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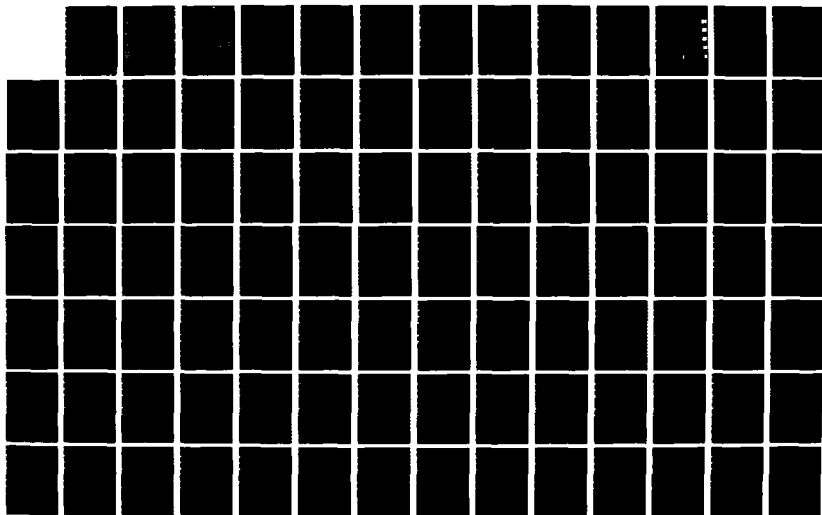
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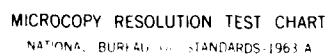
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TUTORIAL

TRACK I

INTRODUCTION TO ADA

By

Major Charles Engle, U.S. Military Academy

and

Lieutenant Tony Dominice, Keesler Air Force Base

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This document contains prints of viewgraphs presented at the
Introduction to Ada Tutorial, Track I June 9, 1987. Topics covered
were The Software Crisis, Technical Background, Basic Constructs,
Subprograms, Generics and Tasks.

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Introduction to Ada[®]

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COMPUTER SCIENCE

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A-1

OVERVIEW

- I. The Software Crisis
- II. Program Units
- III. Types
- IV. Control Statements
- V. Exceptions
- VI. Generics
- VII. Tasks
- VIII. Application Example

Types

Records

```
A_DRIVER : INSURANCE (GOOD);  
ANOTHER : INSURANCE (BAD);
```

```
begin
```

```
  A_DRIVER.NORMAL_RATE := 25;  
  A_DRIVER.DISCOUNT_RATE := 0.15;
```

```
  ANOTHER.NORMAL_RATE := 25;  
  ANOTHER.ADDITIONAL := 10;
```

Types

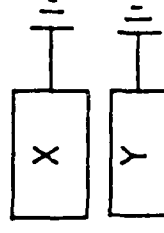
Access

- Pointer variables
- Allow for dynamic allocation of memory
- Objects created via an allocator

type POINTER is access INTEGER;

X, Y : POINTER; -- initialized to
 -- null

begin



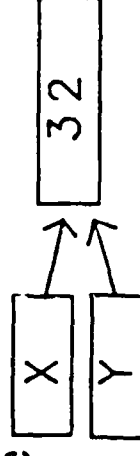
X := new INTEGER; -- allocate
 -- memory to X



X.all := 32; -- place 32 in the
 -- location pointed to
 -- by X



Y := X; -- X and Y point to the same
 -- location



Software Crisis

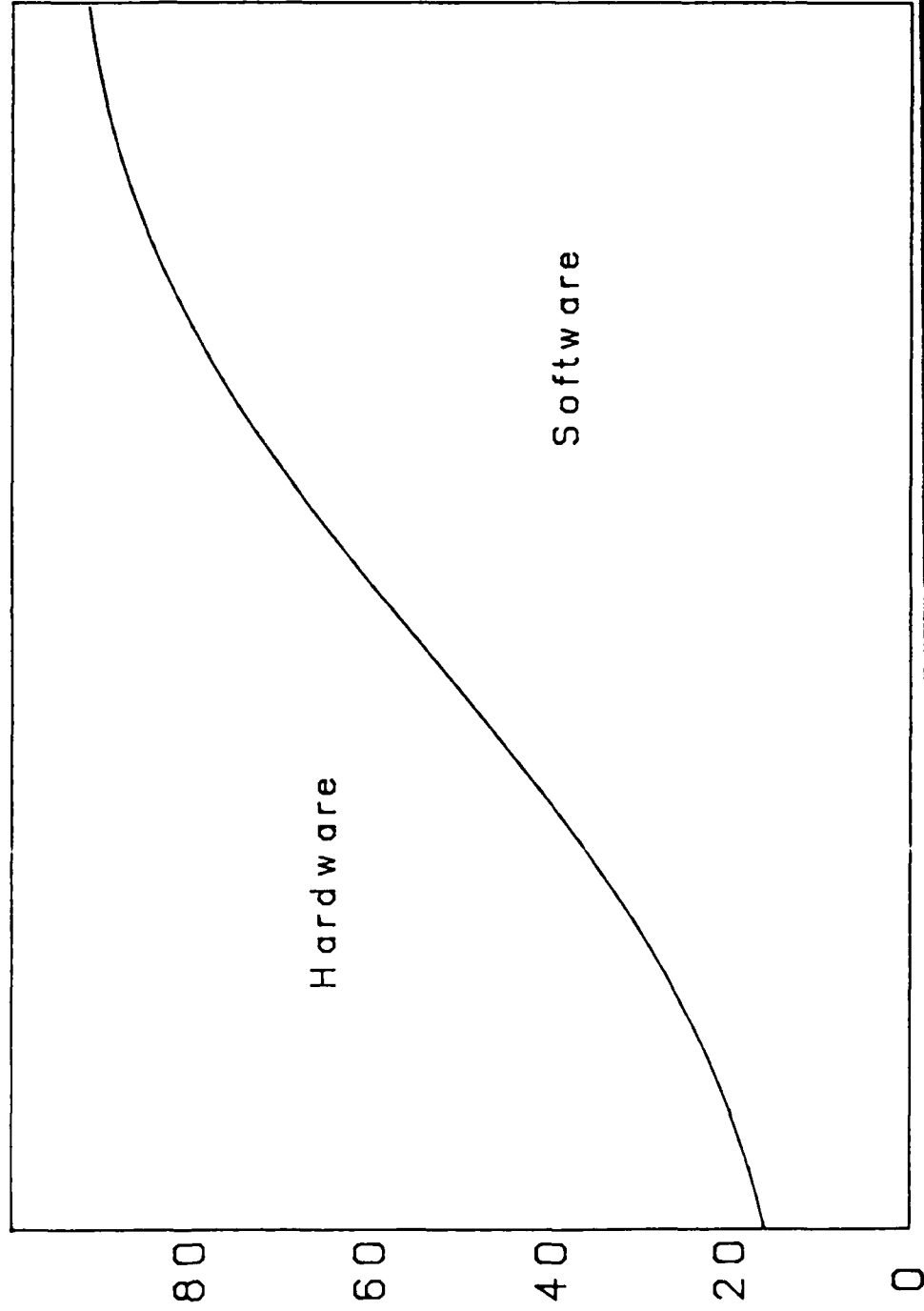
- Rising costs of software
- Unreliable
- Late
- Not maintainable
- Inefficient
- Not transportable

WHY??

- Too many languages
- Poor tools
- Changing technology
- Not enough trained people

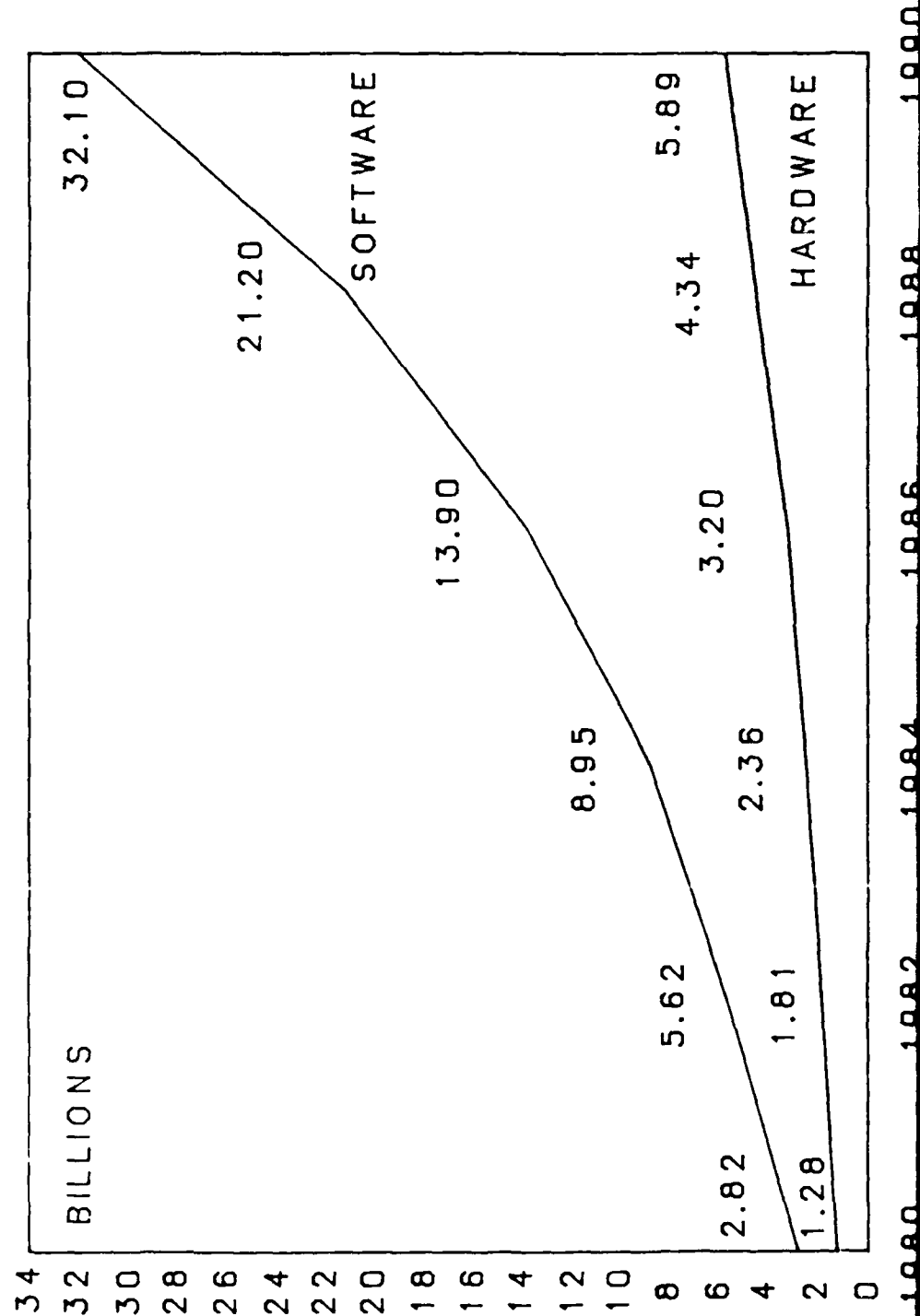
INABILITY TO MANAGE COMPLEX PROBLEMS

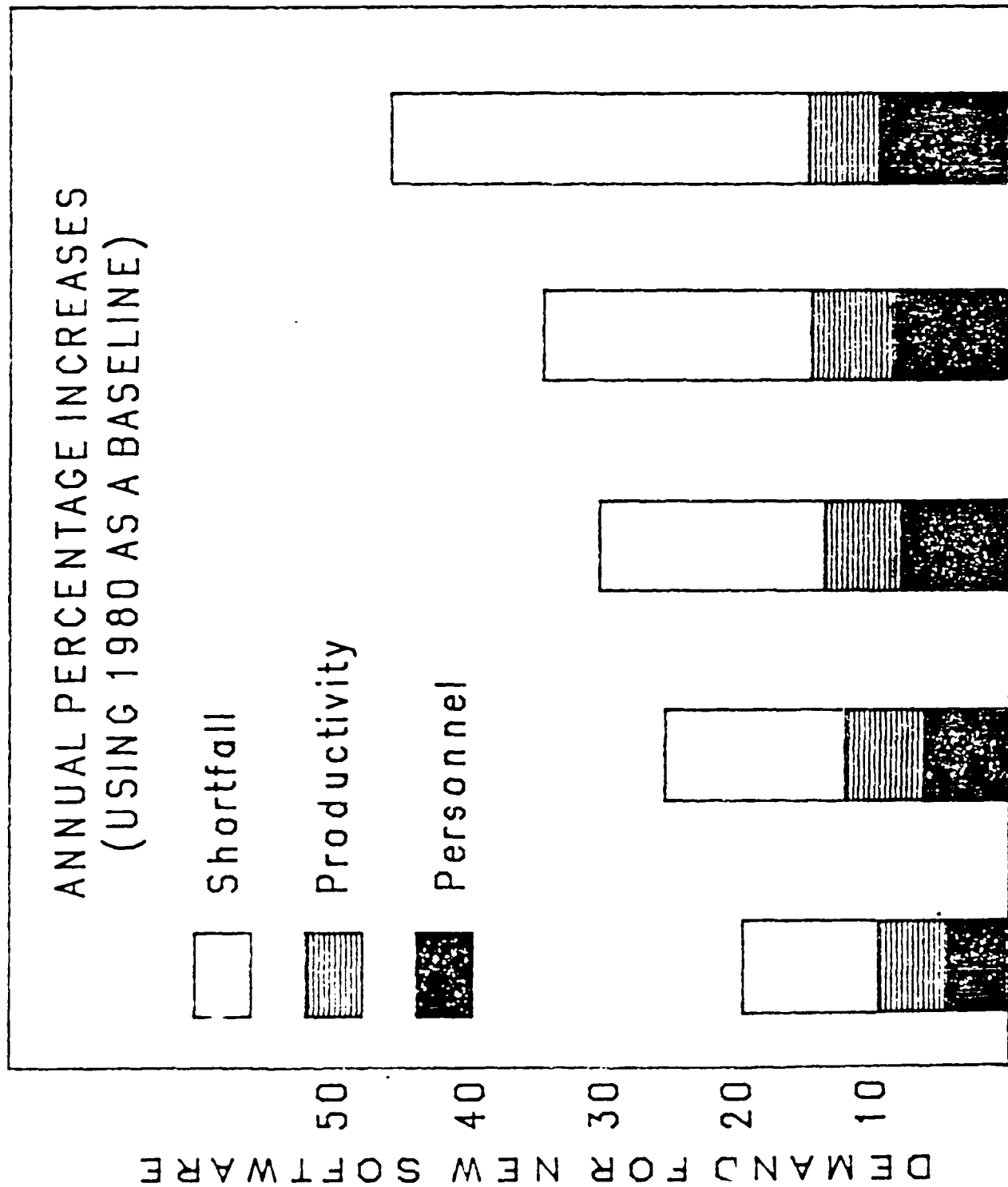
Software Crisis



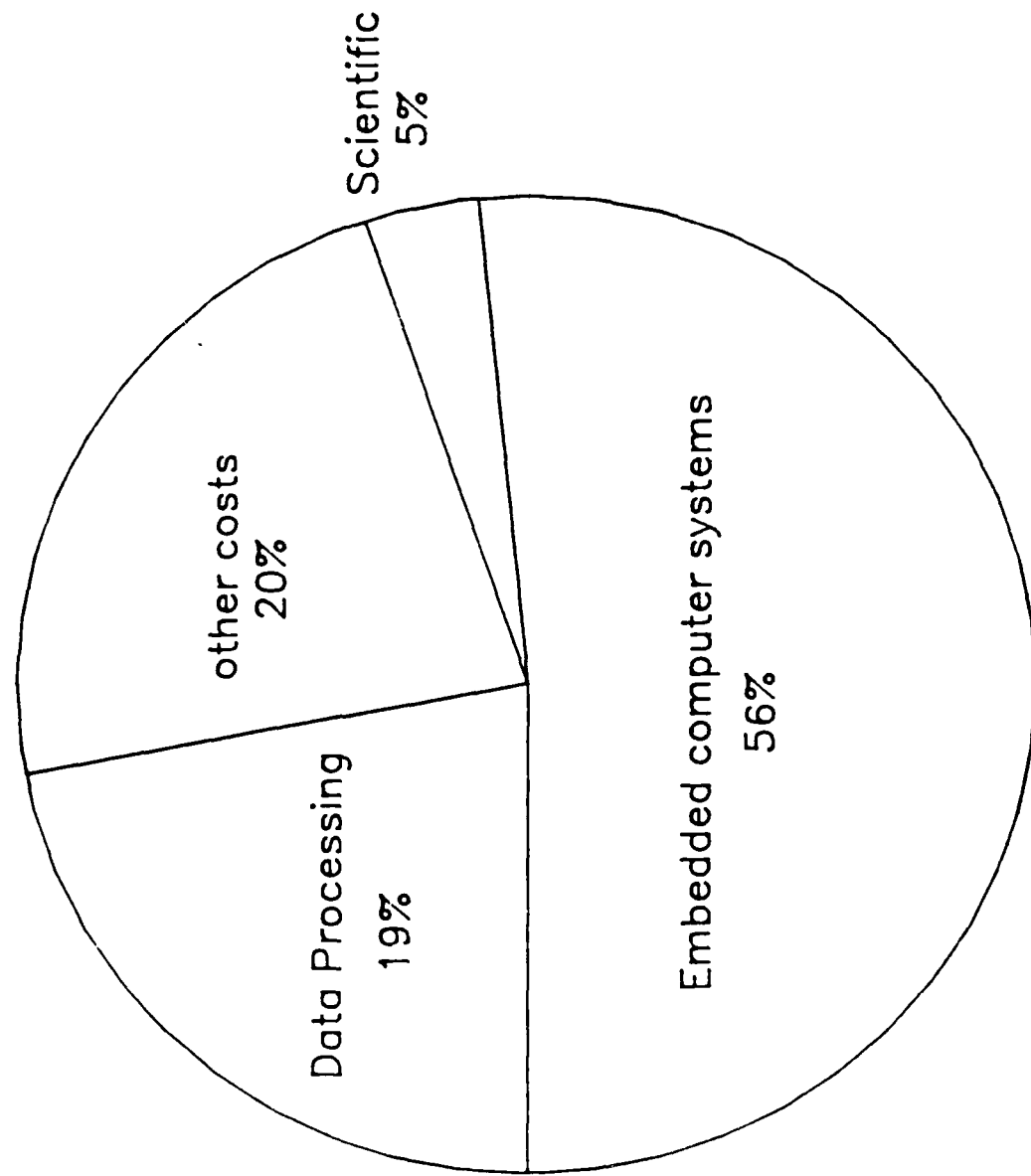
Software Crisis

DoD Embedded Hardware/Software Costs





Software Crisis



Software Crisis

EMBEDDED SYSTEMS

- Large
- Long lived
- Continous change
- Physical constraints
- High reliability

EMBEDDED SYSTEMS SOFTWARE

- Severe reliability requirements
- Time and size constraints
- Parallel processing
- Real time control
- Exception handling
- Unique I/O

Software Crisis

SOLUTIONS

<u>Single Language</u>	<u>Improved Tools</u>	<u>Improved Methodologies</u>
------------------------	-----------------------	-------------------------------

Ada	Ada	Methodman
-----	-----	-----------

	APSE	??
--	------	----

(Ada		
------	--	--

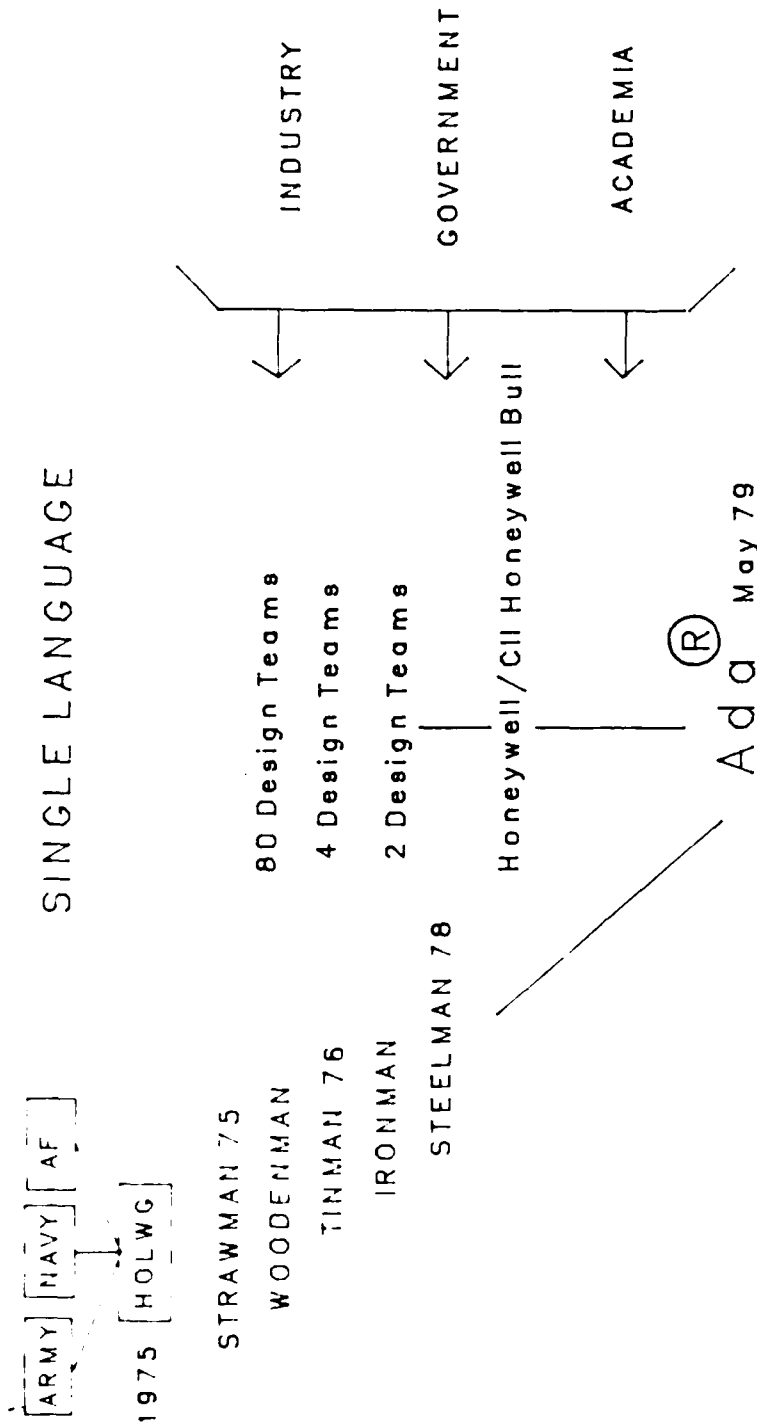
Program ming		
--------------	--	--

Support		
---------	--	--

Environment)		
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SOFTWARE ENGINEERING

Software Crisis



Ada Joint Program Office

ANSI/MIL STD 1815A FEB 83

First Translator APR 83

Software Crisis

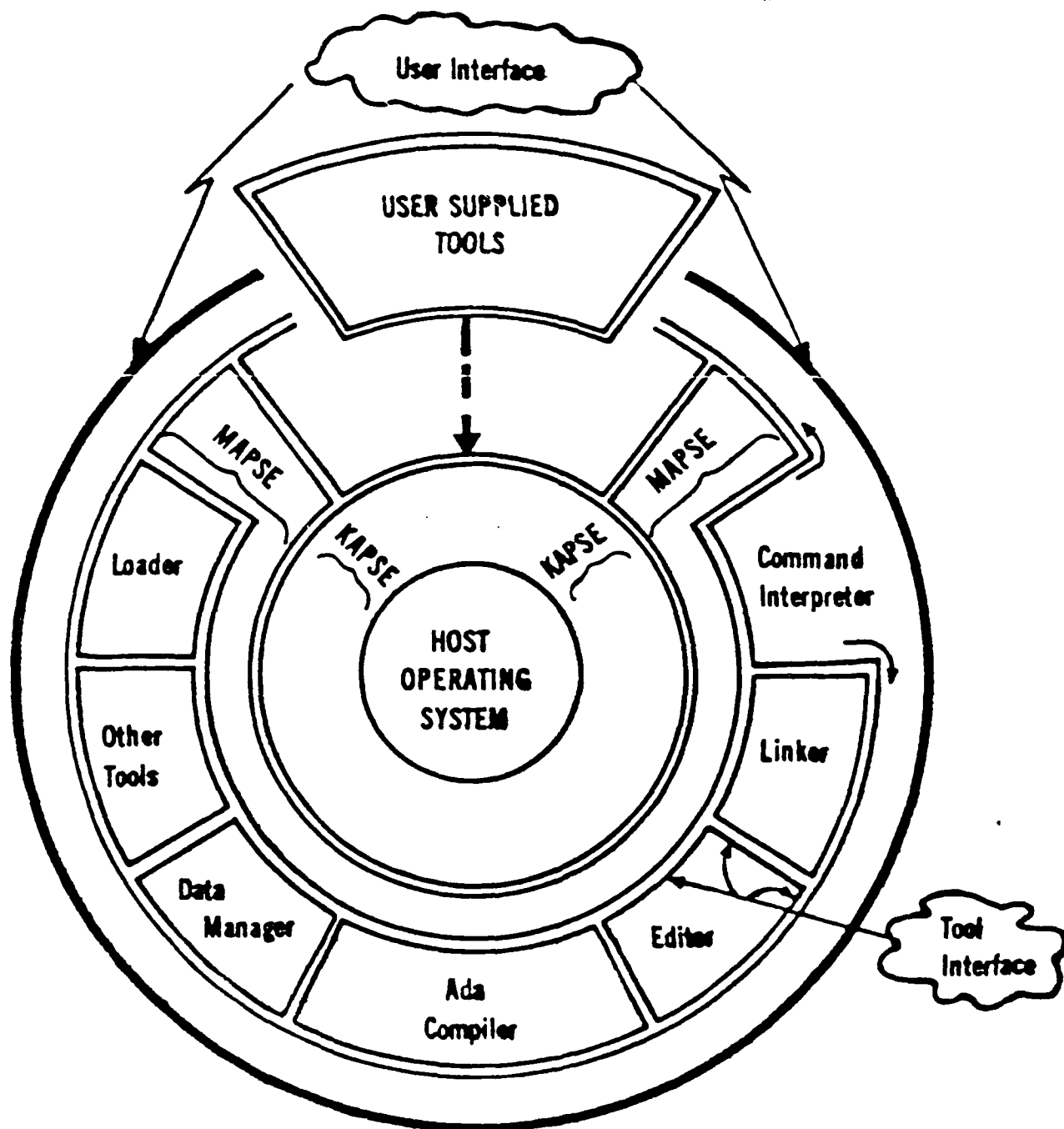
Ada Programming Support Environment

1978 SANDMAN

PEBBLEMAN

1980 STONEMAN

- Software developer productivity
- Retraining costs
- Lack of tools
- Lack of standardization



Software Crisis

"The basic problem is not our mismanagement of technology, but rather our inability to manage the complexity of our systems."

--- E.G. Booch

SOFTWARE ENGINEERING

GOALS

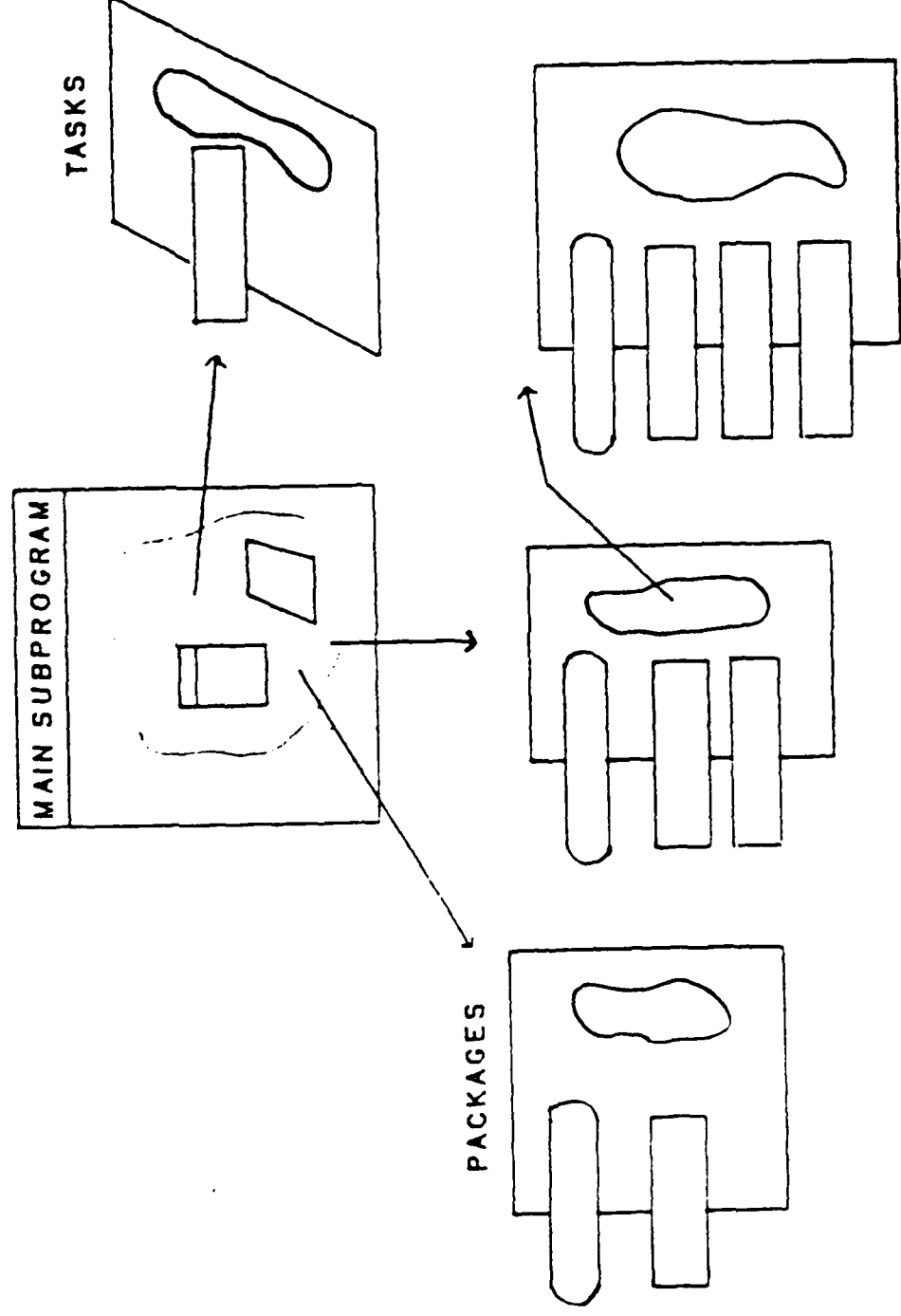
- Understandability
- Modifiability
- Reliability
- Efficiency

PRINCIPLES

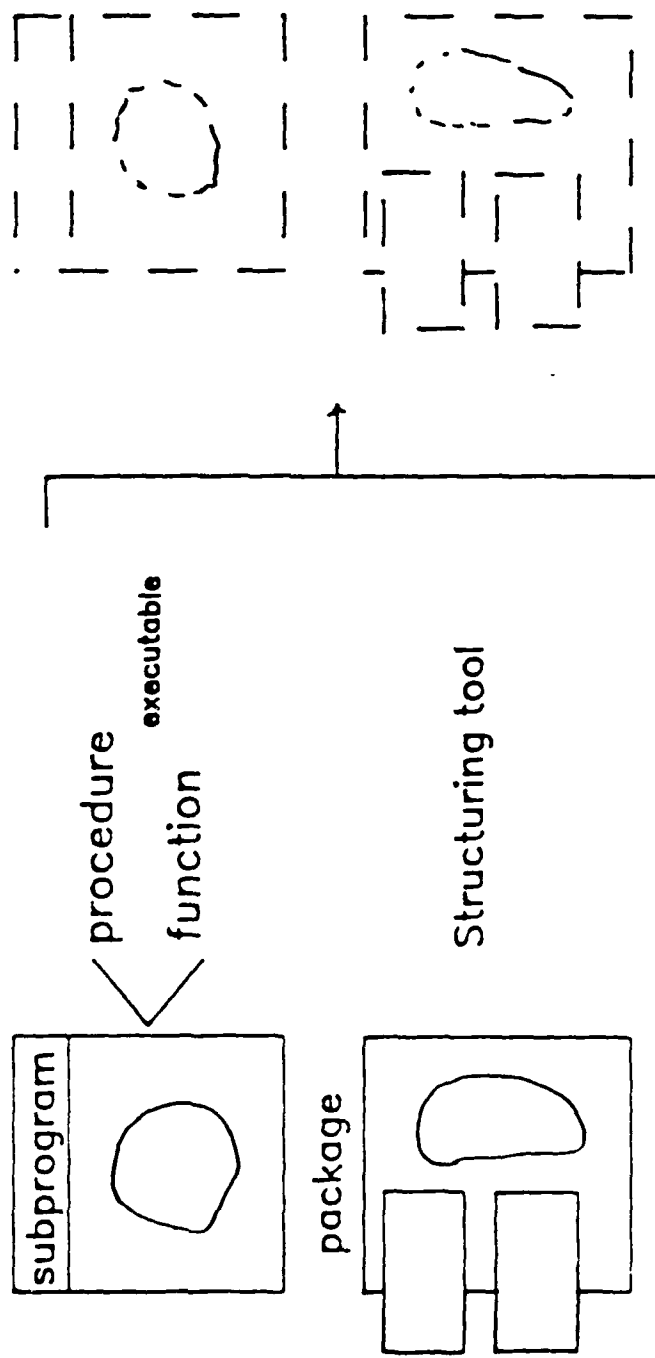
- Abstraction
- Information Hiding
- Modularity
- Localization
- Completeness
- Confirmability
- Consistency

Program Units

-- Ada software systems consist of one or more program units

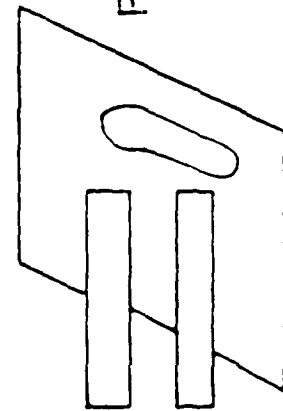


Program Units



Structuring tool

task

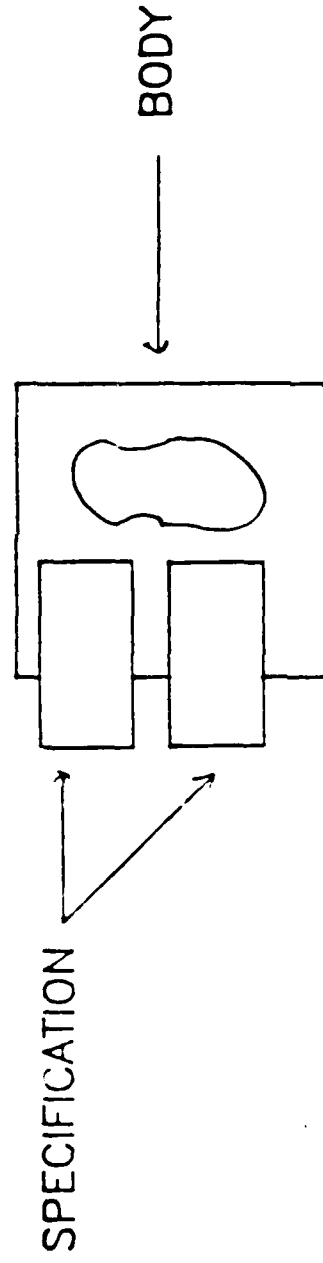


Parallel processing

Generic

Program unit
template

Program Units



"what" the program unit does $\longleftrightarrow$ ABSTRACTION $\Longrightarrow$ "how" the program unit does what it does

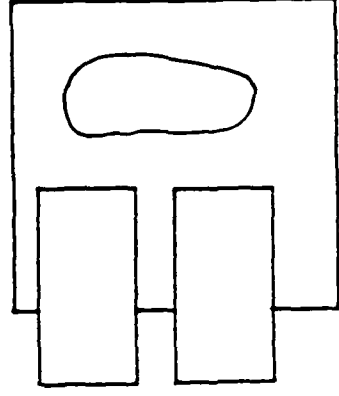
all the user of the program unit needs to know $\longleftrightarrow$ INFORMATION HIDING $\Longrightarrow$ the details of implementation are inaccessible to the user

Program Units

By separating the "what" from the "how"...



we decrease the complexity of the system...

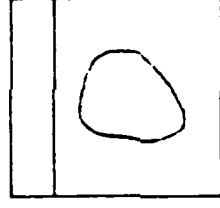


and increase: UNDERSTANDABILITY
MODIFIABILITY

Program Units

Subprograms

- Executable routines
- Main program
- Recursive



PROCEDURE

-- Defines an action to be performed

```
procedure GET_NAME ( NAME : out STRING );
```

```
    GET_NAME ( PERSONS_NAME );
```

FUNCTION

-- Returns a value

```
function SIN ( ANGLE : in RADIANS ) return FLOAT;
```

```
    ANGLE_SIN := SIN ( 2 );
```

Program Units

Procedures

SPECIFICATION

- Defines name
- Defines parameters to be passed

```
procedure ADD ( FIRST : in INTEGER;  
                SECOND : in INTEGER;  
                RESULT : out INTEGER );
```

FIRST	:	in	INTEGER
formal parameter name		parameter mode	parameter type

Program Units

Parameter modes

in — The value passed to the subprogram acts as a constant inside and may only be read. Value remains unchanged after completion.

in out — The variable passed to the procedure may be read and updated. Value may change after completion.

out — The variable passed to the procedure may only be updated. Value may change after completion

Program Units

procedures

BODY

- Defines the action to be performed
- Contains a local declarative part
- Contains a sequence of statements

```
procedure ADD ( FIRST : in INTEGER;  
               SECOND : in INTEGER;  
               RESULT : out INTEGER ) is  
    -- local declarations go here  
begin  
    RESULT := FIRST + SECOND;  
end ADD;
```

with ADD;
procedure SIMPLE_MATH is

VALUE_1, VALUE_2, VALUE_3 : INTEGER := 5;

begin

ADD (VALUE_1, 5, VALUE_2);
ADD (10, 20, VALUE_3);
ADD (VALUE_1, VALUE_2, VALUE_3);

end SIMPLE_MATH;

with TEXT_IO;
procedure SAY_HI is

```
MAX_NAME_LENGTH : constant := 80;  
subtype NAME_TYPE is STRING(1..MAX_NAME_LENGTH);  
YOUR_NAME : NAME_TYPE := (others => ' ');  
NAME_LENGTH : NATURAL := 0;
```

begin

```
TEXT_IO.PUT_LINE("What is your name? ");  
TEXT_IO.GET_LINE( YOUR_NAME, NAME_LENGTH );  
TEXT_IO.PUT( "Hi " );  
TEXT_IO.PUT_LINE( YOUR_NAME(1..NAME_LENGTH) );  
TEXT_IO.PUT_LINE( "Have a nice day!!");
```

end SAY_HI;

Program Units

procedure AN_EXAMPLE is

MY_INTEGER : INTEGER := 10;

TEMP : INTEGER := 0;

procedure NEXT (AN_INTEGER : in INTEGER;
VALUE : out INTEGER) is

begin

VALUE := AN_INTEGER + 1;

end NEXT;

begin

while MY_INTEGER <= 100 loop

NEXT(MY_INTEGER,TEMP);

MY_INTEGER := TEMP;

end loop;

end AN_EXAMPLE;

Program Units

Functions

SPECIFICATION

- Defines name
- Defines parameters to be passed
- Defines result type

```
function ADD ( FIRST, SECOND : in INTEGER )  
    return INTEGER;
```

- parameter mode can only be "in"
- called as an expression

Program Units

Functions

BODY

- Defines the action to be performed
- Contains a declarative part
- Contains a sequence of statements
- Result returned in a "return" statement

```
function ADD ( FIRST, SECOND : INTEGER )
```

```
    return INTEGER is
```

```
begin
```

```
    return FIRST + SECOND;
```

```
end ADD;
```

Program Units

Functions

procedure CALCULATIONS is

VALUE : INTEGER := 1;

function ADD_PREVIOUS (NUMBER : in INTEGER)
return INTEGER is

begin

return NUMBER + (NUMBER - 1);

end ADD_PREVIOUS;

begin

VALUE := ADD_PREVIOUS (5);

-- value equals 9

end CALCULATIONS;

procedure ADD_THEN is

type INDEX_TYPE is range 1 .. 3;

type REAL is digits 9;

type MATRIX_TYPE is array(INDEX_TYPE, INDEX_TYPE)
of REAL;

function "+" (LEFT, RIGHT : in MATRIX_TYPE)
return MATRIX_TYPE is separate;

FIRST, SECOND,

RESULT : MATRIX_TYPE := (others => 0.0);

begin

RESULT := FIRST + SECOND;

end ADD_THEN;

```

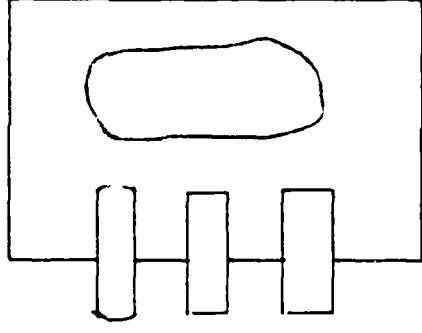
separate ( ADD_I THEM )
function "+" ( LEFT, RIGHT : in MATRIX_TYPE ) return
    MATRIX_TYPE is
    TEMP_MATRIX : MATRIX_TYPE := ( others => 0.0 );

begin
    for FIRST_INDEX in MATRIX_TYPE'RANGE(1) loop
        for SECOND_INDEX in MATRIX_TYPE'RANGE(2) loop
            TEMP_MATRIX(FIRST_INDEX, SECOND_INDEX ) :=
                LEFT(FIRST_INDEX,SECOND_INDEX) +
                RIGHT(FIRST_INDEX,SECOND_INDEX);
        end loop;
    end loop;
    return TEMP_MATRIX;
end "+";

```

Program Units

Packages



- Defines groups of logically related items
- Structuring tool
- Contains a visible part (specification) and a hidden part (private part and body)
- Primary means for extending the language

Program Units

Package specification

-- Define items available to user of package (export)

package CONSTANTS is

PI : constant := 3.14159;

e : constant := 2.71828;

WARP : constant := 3.00E+08;

-- meters/second

end CONSTANTS;

```
with CONSTANTS;  
procedure SOME_PROGRAM is
```

```
    MY_VALUE : FLOAT := 2 * CONSTANTS.PI;  
begin  
    null;  
end SOME_PROGRAM;
```

```
with CONSTANTS;  
procedure ANOTHER_PROGRAM is
```

```
    ANOTHER_VALUE : FLOAT := 2 * CONSTANTS.PI;  
begin  
    null;  
end ANOTHER_PROGRAM;
```

Program Units

```
package ROBOT_CONTROL is
    type SPEED is range 0..100;
    type DISTANCE is range 0..500;
    type DEGREES is range 0..359;
    procedure GO_FORWARD ( HOW_FAST : in SPEED;
                           HOW_FAR : in DISTANCE );
    procedure REVERSE ( HOW_FAST : in SPEED;
                       HOW_FAR : in DISTANCE );
    procedure TURN ( HOW_MUCH : in DEGREES );
end ROBOT_CONTROL;
```

with ROBOT_CONTROL;

procedure DO_A_SQUARE is
begin

ROBOT_CONTROL.GO_FORWARD(HOW_FAST => 100,
HOW_FAR => 20);

ROBOT_CONTROL.TURN(90);

ROBOT_CONTROL.GO_FORWARD(100, 20);

ROBOT_CONTROL.TURN(90);

ROBOT_CONTROL.GO_FORWARD(100, 20);

ROBOT_CONTROL.TURN(90);

ROBOT_CONTROL.GO_FORWARD(100, 20);

ROBOT_CONTROL.TURN (90);

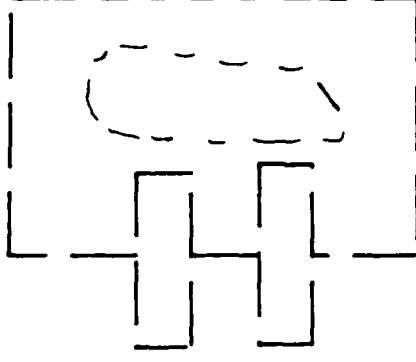
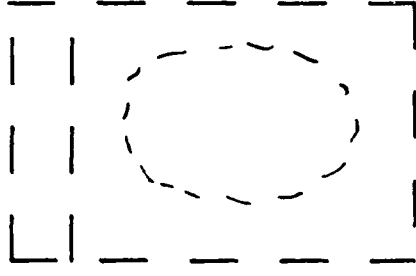
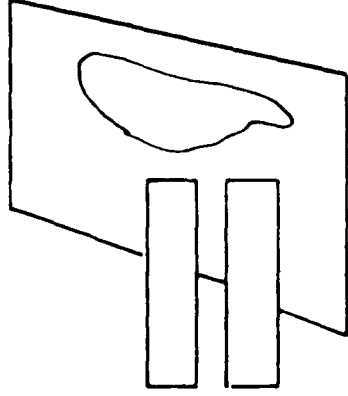
end DO_A_SQUARE;

Program Units

Package bodies

```
--Define local declarations
--Define implementation of subprograms
--- defined in specification
package body ROBOT_CONTROL is
    --local declarations
    procedure RESET_SYSTEM is
begin
    --implementation
    end RESET_SYSTEM;
    procedure GO_FORWARD...is...
    procedure REVERSE...is...
    procedure TURN...is...
end ROBOT_CONTROL;
```

Program Units



TASK

GENERIC

A program unit that operates in parallel with other program units

Template of a subprogram or package

Types

--A type consists of a set of values that
objects of the type may take on, and a
set of operations applicable to those values

--Ada is a strongly typed language!

- *Every object must be declared of some type name
- *Different type names may not be implicitly mixed
- *Operations on a type must preserve the type

```
AN_INTEGER : INTEGER;  
A_FLOAT_NUMBER : FLOAT;  
ANOTHER_FLOAT : FLOAT;
```

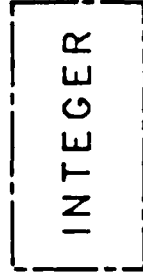
```
A_FLOAT_NUMBER := ANOTHER_FLOAT + AN_INTEGER;  
--illegal
```

Types

Types and Objects

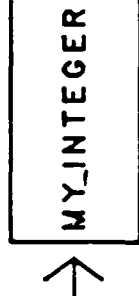
TYPES

Define a template
for objects



OBJECTS

Variables or constants
that are instances
of a type

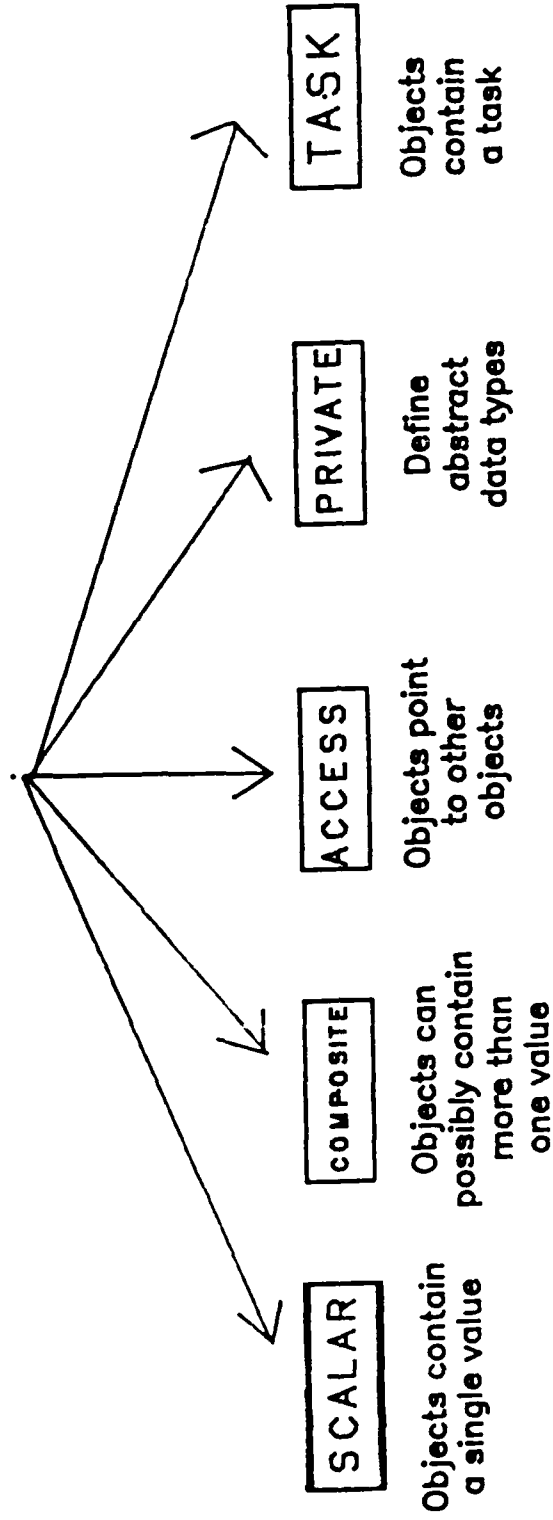


OBJECT DECLARATION

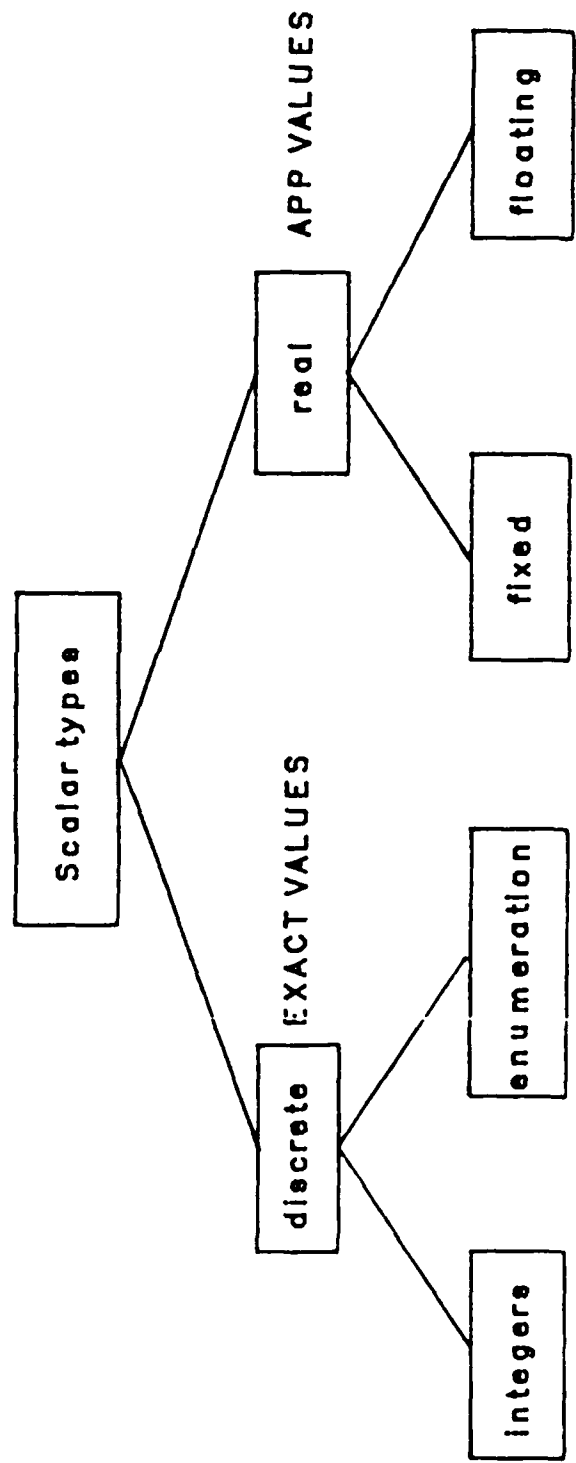
```
MY_INTEGER : INTEGER;
```

```
YOUR_INTEGER : INTEGER := 10;
```

Ada Types



Types



← USER DEFINED →

← PREDEFINED →

Types

Integers

--Define a set of exact, consecutive values

USER DEFINED

type ALTITUDE is range 0..100_000;

type DEPTH is range 0..20_000;

PLANES_HEIGHT : ALTITUDE;

DIVER_DEPTH : DEPTH;

begin

PLANES_HEIGHT := 10_000;

PLANES_HEIGHT := 200_000; -- error

PLANES_HEIGHT := DIVER_DEPTH; -- error

end;

Types

Predefined integer types

INTEGER----->(usually -32,768..32767)

"subtypes" of INTEGER

NATURAL(0..INTEGER'LAST)

POSITIVE(1..INTEGER'LAST)

LONG_INTEGER----->(usually double word)

SHORT_INTEGER----->(usually half word)

Types

Subtypes

- Constrain a range of values or accuracy on a type
- Does not define a new type ,i.e., compatible with base type

```
type ALTITUDE is range 0..200_000;  
subtype HIGH is ALTITUDE range 40_000 .. 200_000;  
subtype MEDIUM is ALTITUDE range 10_000 .. 100_000;  
subtype LOW is ALTITUDE range 0 .. 10_000;
```

Types

Enumeration

- Define a set of ordered enumeration values
- Used in array indexing, case statements,
- and looping

USER DEFINED

```
type SUIT is (CLUBS, HEARTS, DIAMONDS, SPADES);  
type COLOR is (RED, WHITE, BLUE);  
type SWITCH is (OFF, ON);  
type EVEN DIGITS is ('2','4','6','8');  
type MIXED is (ONE,'2',THREE,'*','!',more);
```

where CLUBS < HEARTS < DIAMONDS < SPADES

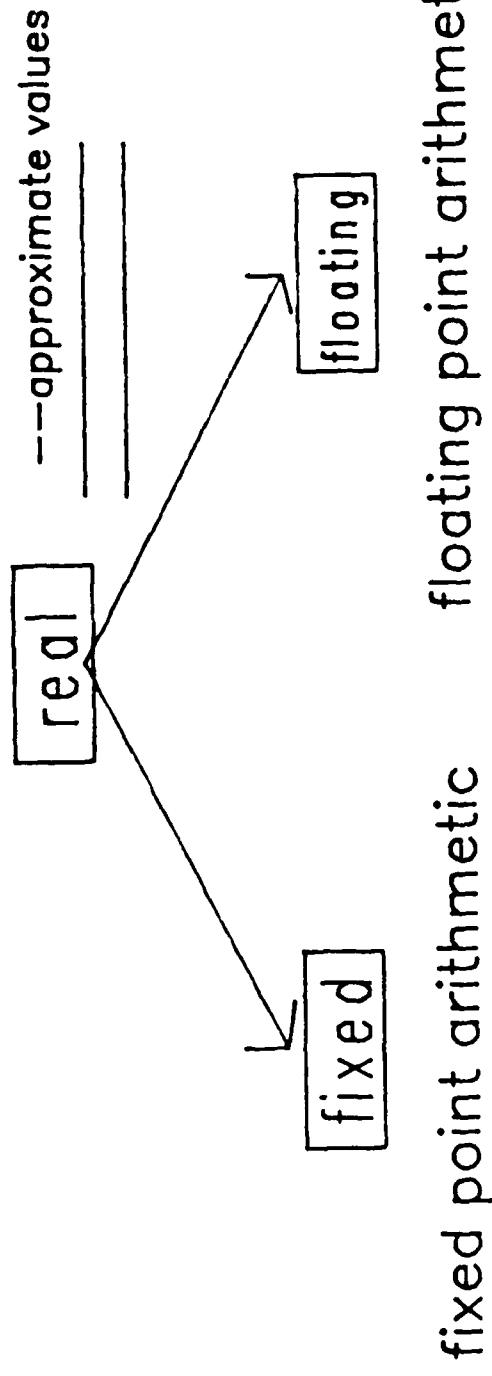
Types

Pre-defined enumeration types

BOOLEAN -----> (FALSE, TRUE)

CHARACTER

Types



Types

Fixed point types

- Absolute bound on error
- Larger error for smaller numbers (around zero)

USER DEFINED

type INCREMENT is delta 1.0/8 range 0.0 .. 1.0;

0, 1*2e-3, 2*2e-3, 4*2e-3, 5*2e-3,...

PREDEFINED

DURATION ---> (Used for "delay" statements)

Types

Floating point types

- Relative bound of error
- Defined in terms of significant digits
- More accurate at smaller numbers, less at larger

USER DEFINED

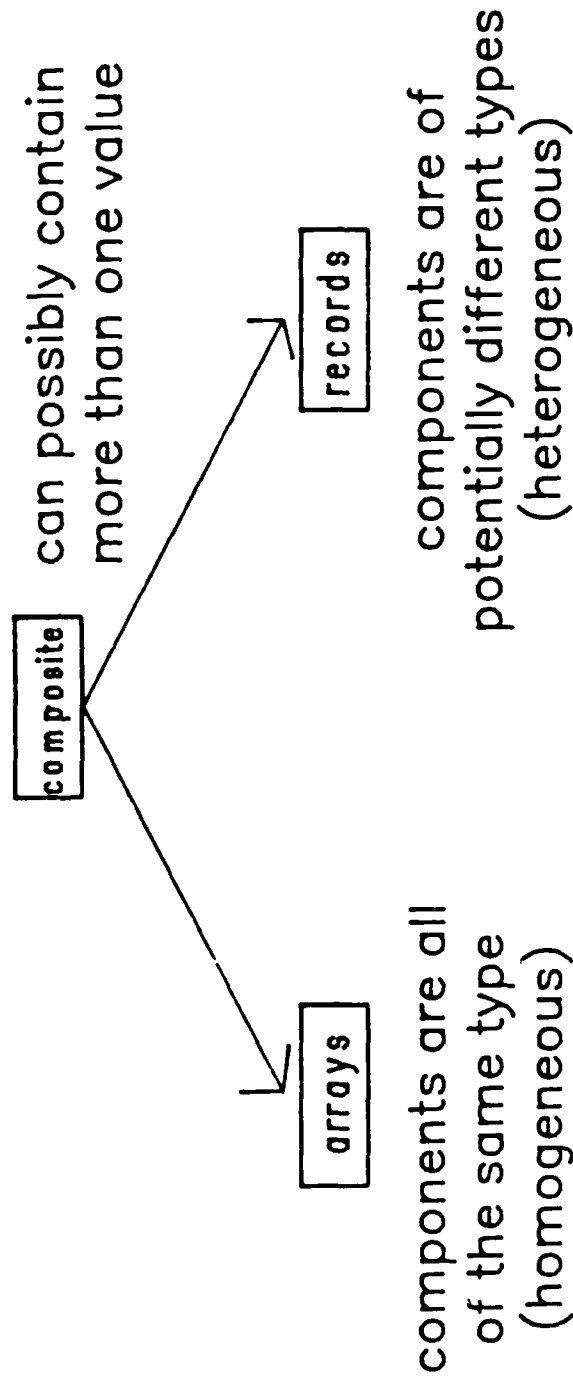
type NUMBERS is digits 3 range 0.0 .. 20_000;

0.001, 0.002, 0.003...9999.0, 1000.0, 1001.0..., 10000.0, 10100.0

PREDEFINED

FLOAT

Types



Types

Arrays

constrained

unconstrained

CONSTRAINED

```
-- Indices are static for all objects of that type  
  
type HOURS is range 0..40;  
type DAYS is ( SUN,MON,TUE,WED,THU,FRI,SAT );  
type WORK_HOURS is array( DAYS ) of HOURS;  
  
MY_HOURS : WORK_HOURS := ( 0,8,8,7,6,1,0 );
```

MY_HOURS(SUN)	MY_HOURS(MON)	MY_HOURS(TUE)	MY_HOURS(SAT)
0	8	8	0

Types

Arrays

UNCONSTRAINED

- Indices are known at elaboration (run) time
- Indices may be different for different objects

type HOURS is range 0..40;

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

type WORK_HOURS is array (DAYS range <>) of HOURS;

HOLIDAY_WEEK : WORK_HOURS (TUE..SAT) :=(others =>0);

FULL_WEEK : WORK_HOURS (DAYS'FIRST..DAYS'LAST);

Types

procedure DAYS_WORKED (FIRST,SECOND: in DAYS) is

 A_WEEK : WORK_HOURS (FIRST..SECOND);

begin

 .

 .

 .

DAYS_WORKED(WED,FRI);



DAYS_WORKED(FRI,SAT);



Types

Multi--dimensional arrays

```
type VALUES is digits 6 range -10.0 .. 100.0;
type INDEX is range 1..3;
type TWO_D_MATRIX is array (INDEX,INDEX) of VALUES;

MY_MATRIX : TWO_D_MATRIX := ( others => 0.0 );
IDENTITY_MATRIX : constant TWO_D_MATRIX := ( (1.0,0.0,0.0),
                                              (0.0,1.0,0.0),
                                              (0.0,0.0,1.0));
```

begin

```
MY_MATRIX := IDENTITY_MATRIX;
MY_MATRIX (3,3) := 2.0;
```

.
. .
.

Types

Array

PREDEFINED

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

USE OF THE PREDEFINED STRING TYPE

YOUR_STRING : STRING (1..10);

MY_STRING : STRING (1..20);

THEIR_STRING : STRING; -- illegal

STRING SLICING

YOUR_STRING := MY_STRING(1..10);

MY_STRING(11..15) := YOUR_STRING(2..6);

MY_STRING(3..4) := MY_STRING(4..5);

MY_STRING(2) := 'G';

MY_STRING(2) := "G"; -- illegal

Types

Records

undiscriminated
discriminated
variant

UNDISCRIMINATED

type DAYS is (MON,TUE,WED,THU,FRI,SAT,SUN);
type DAY is range 1..31;
type MONTH is (JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,
SEP,OCT,NOV,DEC);

type YEAR is range 0..2085;

type DATE is record

DAY_OF_WEEK : DAYS;

DAY_NUMBER : DAY;

MONTH_NAME : MONTH;

YEAR_NUMBER : YEAR;

end record;

TODAY : DATE;

begin

TODAY.DAY_OF_WEEK := TUE;

TODAY.DAY_NUMBER := 26;

TODAY.MONTH_NAME := NOV;

TODAY

DAY_OF_WEEK	TUE
DAY_NUMBER	26
MONTH_NAME	NOV
YEAR_NUMBER	1985

Types

Records

```
type A_MONTH is array (DAY range <>) of DATE;  
NOVEMBER: A_MONTH(1..30);
```

```
begin
```

```
    NOVEMBER(26).DAY_OF_WEEK := TUE;  
    NOVEMBER(27) := (WED,27,NOV,1985);
```

Types

Records

DISCRIMINATED

```
type BUFFER(SIZE:POSITIVE := 10) is record
    ITEMS : STRING(1..SIZE);
end record;
```

```
MY_BUFFER : BUFFER; -- size is 10;
YOUR_BUFFER : BUFFER (20);
THEIR_BUFFER : BUFFER (SIZE => 15);
```

```
begin
    MY_BUFFER.ITEMS := "Hi There!!";
```

Types

Records

VARIANT

```
type DRIVER is (GOOD,BAD);
type INSURANCE_RATE is range 1..50;
type DISCOUNT is delta 0.01 range 0.0..1.0;
type INSURANCE (KIND:DRIVER) is record
    NORMAL_RATE : INSURANCE_RATE;
    case KIND is
        when GOOD => DISCOUNT_RATE : DISCOUNT ;
        when BAD => ADDITIONAL : INSURANCE_RATE;
    end case;
end record;
```

Types

Records

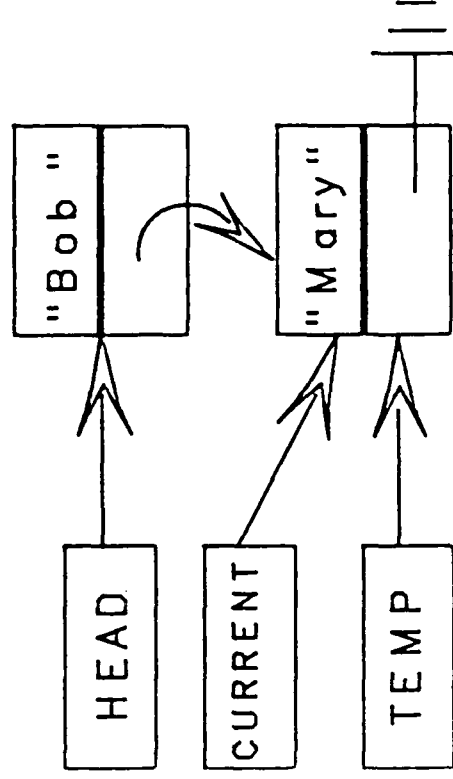
VARIANT

```
type DRIVER is (GOOD,BAD);
type INSURANCE_RATE is range 1..50;
type DISCOUNT is delta 0.01 range 0.0..1.0;
type INSURANCE (KIND:DRIVER) is record
    NORMAL_RATE : INSURANCE_RATE;
    case KIND is
        when GOOD => DISCOUNT_RATE : DISCOUNT ;
        when BAD => ADDITIONAL : INSURANCE_RATE;
    end case;
end record;
```

Types

Access types— Linked list

--Move current pointer
CURRENT := TEMP;

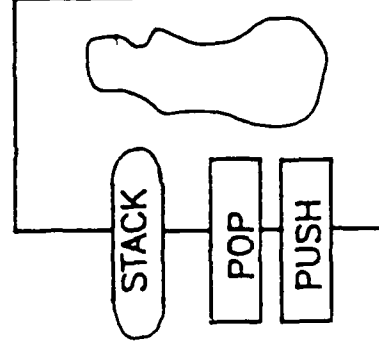


Types

Private types

- Defined in a package
- Used to create abstract data types
- Used to extend the language
- Directly supports abstraction and
- Information hiding

INTEGER_STACK



PRIVATE

$:=$ $=$ $/=$

subprograms defined in
package specification

LIMITED PRIVATE

only subprograms
defined in
package specification

Types

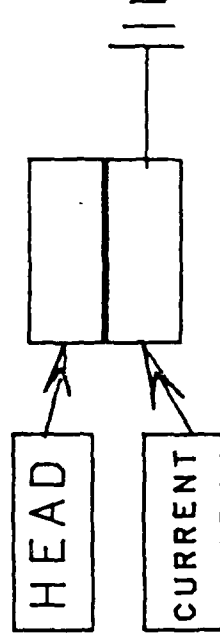
Access types – Linked list

```
procedure LINKED LIST is
  type ITEM; -- incomplete type declaration
  type POINTER is access ITEM;
  type ITEM is record
    NAME: STRING(1..20):=(others => '');
    NEXT : POINTER;
  end record;
```

```
HEAD,CURRENT,TEMP:POINTER; --initialized to null

begin
```

```
HEAD:=new ITEM;
CURRENT:=HEAD;
```



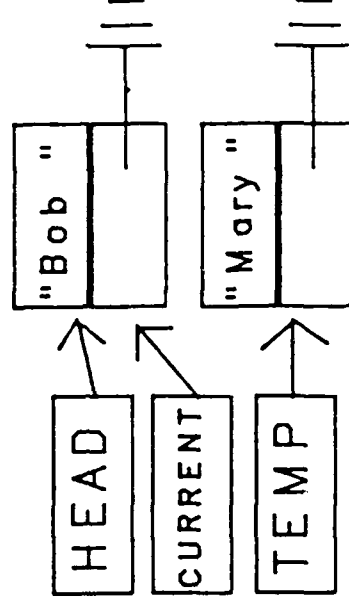
```
CURRENT.NAME(1..3):= "Bob";
```

Types

Access types – Linked list

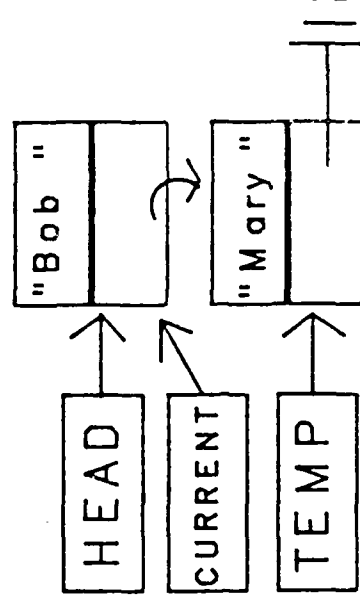
Create a New Item

```
TEMP := new ITEM;  
TEMP.NAME(1..4) := "MARY";
```



Add to List

```
CURRENT.NEXT := TEMP;
```



package BASKIN_ROBBINS is

type NUMBERS is range 0 .. 99;

procedure TAKE(A_NUMBER : out NUMBERS);

procedure NOW_SERVING return NUMBERS;

procedure SERVE(A_NUMBER : in NUMBERS);

end BASKIN_ROBBINS;

with BASKIN_ROBBINS;

procedure GET_ICE_CREAM is

YOUR_NUMBER : BASKIN_ROBBINS.NUMBERS;

begin

BASKIN_ROBBINS.TAKE(YOUR_NUMBER);

loop

if BASKIN_ROBBINS."="(BASKIN_ROBBINS.NOW_SERVING,
YOUR_NUMBER);

BASKIN_ROBBINS.SERVE(YOUR_NUMBER);

exit;

end if;

end loop;

end GET_ICE_CREAM;

with BASKIN_ROBBINS; use BASKIN_ROBBINS;
procedure GET_ICE_CREAM is

YOUR_NUMBER : BASKIN_ROBBINS.NUMBERS;

begin

BASKIN_ROBBINS.TAKE(YOUR_NUMBER);

loop

if BASKIN_ROBBINS.NOW_SERVING = YOUR_NUMBER then
 BASKIN_ROBBINS.SERVE(YOUR_NUMBER);
 exit;

else

YOUR_NUMBER := YOUR_NUMBER - 1;

end if;

end loop;

end GET_ICE_CREAM;

package BASKIN_ROBBINS is

type NUMBERS is private;

procedure TAKE(A_NUMBER : out NUMBERS);

procedure NOW_SERVING return NUMBERS;

procedure SERVE(A_NUMBER : in NUMBERS);

private

type NUMBERS is range 0 .. 99;

end BASKIN_ROBBINS;

with BASKIN_ROBBINS; use BASKIN_ROBBINS;
procedure GET_ICE_CREAM is

YOUR_NUMBER : BASKIN_ROBBINS.NUMBERS;

begin

BASKIN_ROBBINS.TAKE(YOUR_NUMBER);

loop

if BASKIN_ROBBINS.NOW_SERVING = YOUR_NUMBER then
 BASKIN_ROBBINS.SERVE(YOUR_NUMBER);
 exit;
else

 YOUR_NUMBER := BASKIN_ROBBINS.NOW_SERVING;

end if;

end loop;

end GET_ICE_CREAM;

```
package BASKIN_ROBBINS is

    type NUMBERS is limited private;

    procedure TAKE( A_NUMBER : out NUMBERS );

    procedure NOW_SERVING return NUMBERS;

    procedure SERVE( A_NUMBER : in NUMBERS );

    function "="( LEFT, RIGHT : NUMBERS) return BOOLEAN;

private

    type NUMBERS is range 0 .. 99;

end BASKIN_ROBBINS;
```

```
with BASKIN_ROBBINS; use BASKIN_ROBBINS;  
procedure GET_ICE_CREAM is  
  YOUR_NUMBER : BASKIN_ROBBINS.NUMBERS;  
  procedure GO_TO_DAIRY_QUEEN is separate;  
begin  
  BASKIN_ROBBINS.TAKE( YOUR_NUMBER );  
  loop  
    if BASKIN_ROBBINS.NOW_SERVING = YOUR_NUMBER then  
      BASKIN_ROBBINS.SERVE( YOUR_NUMBER );  
      exit;  
    else  
      GO_TO_DAIRY_QUEEN;  
      exit;  
    end if;  
  end loop;  
end GET_ICE_CREAM;
```

Types

Private types

```
package INTEGER_STACK is
  type STACK is limited private;
  procedure POP ( ITEM : out INTEGER;
                 OFF_OF:in out STACK);
  procedure PUSH (ITEM: in INTEGER;
                  ON: in out STACK);
private
  --Define what a stack looks like
end INTEGER_STACK;
```

Types

Private types

```
with INTEGER_STACK;  
use INTEGER_STACK;  
procedure STACK_THEM is  
    MY_STACK, YOUR_STACK: STACK;  
    AN_ITEM: INTEGER  
begin  
    PUSH (ITEM=>20, ON=>MY_STACK);  
    PUSH (ITEM=>30, ON=>YOUR_STACK);  
    PUSH (40, ON=>MY_STACK);  
    .  
    .  
    POP (AN_ITEM, OFF_OF=>MY_STACK);  
    --AN_ITEM = 40  
end STACK_THEM;
```

Control Statements

SEQUENTIAL -----	CONDITIONAL -----	ITERATIVE -----
ASSIGNMENT	IF	LOOP
PROCEDURE CALL	CASE	
RETURN		
NULL		
BLOCK		
TASKING -----	OTHERS -----	
ENTRY CALL	GOTO	
DELAY	RAISE	
ABORT	CODE	
ACCEPT		
SELECT		

Control Statements

Sequential

ASSIGNMENT

-- Replaces variable on left with expression on right
AN_INTEGER := (5*2) + 34;

PROCEDURE CALL

-- Executes a procedure
POP (AN_INTEGER, OFF_OF => MY_STACK);

NULL

-- Explicitly does nothing
null;

Control Statements

Sequential

RETURN

-- Causes control to be passed back to the caller
of a subprogram

For a procedure...

procedure A_PROCEDURE is

 AN_INTEGER : INTEGER;

begin

 AN_INTEGER := 5;

 return;

 null; -- never gets executed

end A_PROCEDURE;

Control Statements

Sequential

RETURN

-- For a function, returns a value

```
function IS_GREATER ( FIRST, SECOND : in INTEGER )  
    return BOOLEAN;
```

begin

```
    return ( FIRST > SECOND );  
end IS_GREATER;
```

-- Every function must have at least one
return statement

Control Statements

Sequential

BLOCK

-- Used to localize declarations and/or effects

procedure MAIN_PROGRAM is

 VARIABLE : FLOAT;

begin

 -- some statements

declare

 LOCAL_VARIABLE : FLOAT;

begin

 LOCAL_VARIABLE := 4.0;

 VARIABLE := 70.0;

end;

 VARIABLE := 10.0;

end MAIN_PROGRAM;

Control Statements

Conditional

IF

```
if MY_VALUE = 27 then  
  HIS_VALUE := 21;  
  THEIR_VALUE := 22;  
end if;
```

```
if MACHINE_IS_RUNNING then  
  SET_NEW_SPEED ( 47 );  
else  
  COUNT_TIME_DOWN ( CURRENT_TIME );  
end if;
```

Control Statements

Conditional

IF

```
if MACHINE_IS_RUNNING then
    SET_NEW_SPEED ( 47 );
elseif MACHINE_IS_IDLE then
    START_MACHINE_UP;
else
    COUNT_TIME_DOWN ( CURRENT_TIME );
end if;
```

Control Statements

Conditional

```
type DAY_TIMES is ( EARLY_AM,MID_AM,LUNCH,AFTERNOON,  
                    LATE_AFTERNOON,DINNER,EVENING,NIGHT );
```

```
TIME : DAY_TIMES := AFTERNOON;
```

```
begin
```

```
  if TIME = EARLY_AM then
```

```
    DRINK_COFFEE;
```

```
  elsif TIME = MID_AM then
```

```
    DRINK_COFFEE;
```

```
  elsif TIME = LUNCH then
```

```
    GO_EAT;
```

```
  elsif TIME = AFTERNOON then
```

```
    STAY_AWAKE;
```

```
  elsif TIME = LATE_AFTERNOON then
```

```
    GET_READY_TO_GO_HOME;
```

```
  else
```

```
    GET_READY_FOR_TOMMORROW;
```

```
  end if;
```

```
end;
```

Control Statements

Conditional

CASE

```
case TIME is
  when EARLY_AM | MID_AM => DRINK_COFFEE;
  when LUNCH => GO_EAT;
  when AFTERNOON => STAY_AWAKE;
  when LATE_AFTERNOON => GET_READY_TO_GO_HOME;
  when others => GET_READY_FOR_TOMMORROW;

end case;
```

Control Statements

Iterative

BASIC LOOP

```
loop
  -- statements
end loop;
```

EXIT STATEMENT

```
loop
  if X = 20 then
    exit;
  end if;
end loop;
```

```
loop
  if X = 20 then
    exit;
  end if;
end loop;
end loop;
end loop;
```

Control Statements

Iterative

OUTER:
loop

INNER:
loop
if $X = 20$ then
 exit OUTER;
end if;
exit INNER when $X = 21$;
 $X := X + 2$;
end loop INNER;
end loop OUTER;

Control Statements

Iterative

FOR LOOP ITERATION SCHEME

```
with TEXT_IO; use TEXT_IO;
procedure PRINT_ALL_VALUES is
type COLORS is ( RED, WHITE, BLUE );
package COLOR_IO is new ENUMERATION_IO ( COLORS );
use COLOR_IO;

begin
  for INDEX in 1..5 loop
    null;
  end loop;

  for A_COLOR in COLORS loop
    PUT ( A_COLOR );
    NEW_LINE;
  end loop;
end PRINT_ALL_VALUES;
```

Control Statements

Iterative

```
for MY_INDEX in 20..40 loop
  -- some statements
end loop;
```

```
for YOUR_INDEX in reverse 20..40 loop
  -- some statements
end loop;
```

Control Statements

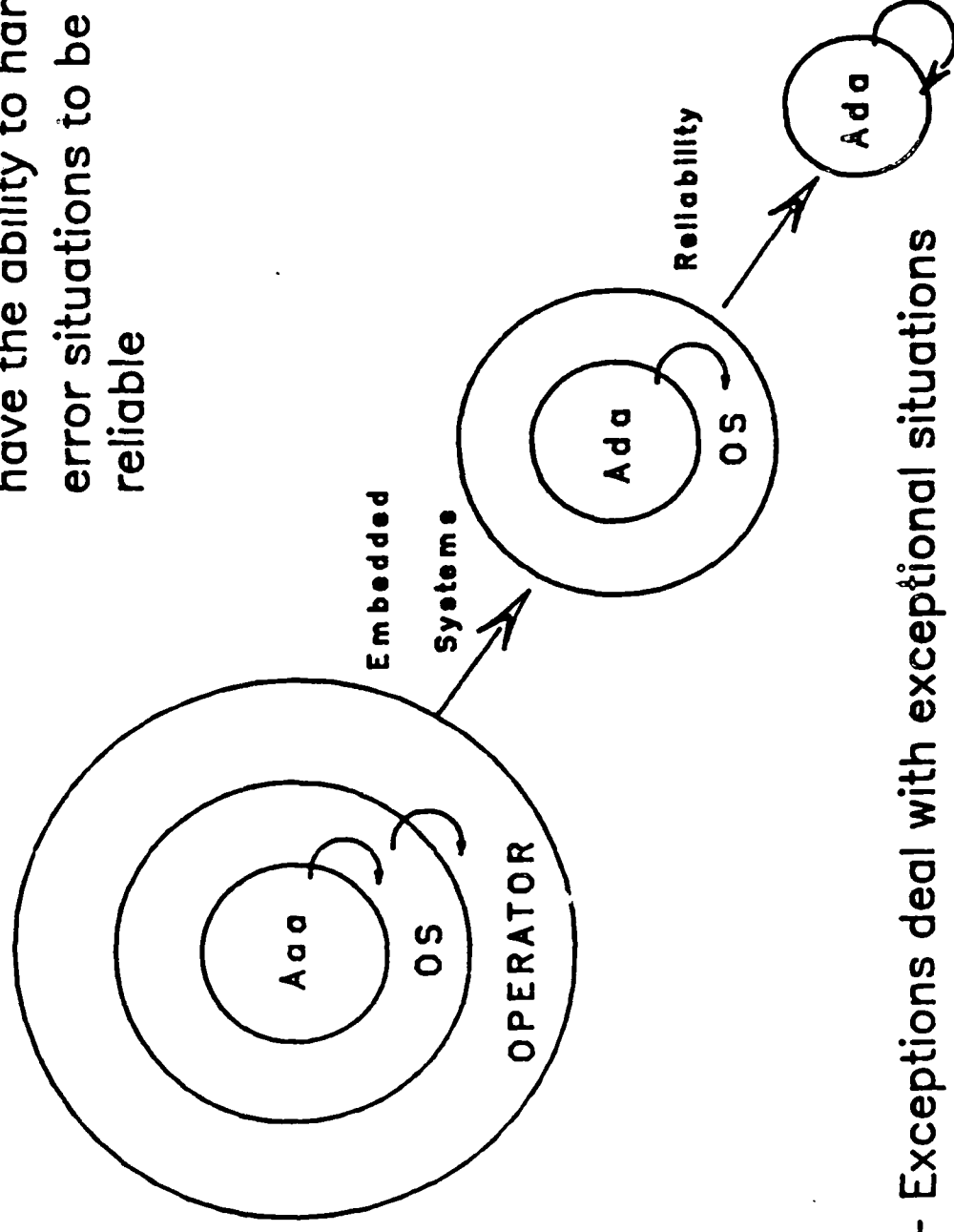
Iterative

WHILE LOOP ITERATION SCHEME

```
while NOT_DARK loop
    PLAY_TENNIS;
end loop;
TURN_ON_LIGHTS;
```

Exceptions

- Real time systems must have the ability to handle error situations to be reliable



- Exceptions deal with exceptional situations

Exceptions

```
with TEXT_IO; use TEXT_IO;
procedure GET_NUMBERS is
type NUMBERS is range 1..100;
package NUM_IO is new INTEGER_IO ( NUMBERS );
use NUM_IO;
A_NUMBER : NUMBERS;
begin
loop
GET ( A_NUMBER );
NEW_LINE;
PUT("The number is ");
PUT ( A_NUMBER );
NEW_LINE;
end loop;
exception
when DATA_ERROR => PUT_LINE("That was a bad number");
end GET_NUMBERS;
```

Exceptions

- When an exception situation occurs, the exception is said to be "raised"
- What happens then, depends on the presence or absence of an exception handler

```
begin
  loop
    GET ( A_NUMBER );
    NEW_LINE;
    PUT("The number is");
    PUT ( A_NUMBER );
    NEW_LINE;
  end loop;
end GET_NUMBERS;
```

Exceptions

```
begin
loop
begin
  GET ( A_NUMBER );
  NEW_LINE;
  PUT ( "The number is " );
  PUT ( A_NUMBER );
  NEW_LINE;
exception
  when DATA_ERROR => PUT_LINE("Bad number, try again");
end;
end loop;
end GET_NUMBERS;
```

Exceptions

USER DEFINED

PREDEFINED

STACK_OVERFLOW : exception;

BAD_INPUT : exception;

DEAD_SENSOR : exception;

CONSTRAINT_ERROR

NUMERIC_ERROR

PROGRAM_ERROR

STORAGE_ERROR

TASKING_ERROR

I/O EXCEPTIONS

STATUS_ERROR

MODE_ERROR

NAME_ERROR

USE_ERROR

DEVICE_ERROR

END_ERROR

DATA_ERROR

package SIMPLE_STACK is

type STACK_TYPE is limited private;
subtype ELEMENT_TYPE is CHARACTER;

procedure PUSH (AVALUE : in ELEMENT_TYPE;
 STACK : in out STACK_TYPE);

procedure POP (AVALUE : out ELEMENT_TYPE;
 STACK : in out STACK_TYPE);

STACK_OVERFLOW, STACK_UNDERFLOW : exception;

private

type STACK_ITEM;
type STACK_TYPE is access STACK_ITEM;
type STACK_ITEM is record
 VALUE : ELEMENT_TYPE;
 NEXT : STACK_TYPE;
end record;

end SIMPLE_STACK;

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TUTORIAL TRACK I INTRODUCTION TO ADA(U) INFORMATION
SYSTEMS AND TECHNOLOGY CENTER W-P AFB OH ADA VALIDATION
FACILITY C ENGLE ET AL 89 JUN 87

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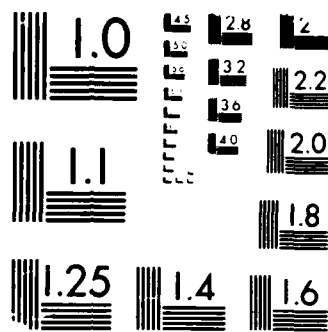
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[illegible]



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

separate (SIMPLE_STACK)
procedure POP (A_VALUE : out ELEMENT_TYPE;
 A_STACK : in out STACK_TYPE) is

begin

 A_VALUE := A_STACK.VALUE;
 A_STACK := A_STACK.NEXT;

exception

 when CONSTRAINT_ERROR =>
 raise STACK_UNDERFLOW;

end POP;

separate (SIMPLE_STACK)
procedure PUSH (A_VALUE : in ELEMENT_TYPE;
 A_STACK : in out STACK_TYPE) is

TEMP_ITEM : STACK_TYPE;

begin

TEMP_ITEM := new STACK_TYPE;
TEMP_ITEM.NEXT := A_STACK;
TEMP_ITEM.VALUE := A_VALUE;
A_STACK := TEMP_ITEM;

exception

when STORAGE_ERROR =>
 raise STACK_OVERFLOW;

end PUSH;

with TEXT_IO, SIMPLE_STACK;
procedure STACK_USER is

package COUNT_IO is new TEXT_IO.INTEGER_IO(LONG_INTEGER);

MY_STACK : SIMPLE_STACK.STACK_TYPE;
COUNTER : LONG_INTEGER := 0;

begin

loop

SIMPLE_STACK.PUSH('a', MY_STACK);
COUNTER := COUNTER + 1;

end loop;

exception

when SIMPLE_STACK.STACK_OVERFLOW =>
TEXT_IO.PUT("Pushed");
COUNT_IO.PUT(COUNTER);
TEXT_IO.PUT_LINE(" times");

end STACK_USER;

Generics

Parameterized Program Unit
subprograms
packages

Cannot be called

Must be instantiated

Generics

Data Objects

- To define the template: use type declaration
- To define an instance: use object declaration

Generic program units

- To define the template: use generic declaration
- To define an instance: use generic instantiation

Generics

Generics Provide:

- factorization
- reduction in size of program text
- more compact code
- no unnecessary duplication of source
- maintainability
- readability
- efficiency

Generics

procedure INTEGER_SWAP (FIRST_INTEGER, SECOND_INTEGER:
in out INTEGER) is

TEMP : INTEGER;

begin

```
TEMP      := FIRST_INTEGER;  
FIRST_INTEGER := SECOND_INTEGER;  
SECOND_INTEGER := TEMP;
```

end INTEGER_SWAP;

Generics

generic

type ELEMENT is private;

procedure SWAP (ITEM_1,ITEM_2:in out ELEMENT);

procedure SWAP(ITEM_1,ITEM_2:in out ELEMENT) is

TEMP:ELEMENT;

begin

TEMP := ITEM_1;

ITEM_1 := ITEM_2;

ITEM_2 := TEMP;

end SWAP;

Generics

with SWAP;

procedure EXAMPLE is

 procedure INTEGER_SWAP is new SWAP(INTEGER);

 procedure CHARACTER_SWAP is new SWAP(CHARACTER);

 NUM_1, NUM_2 : INTEGER;

 CHAR_1, CHAR_2 : CHARACTER;

begin

 NUM_1 := 10;

 NUM_2 := 25;

 INTEGER_SWAP(NUM_1, NUM_2);

 CHAR_1 := 'A';

 CHAR_2 := 'S';

 CHARACTER_SWAP(CHAR_1, CHAR_2);

end EXAMPLE;

Generics

```
generic
  type DISCRETE_TYPE is (<>);
function NEXT(VALUE : in DISCRETE_TYPE)
  return DISCRETE_TYPE;
function NEXT(VALUE : in DISCRETE_TYPE)
  return DISCRETE_TYPE is
begin
  if VALUE = DISCRETE_TYPE'LAST then
    return DISCRETE_TYPE'FIRST
  else
    return DISCRETE_TYPE'SUCC(VALUE);
  end if;
end NEXT;
```

Generics

```
with NEXT;
with TEXT_IO; use TEXT_IO;
procedure MAIN_DRIVER is

  type DAYS is (MON, TUE, WED, THUR, FRI, SAT, SUN);
  TODAY, TOMORROW : DAYS;
  package DAYS_IO is new ENUMERATION_IO (DAYS);
  function DAY_AFTER is new NEXT (DAYS);

begin
  PUT ("Enter the day: ");
  DAYS_IO.GET (TODAY);
  TOMORROW := DAY_AFTER (TODAY);
  PUT ("Tomorrow is: ");
  DAYS_IO.PUT (TOMORROW);

end MAIN_DRIVER;
```

Generics

```
with NEXT;
with TEXT_IO; use TEXT_IO;
procedure MAIN_DRIVER_2 is

    type HOUR is range 1..12;
    THIS_HOUR, NEXT_HOUR : HOUR;
    package HOUR_JO is new ENUMERATION_JO (HOUR);
    function HOUR_AFTER is new NEXT (HOUR);

begin

    PUT ("The current hour is: ");
    HOUR_JO.GET (THIS_HOUR);
    NEXT_HOUR := HOUR_AFTER(THIS_HOUR);
    PUT ("Next hour is: ");
    HOUR_JO.PUT (NEXT_HOUR);

end MAIN_DRIVER_2;
```

Generics

generic

SIZE: in POSITIVE;
type ELEMENT is private;

package STACK is

STACK_UNDERFLOW,
STACK_OVERFLOW : exception;
procedure PUSH (ITEM:in ELEMENT);
procedure POP (ITEM:in out ELEMENT);

end STACK;

Generics

package body STACK is

SPACE: array (1..SIZE) of ELEMENT;

TOP: INTEGER range 0..SIZE:= 0;

procedure PUSH(ITEM:in ELEMENT)is

begin

if TOP = SIZE then

raise STACK_OVERFLOW;

end if;

TOP := TOP +1;

SPACE(TOP) := ITEM;

end PUSH;

procedure POP(ITEM:in out ELEMENT) is

begin

if TOP = 0 then

raise STACK_UNDERFLOW;

end if;

ITEM := SPACE(TOP);

TOP := TOP -1;

end POP;

end STACK;

Generics

```
with STACK;
with TEXT_IO; use TEXT_IO;
procedure STACK_OPS is

    package INT_IO is new INTEGER_IO (POSITIVE);
    use INT_IO;
    INT_ELEMENT : POSITIVE;
    STACK_SIZE : POSITIVE := 50;
    package INTEGER_STACK is new STACK
        (STACK_SIZE, POSITIVE);
    use INTEGER_STACK;
begin
    PUT ("Enter an element to push on the stack: ");
    GET (INT_ELEMENT);
    PUSH (INT_ELEMENT);
    POP (INT_ELEMENT);
    PUT ("The element popped off the stack was: ");
    PUT (INT_ELEMENT);
```

Generics

```
with STACK, TEXTJO; use TEXTJO;
procedure STACK_OPS_2 is

    STACK_SIZE : POSITIVE := 50;
    INT_ELEMENT : POSITIVE;
    FLOAT_ELEMENT : FLOAT;

    package INTJO is new INTEGERJO (POSITIVE);
    package REALJO is new FLOATJO (FLOAT);
    package INT_STACK is new STACK (STACK_SIZE, POSITIVE);
    package FLOAT_STACK is new STACK (100, FLOAT);

    use INTJO, REALJO, INT_STACK, FLOAT_STACK;

begin

    PUT ("Enter a positive element to push on the stack: ");
    GET (INT_ELEMENT);
    PUSH (INT_ELEMENT);

    PUT ("Enter a FLOAT element to push on the stack: ");
    GET (FLOAT_ELEMENT);
    PUSH (FLOAT_ELEMENT);

end STACK_OPS_2;
```

Generics

generic

type ELEM is private;

with function "*" (LEFT, RIGHT : ELEM)

return ELEM is < >;

function SQUARING (X : ELEM) return ELEM;

function SQUARING (X : ELEM) return ELEM is

begin

return X * X;

end SQUARING;

Generics

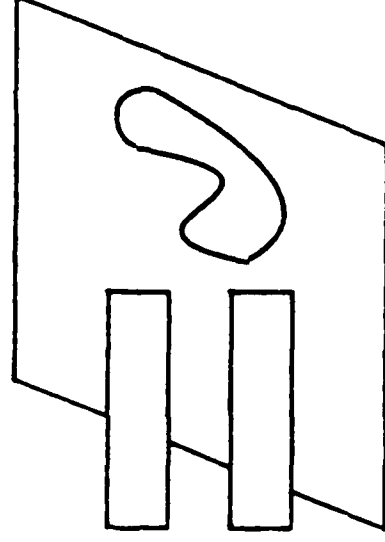
```
with SQUARING;  
procedure MATH_PROGRAM is  
  
    function SQUARE is new SQUARING (INTEGER);  
    X : INTEGER := 8;  
  
begin  
  
    X := SQUARE (X);  
  
end MATH_PROGRAM;
```

Generics

```
with SQUARING;  
procedure MATH_PROGRAM_2 is  
  type MATRIX is array (1..3, 1..3) of INTEGER;  
  A_MATRIX : MATRIX :=  
    (others => (others => 2));  
  function MULT (LEFT, RIGHT : MATRIX) return  
    MATRIX is separate;  
  function SQUARE_A_MATRIX is new SQUARING  
    (MATRIX, MULT);  
begin  
  A_MATRIX := SQUARE_A_MATRIX (A_MATRIX);  
end MATH_PROGRAM_2;
```

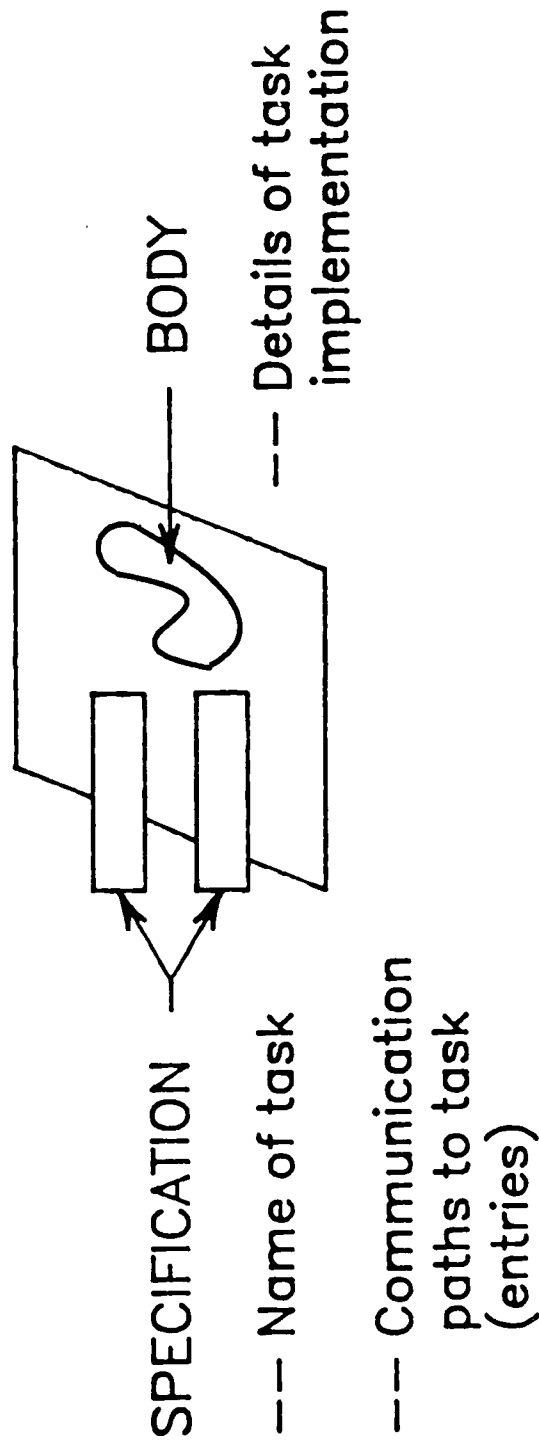
```
generic
  type ELEMENT_TYPE is private;
  procedure SWAP ( LEFT, RIGHT : in out ELEMENT_TYPE );
  procedure SWAP ( LEFT, RIGHT : in out ELEMENT_TYPE ) is
    TEMP_ELEMENT : ELEMENT_TYPE := LEFT;
  begin
    LEFT := RIGHT;
    RIGHT := TEMP_ELEMENT;
  end SWAP;
```

Tasks



- A task is an entity that operates in parallel with other entities
- Tasking may be implemented on
 - Single Processors
 - Multi-processors
 - Multi-computers

Tasks



Tasks

```
procedure SENSOR_CONTROLLER is
```

```
function OUT_OF_LIMITS return BOOLEAN;  
procedure SOUND_ALARM;
```

```
task MONITOR_SENSOR; --- specification  
task body MONITOR_SENSOR is --- body  
begin
```

```
    loop  
        if OUT_OF_LIMITS then  
            SOUND_ALARM;  
        end if;  
    end loop;  
end MONITOR_SENSOR;
```

```
function OUT_OF_LIMITS return BOOLEAN is separate;  
procedure SOUND_ALARM is separate;  
begin
```

```
    null; --- Task is activated here
```

```
end SENSOR_CONTROLLER;
```

Tasks

```
-- a basic task with no communication
with TEXTJO; use TEXTJO;
procedure COUNT_NUMBERS is
package INTJO is new INTEGERJO (INTEGER);
use INTJO;
task COUNT_SMALL;
task COUNT_LARGE;

task body COUNT_SMALL is
begin
  for INDEX in -100..0 loop
    PUT(INDEX);
    NEW_LINE;
  end loop;
end COUNT_SMALL;

task body COUNT_LARGE is
begin
  for INDEX in 0..100 loop
    PUT(INDEX);
    NEW_LINE;
  end loop;
end COUNT_LARGE;

begin
  null; --tasks are started here
end COUNT_NUMBERS;
```

Tasks

```
--Tasks can communicate with each other  
-- via parameters defined in entries
```

```
task CHANNEL is  
    entry PRINT(JOB:in JOB_NUMBER);  
end CHANNEL;
```

```
--To communicate use an "entry" call  
CHANNEL.PRINT(24);
```

```
--When two tasks are synchronized in time  
-- and are communicating, we say that the  
-- two tasks are in "rendezvous"
```

Tasks

--Inside a task, rendezvous occurs when
-- a task's entry has been called and
-- an accept statement is reached

task body CHANNEL is

 LOCAL_NUMBER : JOB_NUMBER;

begin

 loop

 accept PRINT(JOB:in JOB_NUMBER)do

 LOCAL_NUMBER := JOB;

 end;

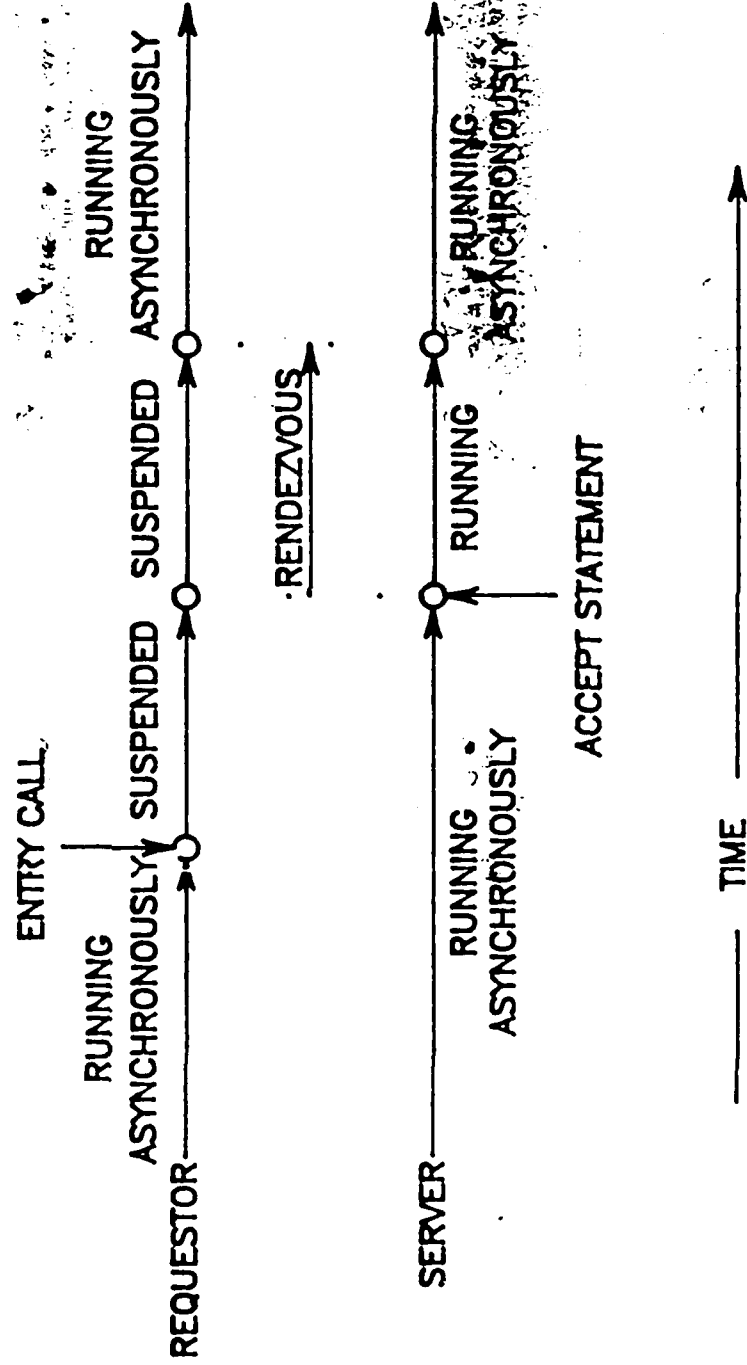
 CALL_PRINTER (LOCAL_NUMBER);

 end loop;

end CHANNEL;

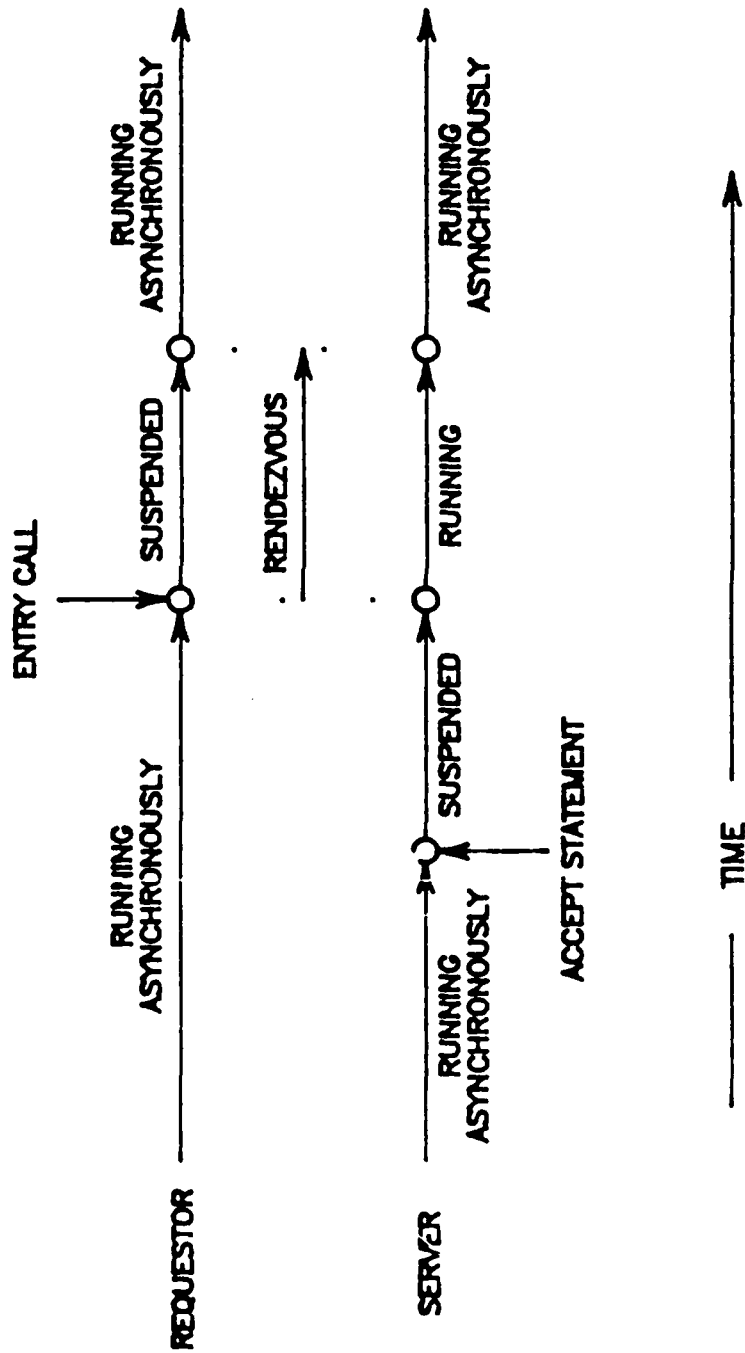
Tasks

STAGES OF A RENDEZVOUS (ENTRY CALL FIRST)



Tasks

STAGES OF A RENDEZVOUS (ACCEPT FIRST)



Tasks

Tasking statements

ENTRY CALL
DELAY
ABORT
ACCEPT
SELECT

Tasks

DELAY -----

- Used to suspend execution for at least
- the time interval specified
- delay 30.0;

ABORT -----

- Used to unconditionally terminate a task
- Only used in extreme circumstances
- abort CHANNEL;

Tasks

SELECT

```
--Used to choose between entries in a task
task DRIVE_CONTROL is
    entry READ(DATA: out DATA_TYPE);
    entry WRITE(DATA: in DATA_TYPE);
end DRIVE_CONTROL;

task body DRIVE_CONTROL is
begin
    loop
        select
            accept READ(DATA:out DATA_TYPE)do
                .
            end;
        or
            accept WRITE(DATA:in DATA_TYPE)do
                .
            end;
        end select;
    end loop;
```

```
with LIST_PACKAGE, TEXTJO;  
use LIST_PACKAGE, TEXTJO;  
procedure ORDERLIST is
```

```
    UNSORTED_FILE : FILE_TYPE;  
    SORTED_FILE : FILE_TYPE;
```

```
    MAX_ITEMS : constant := 20;
```

```
    THE_LIST : ALIST(1..MAX_ITEMS);  
    LIST_INDEX : POSITIVE := 1;
```

```
    LAST : NATURAL;  
    FILE_NAME : STRING(1..40);
```

```
begin
    PUT_LINE ("This program sorts a list of names, addresses and ");
    PUT_LINE ("phone numbers and puts that sorted list in a file.");
    NEW_LINE (2);
    PUT_LINE ("What is the name of the file to sort?");
    GET_LINE (FILE_NAME, LAST);
    OPEN (UNSORTED_FILE, IN_FILE, FILE_NAME (1..LAST));
    while not END_OF_FILE (UNSORTED_FILE) loop
        GET_LINE (UNSORTED_FILE, THE_LIST (LIST_INDEX).NAME, LAST);
        GET_LINE (UNSORTED_FILE, THE_LIST (LIST_INDEX).ADDRESS, LAST);
        GET_LINE (UNSORTED_FILE, THE_LIST (LIST_INDEX).PHONE_NUMBER, LAST);
        LIST_INDEX := LIST_INDEX + 1;
    end loop;
    SORT (THE_LIST (1..LIST_INDEX - 1));
    CLOSE (UNSORTED_FILE);
```

package LIST_PACKAGE is

MAX_LINE_LENGTH : constant := 80;

subtype ALINE is STRING(1..MAX_LINE_LENGTH);

type ITEMS is record

NAME : ALINE := (others => '');

ADDRESS : ALINE := (others => '');

PHONE_NUMBER := (others => '');

end record;

type ALLIST is array(POSITIVE range <>) of ITEMS;

procedure SORT (ANY_LIST : in out ALLIST);

end LIST_PACKAGE;

```

with SWAP;
package body LIST_PACKAGE is

  procedure SWAP_ITEMS is new SWAP ( ELEMENT_TYPE => ITEMS );

  procedure SORT ( ANY_LIST : in out A_LIST ) is
  -- implements a selection sort
    SMALLEST_INDEX, TEMP_INDEX : POSITIVE;
    SMALLEST_NAME : A_LINE := ( others => ' ' );

  begin
    for SORTED_INDEX in ANY_LIST'RANGE loop
      SMALLEST_INDEX := SORTED_INDEX;
      for CHECK_INDEX in (SORTED_INDEX+1)..ANY_LIST'LAST loop
        if ANY_LIST ( CHECK_INDEX).NAME <
           ANY_LIST (SMALLEST_INDEX).NAME then
          SMALLEST_INDEX := CHECK_INDEX;
        end if;
      end loop;
      SWAP_ITEMS ( ANY_LIST(SMALLEST_INDEX),
                   ANY_LIST(SORTED_INDEX) );
    end loop;
  end SORT;

end LIST_PACKAGE;

```

```
PUT_LINE("What is the name of the file to output to?");
GET_LINE( FILE_NAME, LAST );

CREATE ( SORTED_FILE, OUT_FILE, FILE_NAME(1..LAST) );

for FILE_ITEM in 1 .. LIST_INDEX - 1 loop

    PUT_LINE( SORTED_FILE,THE_LIST(FILE_ITEM).NAME );
    PUT_LINE(SORTED_FILE,THE_LIST(FILE_ITEM).ADDRESS );
    PUT_LINE(SORTED_FILE,THE_LIST(FILE_ITEM).PHONE_NUMBER);

    NEW_LINE(SORTED_FILE);

end loop;

CLOSE ( SORTED_FILE );

end ORDER_LIST;
```

END

DATE

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