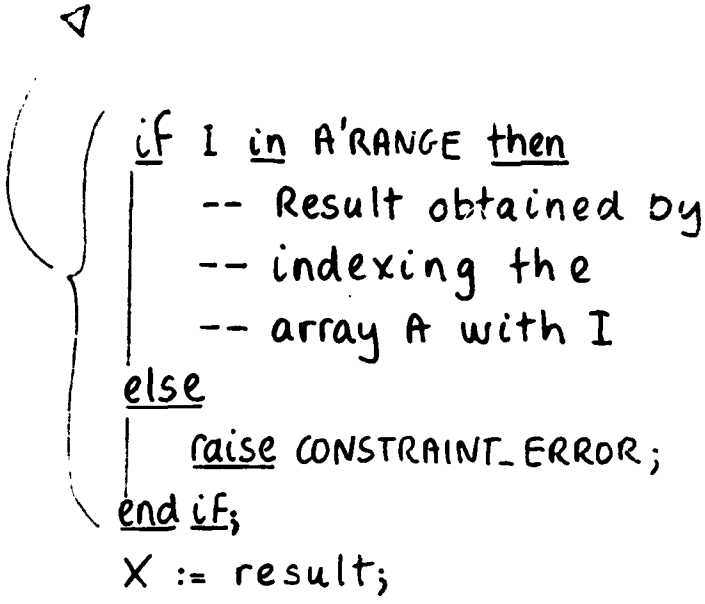
bloc, subprogram body, package body, task body

handlers of the begin-end part

PROPAGATION OF A PREDEFINED EXCEPTION

Consider

```
X := A( I );
```



```
if I in A'RANGE then
    -- Result obtained by
    -- indexing the
    -- array A with I
else
    raise CONSTRAINT_ERROR;
end if;
X := result;
```

in line expansion

or

hardware operation

HANDLING AN EXCEPTION

GENERAL CASE

blocks, subprogram, package

no handler =>

execution of unit is abandoned

same exception propagated in caller

a handler exists for the exception =>

execution of the handler terminate the execution of the unit

TASKS

no implicit propagation

HANDLING AN EXCEPTION

the handlers apply to the begin-end part

hence an exception in the declarative part of a block subprogram or package is always propagated

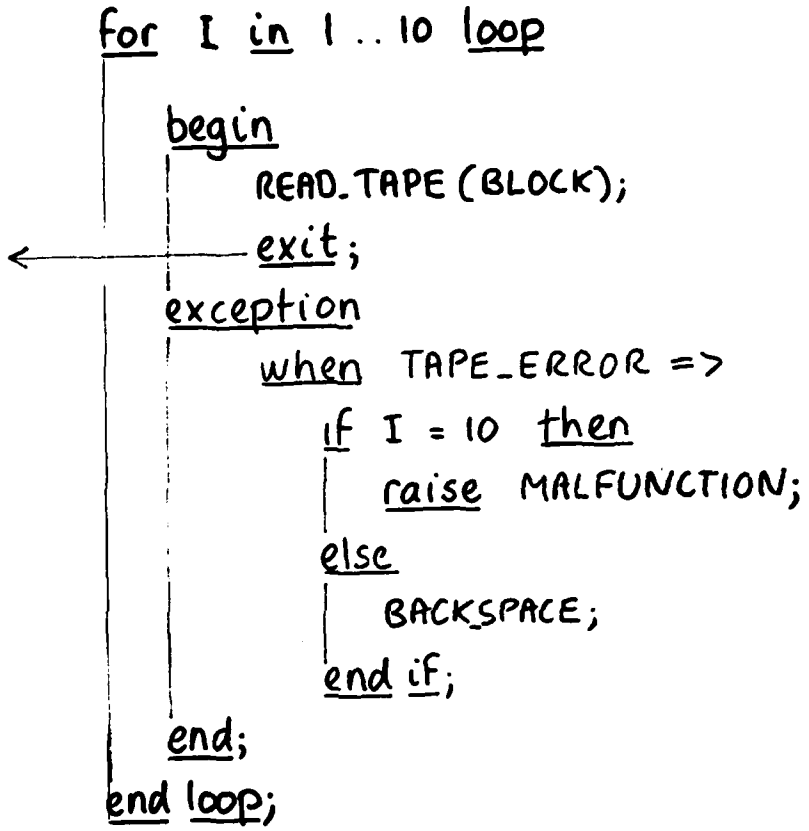
library units : abandon

TERMINATING CONDITION

- Exceptions are "terminating" conditions

```
Function DIVIDE (U,V : REAL) return REAL is
begin
   return U / V;
exception
   when NUMERIC_ERROR => return REAL'LARGE;
end;
```

RETRYING AN OPERATION



EXCEPTIONS AND TASKING

ASYNCHRONOUS INTERVENTIONS

```
raise T'FAILURE;
```

T is allowed last wishes

```
abort T;
```

terminate unconditionally !

in either case "partners" of T receive the exception TASKING_ERROR

example of termination sequence:

```
raise T'FAILURE;
delay 20.0*SECONDS;
abort T;
```

Abnormal termination

EXCEPTIONS IN COMMUNICATIONS

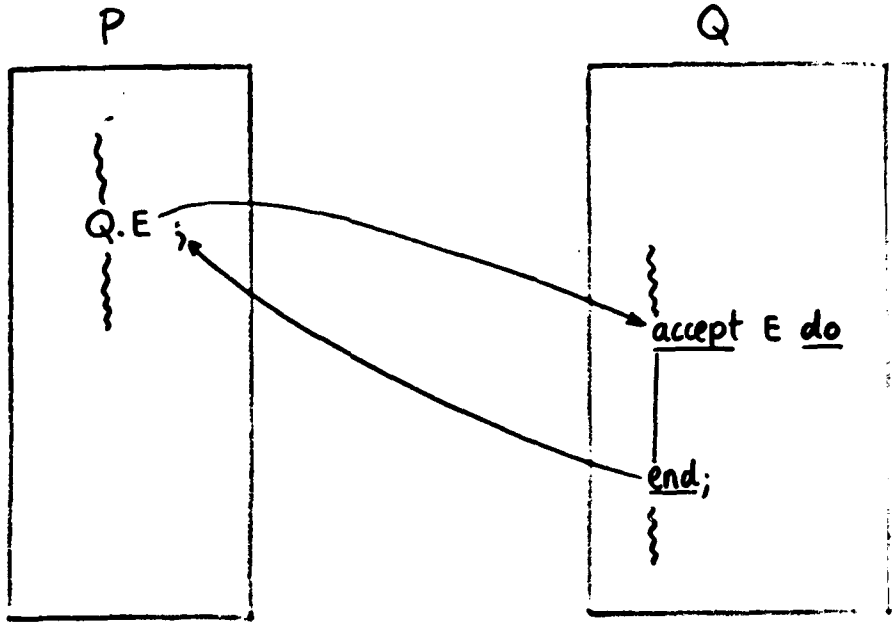
Calling an entry of a terminated task

the calling task receives the exception TASKING_ERROR

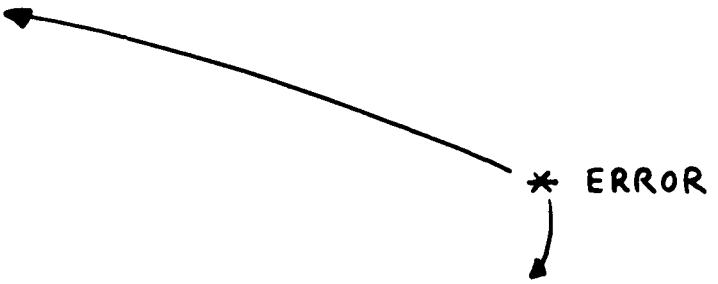
Exceptions occurring during a rendezvous

- during execution of the accept statement
- the called task dies
- the caller dies

RENDEZVOUS



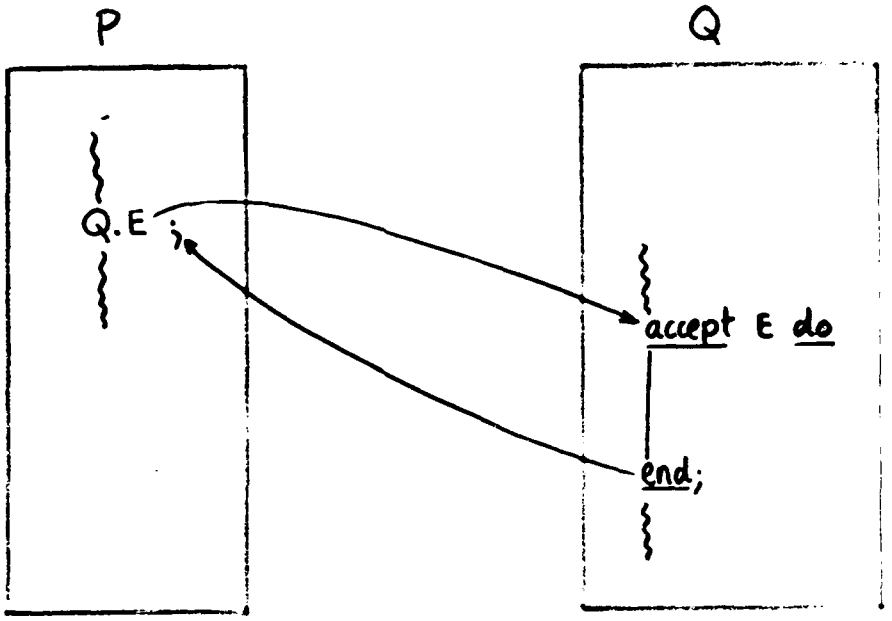
the exception ERROR is raised or
propagated within the accept statement



ERROR in P

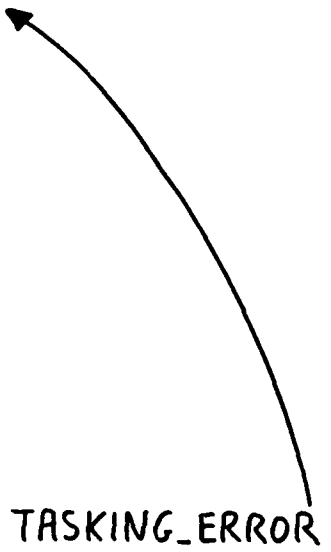
error in Q

RENDEZVOUS



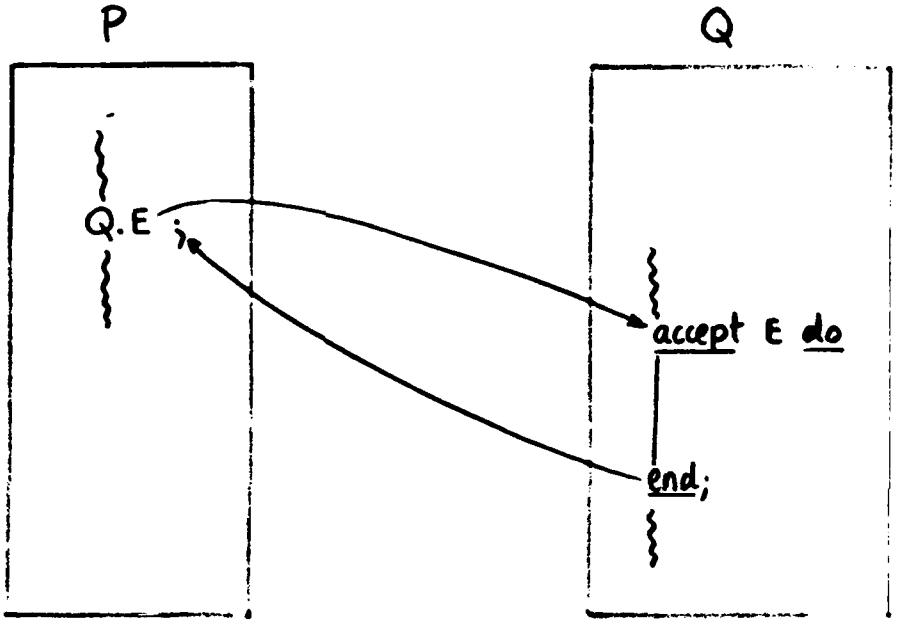
CALLED TASK

- receives a FAILURE
- is abnormally terminated



FAILURE is not propagated to calling task

RENDEZVOUS



CALLER DIES

The server completes the rendezvous

The server is unaffected

SUPPRESSING CHECKS

```
pragma SUPPRESS (RANGE_CHECK);

pragma SUPPRESS (INDEX_CHECK, ON => TABLE);
```

the pragma may appear in the declarative part of a unit and applies to the end of the unit

checks are not required

- but they may be performed nevertheless
- hence the corresponding expressions may still occur
- they may also be raised explicitly or propagated

SUMMARY OF USE

to regain control when attempted actions cannot be completed

the invoker of the action is given the opportunity to perform appropriate actions

abandon

retry

use an alternative approach

clean-up (LAST WISHES)

continue if appropriate

MR. WILLIAM CARLSON'S CLOSING REMARKS

A frequent complaint that we hear about the software business is that we are still a cottage industry. We are like shoemakers who do not do a very good job providing their own children with shoes. Most software projects use relatively few and primative tools, and in general software tools are less impressive than the tools that people in the computer aided design business or production control have.

The few programming environments that provide a significant number of productivity enhancing tools are built around a single common language.

I've heard various theories about how to invest in software tools without having a standard language. In fact, many of you probably have heard me talk about the benefits of computer networking and the possibility of having tools written in several different languages which communicate over a network. I can tell you for myself that I was doing that because there wasn't a common language and I was looking for some way to get around that.

Having a common language makes the job of a tool provider very much easier. Now we have the common language that is going to allow us to invest effectively in software tools, standard reuseable packages, and reuseable components. We can begin to capitalize not only the defense software industry, but the software industry as a whole.

I see this Ada Debut not as the end of a program but really as the begining. The Services are investing significant dollars in building, compilers, and eventually complete families of tools. We at ARPA are going to be pushing very hard to take advantage of having this common language.

I look forward to the 1980's and the benefits that are going to come to us from having a common medium of expression. I'm sure you share my enthusiam for the outstanding job the Language Design Team has done.

I want to close by thanking Jean Ichbiah for the outstanding presentation these two days, and thank you for coming.