An Introduction to Ada 95 for Programmers

(Part 2 – Parallel and Real-time Programming)

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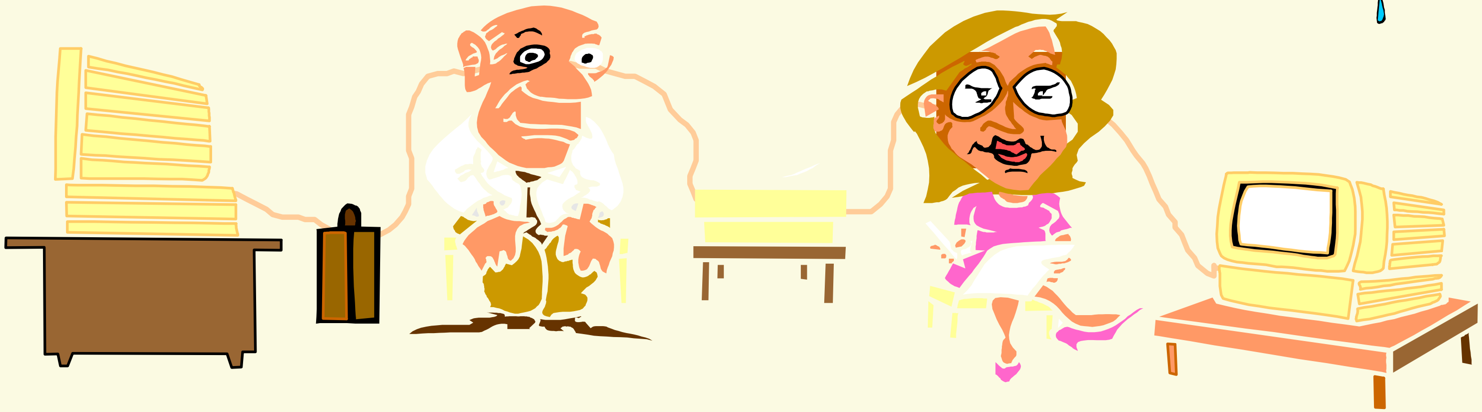
Ada
The Language For a Complex World

Multitasking

What is Real-time?



Tasks Construction

- Task types
- Protected types
- 7 Task communications

Task Structure

- Anonymous Tasks
- Task Types
- Task Attributes
- Delay, Delay Until
- Exceptions During Tasking

Task Execution Control

- Task States
- Aborting Task
- Synchronization Points
- Task access types

Real Time Issue

- Potential Overhead Factors.
- Improving Performance
- Special Tasking Issues

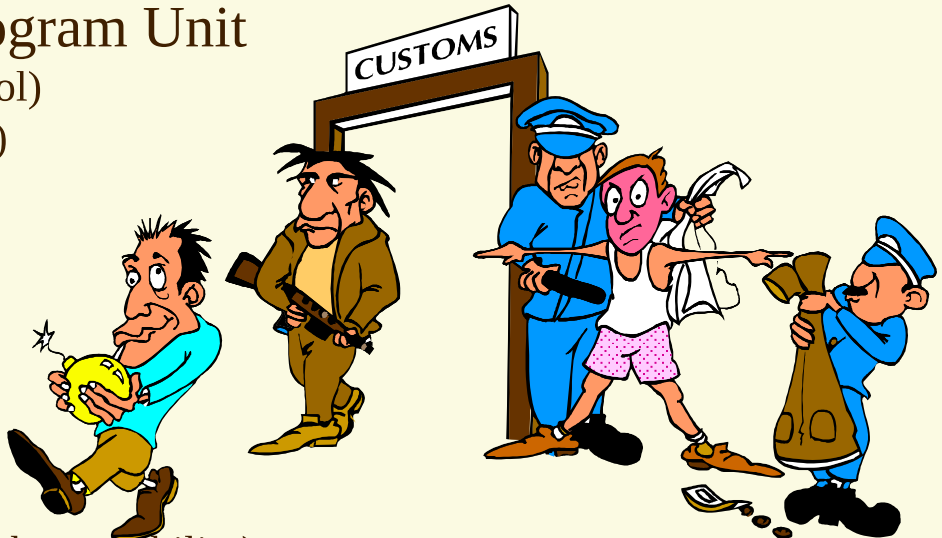
Parallel Processing (Tasking)

- The Ada parallel processing model is a useful model for the abstract description of many parallel processing problems. In addition, a more static monitor-like approach is available for shared data-access applications.

- Ada provides support for single and multiple processor parallel processing, and also includes support for time-critical real-time and distributed applications.

What a Task is

- **Concurrently Executing Program Unit**
  - One processor (single thread of control)
  - Multi-programming (multiple threads)
  - Multi-processing (multiple threads)
  - Distributed Environment (sterile)
  - Distributed Environment



- **Always a *Slave***
  - Must have a master
  - Sometimes *abortable*
  - Can be *aborted* by **ANYBODY** (who has visibility)
  - Since a task must have a master, it can never be a library unit
- **What makes the master important?**
  - The master may not terminate until all “children” are finished
  - Library packages acting as a master may have “rogue” tasks

Simple Task Syntax

```
task [type]  task_simple_name  [ is
        {entry declaration}
        {representation clause}
end [ task_simple_name ]   ]  ;


task body task_simple_name is
      [declarative part]
begin
        sequence_of_statements
[exception
        exception handler ]
end [ task_simple_name ]  ;
```

Examples

- Using simple task types

```
task type EAT_UP_RESOURCES ;


task body EAT_UP_RESOURCES  is
    begin
    loop
              null;
    end loop;
end EAT_UP_RESOURCES;



EAT_UP_1 : EAT_UP_RESOURCES;

BIG_EAT : array (1..10) of
               EAT_UP_RESOURCES;
```

- Using access types with task types

```
task type EAT_UP_RESOURCES ;

task body EAT_UP_RESOURCES  is
    begin
    loop
              null;
    end loop;
end EAT_UP_RESOURCES;


type EATER is access EAT_UP_RESOURCES;

EAT_UP_1 : EATER;

EAT_UP_A_LOT : array (1..10) of
              EATER;
```

When does a task start?

- A task starts after the elaboration of the declarative part that each task is declared in. Basically, after the “begin” statement, but before any other executable statement
- This allows **TASKING_ERROR** to be raised in the “master” in case of problems in the elaboration of a task

NOTE - This is the ONLY time that a task will raise an asynchronous exception in the master. There may be only **1 TASKING_ERROR** per master per declarative region

Synchronization Calls

```
task type DO_SOMETHING is
        entry SYNC_POINT;
end DO_SOMETHING;

task body DO_SOMETHING is
        begin
                loop
                        accept SYNC_POINT do
                                <SOS #1>
                        end SYNC_POINT;
                        <SOS #2>
                end loop;
        end DO_SOMETHING;
```

The “accept” synchronizes the caller and server, during SOS #1 and prepares the task to execute SOS #2.

SOS #1 occurs during rendezvous, and the caller is “blocked” while the receiver (server) executes the statements. SOS #1 should be only as long as absolutely necessary. SOS #1 may be null.

SOS #2 occurs after rendezvous, and multiple threads of control exist. Both the caller and server are executing in parallel.

Task Communications

7 An “ENTRY POINT” defines a point to rendezvous (synchronization or exchange data point) with a task.

You can NEVER call a task, only rendezvous with it at an entry point. An entry point is like a “phone number” to the task

```
task type DO_SOMETHING is
        entry SYNC_POINT;
end DO_SOMETHING;

task body DO_SOMETHING is
        begin
                loop
                        accept SYNC_POINT;
                        <SOS> --Sequence Of Statements
                end loop;
        end DO_SOMETHING;
```

– This is the “WAIT FOREVER” model

Multiple Accept Statements

- There is nothing "sacred" about "accept" statements.
- There may be multiple accepts per entry point

```
task type DO_SOMETHING_ELSE is
       entry SYNC_POINT;
end DO_SOMETHING_ELSE

task body DO_SOMETHING_ELSE is
       begin
              loop
                     accept SYNC_POINT do
                                   <SOS #1>
                     end SYNC_POINT;

                     <SOS #2>
                     accept SYNC_POINT;

              end loop;
end DO_SOMETHING_ELSE;
```

Entry Call Parameters

An entry point may define parameters

(like a procedure or function definition)

```
task type DO_LITTLE is
        entry GET_DATA ( PARAM1 : in   SOME_TYPE);
        entry PUT_DATA (PARAM2 : out  SOME_TYPE);
end DO_LITTLE;

TASK_DO_LITTLE : DO_LITTLE;

task body DO_LITTLE is
        HOLDER : SOME_TYPE;
begin
        loop
                accept GET_DATA  ( PARAM1: in SOME_TYPE) do
                        HOLDER := PARAM1;
                 end GET_DATA;

                 accept PUT_DATA (PARAM2 : out  SOME_TYPE) do
                        PARAM2 := HOLDER;
                 end PUT_DATA;
        end loop;
end DO_LITTLE;
```

What the Previous Example Does

- Enforces “server-client” relationship for a “critical” data item.
- Requires a “new” item to be created before it can be “consumed”
- Requires the current item to be “consumed” before a new item can be created.
- Will allow multiple producers/consumers to interact by using the task as a “middleman”

Implicit Queues for Entry Points

- Queues
  - By definition of accept statement, only 1 caller may be in rendezvous per task.
  - This means that calls for task entries are neither reentrant or recursive
- There is a queue associated with each entry point. All callers to this entry stand in an ordered line.

Use “Wait Until I get Done” with Great Care!

- Could be replaced with a simple procedure/function call except in special Cases!
- Use entry points to pass data “one way”

NOT

```
task type DO_PROCESSING is
        entry DO_WORK ( DATA : in out SOME_TYPE);
end DO_PROCESSING;

WORKER : DO_PROCESSING;

task body DO_PROCESSING is
begin
        loop
                accept DO_WORK (DATA : in out SOME_TYPE) do
                        <LSOS> -- some long, involved processing here
                end DO_WORK;
        end loop;
end DO_PROCESSING;
```

When You Need to Send and Receive Data From a Task

```
task DO_PROCESSING is
    entry GET_DATA ( DATA : in  SOME_TYPE);
    entry PUT_DATA ( DATA : out SOME_TYPE);
end DO_PROCESSING;

task body DO_PROCESSING is
    HOLDER : SOME_TYPE;
begin
  loop

    accept GET_DATA(DATA: in SOME_TYPE) do
           HOLDER := DATA;
    end GET_DATA;

    <LSOS>  -- some long, involved processing here

    accept PUT_DATA(DATA: out SOME_TYPE) do
           DATA := HOLDER;
    end PUT_DATA;

  end loop;
end DO_PROCESSING;
```

Exiting or Quitting a Task

Task “quits” under task control

```
task type DO_PROCESSING is
      entry GET_DATA ( DATA : in
      SOME_TYPE);
      entry PUT_DATA ( DATA : out
      SOME_TYPE);
end DO_PROCESSING;

WORKER : DO_PROCESSING;

task body DO_PROCESSING is
      HOLDER : SOME_TYPE;
```

```
begin
   loop

      accept GET_DATA(DATA: in
                           SOME_TYPE) do
            HOLDER := DATA;
      end GET_DATA;

      -- some long processing here

      accept PUT_DATA(DATA: out
                           SOME_TYPE) do
            DATA := HOLDER;
      end PUT_DATA;

      exit when <some condition>;

   end loop;
end DO_PROCESSING;
```

Multiple Callers - the *Select*

```
Task TASK2 is
        entry ENTRY1;
        entry ENTRY2;
end TASK2;

Task body TASK2 is
  begin
        loop
              select    --Waits for a call of ENTRY1 or ENTRY2
                                accept ENTRY1 [do
                                                <SOS>
                                end ENTRY1];
                                [<SOS>]
              or
                                accept ENTRY2 [do
                                    <SOS>
                                end ENTRY2];
                                [<SOS>]
              end select;
        end loop;
end  TASK2;
```

The *Select Concerns*

- The order of selection is not defined by the language!!!
  - It may be arbitrary, fair, consistent, inconsistent or predefined!!!
  - Any program that makes assumptions about the order of the selection of the open alternatives should be considered “erroneous”!!!

The Select (cont.)

7 Each accept statement in a “select” is called an ALTERNATIVE
- Each alternative is allowed to have an optional “guard” of the form

  when <Boolean condition> =>
  accept ...
- If the guard is true, then the alternative is “open” and the corresponding “accept” is considered
- If the guard is false, the alternative is called “closed”, and not a possible alternative
- If all alternatives are closed, a PROGRAM_ERROR is raised!!
- In any “Wait case”, an alternative is evaluated only once per select!!

Quitting Under Caller Control

```
task type DO_PROCESSING is
    entry GET_DATA ( DATA :
     in  SOME_TYPE);
    entry PUT_DATA ( DATA :
     out SOME_TYPE);
    entry SHUTDOWN;
end DO_PROCESSING;

WORKER : DO_PROCESSING;

task body DO_PROCESSING is
    HOLDER : SOME_TYPE;
```

```
begin
loop
   select
      accept GET_DATA(DATA: in SOME_TYPE)
      do
               HOLDER := DATA;
      end GET_DATA;
   or
      accept PUT_DATA(DATA: out SOME_TYPE)
      do
               DATA := HOLDER;
      end PUT_DATA;
   or
      accept SHUTDOWN;
               --sync call only
      exit;
   end select;
end loop;
end DO_PROCESSING;
--Question: What f callers still in queue?
```

Finite Wait - the *Delay*

- This is the **WAIT FOR A FINITE AMOUNT OF TIME option**
- The syntax is

```
   or
      delay <fixed-point DURATION>;
         [ <SOS> ]
```

- The duration is expressed in seconds (X.X)
- Since the delay may be dynamic (an expression), a negative value may be used (treated as 0)
- Multiple delays are allowed (the shortest one “wins”)
- the delay statement may also have a guard
- After a time equal to the delay, no other open alternatives will be allowed
- After a time >= the delay, the optional <SOS> after the delay is executed, and the select terminates

Dave's Fast Food

```
task FAST_FOOD is
          entry WALK_IN;
          entry DRIVE_UP;
end FAST_FOOD;

task body FAST_FOOD is
  begin
    loop
          select
              when WALK_IN_HOURS =>   accept WALK_IN do
                      ..
              end WALK_IN;
          or
              when DRIVE_UP_HOURS =>  accept DRIVE_UP do
                      ..
              end DRIVE_UP;
          or
              delay 60.0;      --if no customers after 1 minute, clean up
              CLEAN_UP_TABLES;
          end select;
     end loop;
end FAST_FOOD;
```

Passive Quitting - *Terminate*

```
select
        accept ...
or
        accept ...
or
        terminate;
end select;
```

- This says "If I have no callers in line, and my master is waiting to quit, and all of my children are ready to quit, then I may now terminate"

- This option is mutually exclusive with the ***delay***   Thus, you can only use the ***terminate*** option with a ***wait forever*** in a select

Don’t Wait at All - the *Else*

- This option is mutually exclusive with both the *delay* and the *terminate* alternative

```
select
   accept ...
or
   accept ...
or
   accept ...
else
   <SOS>;
end select;
```

- If there is NOBODY in queue, then perform the sequence of statements
- This option must be used carefully. Depending upon the type of wait the caller will take, it can cause huge overhead and prevent “real” work from getting done!
- If a caller is using the “don’t wait” option also, what are the odds of achieving a rendezvous??

Never Code a *Busy Wait*

```
loop

        select
                accept SOME_ENTRY_CALL do ..
                        ..
                        ..
                end SOME_ENTRY_CALL;
        else
                null;
        end select;

end loop;
```

- A "busy wait" consumes resources, but can tie up a non-time-slicing system!
- Specifically, single processor systems are very sensitive to this.

Calling Task Entries

- As we have seen, there are three ways to “receive” an entry call
    1. Wait forever
    2. Wait for a determinate time
    3. Don’t wait at all
- There are three corresponding ways to “call” an entry point

NOTE: inside a task, you don’t know who was “placing” the call. However, to call an entry, you MUST specify both the task name and the entry point.

Wait Forever Entry Call

- Much like a procedure call. You simply specify the TASK_NAME.ENTRY_NAME;

```
....
....
Some_Task.Some_Entry(Some_Parameters);
....
....
```

- Once the “call” is placed, you have ABSOLUTELY NO CONTROL over how long you wait. Also, you can’t even determine how many people are in line ahead of you!!

Timed Entry Call

This allows you to wait for a maximum time in queue, then "jump out of the queue".

```
select
        TASK_NAME.ENTRY_NAME
(optional_data);
        <optional SOS>
    or
        delay 60.0;
        <optional SOS>;
    end select;
```

The select statement is used for BOTH the "selective waits" in receiving an entry call in the task, and for placing calls to a task entry. This orthogonality is very confusing to beginning Ada code readers.

Only On Task at a Time

```
select
        TASK_ONE.ENTRY_NAME;
or
        TASK_TWO.ENTRY_NAME;      -- ILLEGAL
end select;
```

- You can only call one task at a time.

Don’t Wait at All Entry Call

```
select
        TASK_NAME.ENTRY_NAME;
        <optional SOS>
else
        <SOS>
end select;
```

NEVER use this type of call if there is ANY chance that the task you are calling is also using the “else” option.

(translation - don’t use this option except in very special circumstances.)

Task Attributes

Task_Type'Callable; - - is Task in a callable state.
- - Boolean returned.

Task_Type'Terminated; - - is Task Terminated.
- - Boolean returned.

E'Count; - - number of calls waiting in queue on an Entry.
- - return Unversal_Integer;

T'Identify; - - Yields a value of Task_ID (Annex C)
- - Only allowed inside an entry_body or
- - accept statement.

Asynchronous Transfer of Control (*then abort*)

- Allows a sequence of statements to be interrupted and then abandoned upon some event.
- Event is either completion of an entry call, or expiration of a delay.
- Used for a mode change, time bounded computations, user-initiated interruption, etc..

Asynchronous Transfer of Control (Creating a *Timeout*)

```
select
        delay 5.0;
        Ada.Text_IO.Put_Line("Calculation does not converge");
        Some_Default_Action;
    then abort
        Horribly_Complicated_Recursive_Function(X,Y);
    end select;
    -- After 5 seconds (plus a little), I will reach here
```

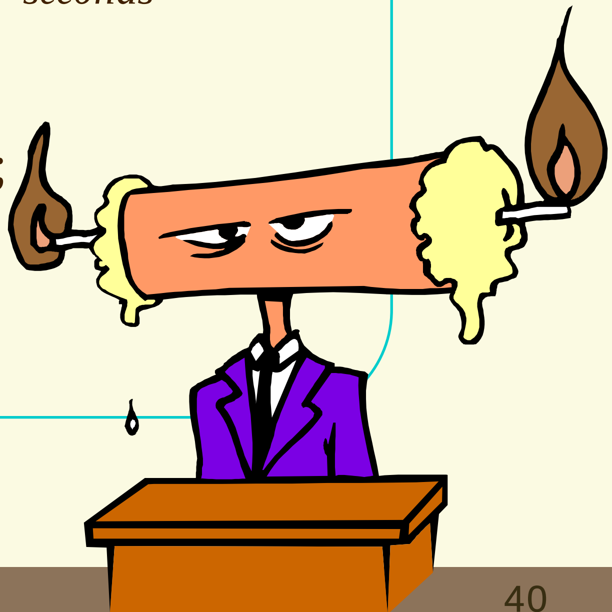
User-initiated Interrupt

```
loop
   select
      Terminal.Wait_for_Interrupt;
      Put_Line ("Process Interrupted..");

   then abort
      Put_Line ("-> ");
      Get_Line (Command, Last);
      Process_Command (Command
      (1..Last));
   end select;
end loop;
```

This process will be abandon by terminal interrupt

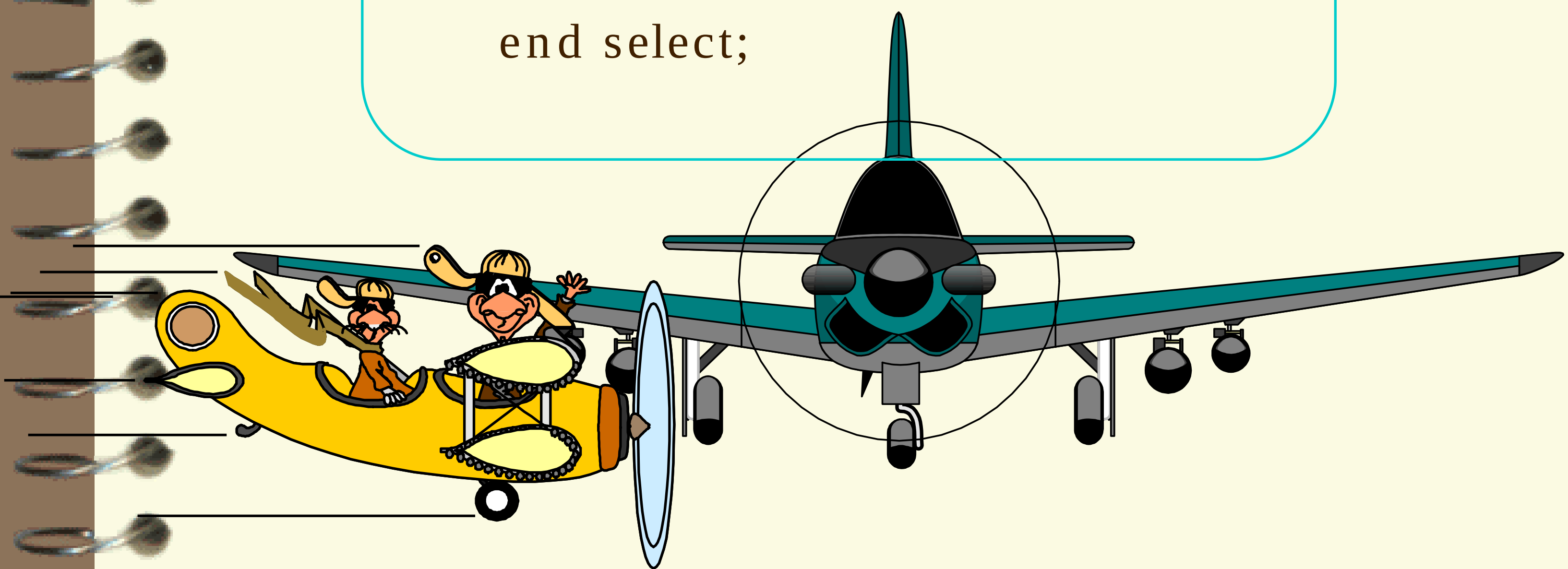
Time Bounded Situation

```
select                  -- Time Critical Data Processing
     delay 5.0;
     Set_Display_Object_Color (Yellow);
     Put_Line ("Target lock aborted data too old.");
then abort              -- Data not  received in 5.0  seconds
     Position_Object;
     Set_Display_Object_Color (Green);
end select;
```

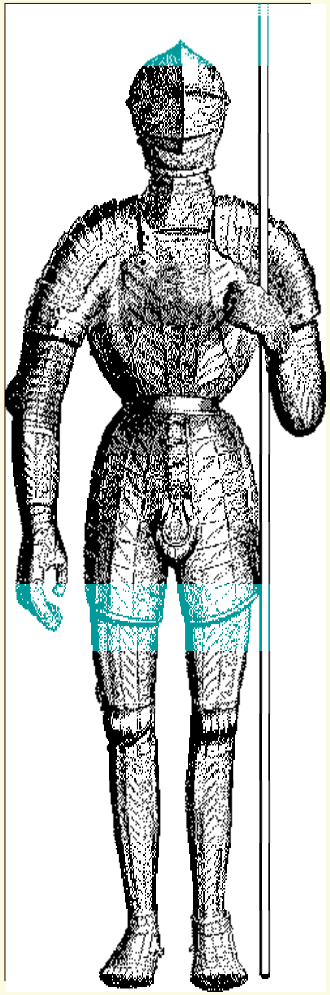


Mode Change

```
select          -- Mode Change
        Confirmed_Air_Threat;
        Sound_ Tone;
        Crash_Avoidance;
then abort
        Land_Aircraft;
end select;
```



Protected Types



Protected types provide a low-level, lightweight synchronization mechanism whose key features are:

- Protected types are used to control access to data shared among multiple processes.
- Operations of the protected type synchronize access to the data.
- Protected types have three kinds of operations: protected functions, protected procedures, and entries.

Protected Units & Protected Objects

- Protected procedures provide mutually exclusive read-write access to the data of a protected object
- Protected functions provide concurrent read-only access to the data.
- Protected entries also provide exclusive read-write access to the data.
- Protected entries have a specified barrier (a Boolean expression). This barrier must be true prior to the entry call allowing access to the data.

Protected Types

```
package Mailbox_Pkg is
    type Parcels_Count is range 0 .. Mbox_Size;
    type Parcels_Index is range 1 .. Mbox_Size;
    type Parcels_Array is array ( Parcel_Index ) of Parcels
    protected type Mailbox is
                -- put a data element into the buffer
        entry Send (Item : Parcels);
                -- retrieve a data element from the buffer
        entry Receive (Item : out Parcels);
        procedure Clear;
        function Number_In_Box return Integer;
    private
        Count           : Parcels_count := 0;
        Out_Index       : Parcels_Index := 1;
        In_Index  : Parcels_Index := 1;
        Data            : Parcels_Array ;
    end Mailbox;
end Mailbox_Pkg;
```

Protected Types Example

```
package body Mailbox_Pkg is

  protected body  Mailbox is

      entry Send ( Item : Parcels) when Count < Mbox_Size is
                                                   -- block until room
      begin
          Data ( In_Index ) := Item;
          In_Index := In_Index mod Mbox_size + 1;
          Count := Count + 1;
      end Send;

      entry Receive ( Item : out Parcels ) when Count > 0 is
                                                   -- block until non-
      empty
      begin
          Item := Data( Out_Index );
          Out_Index := Out_Index mod Mbox_Size + 1;
          Count := Count -1;
      end Receive;
```

Protected Types Example (cont)

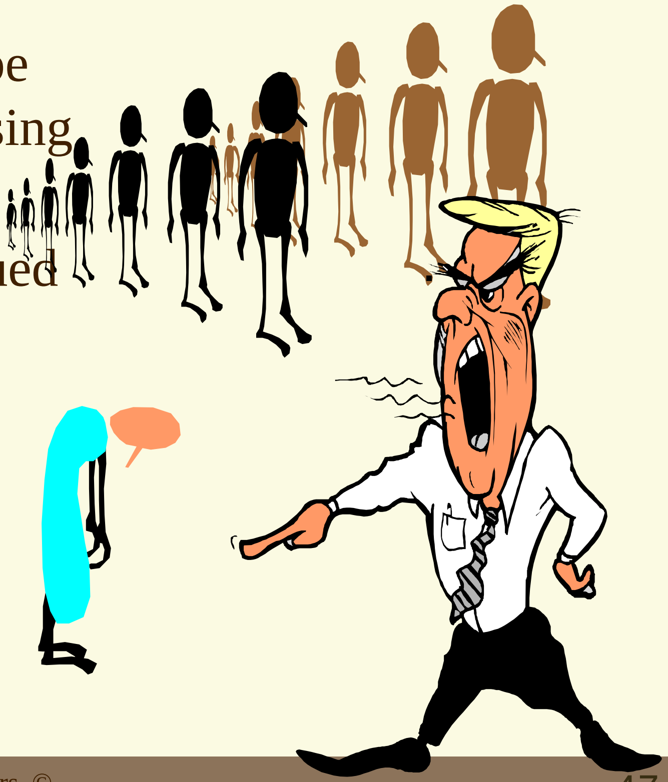
```
        procedure Clear is      --only one user in Clear at a time
        begin
            Count := 0;
            Out_Index := 1;
            In_Index := 1;
        end Clear;

        function Number_In_Box return Integer is
                                          -- many users can check # in
        Box
        begin
            return Count;
        end Number_In_Box;

    end Mailbox;

end Mailbox_Pkg;
```

Requeue Statement

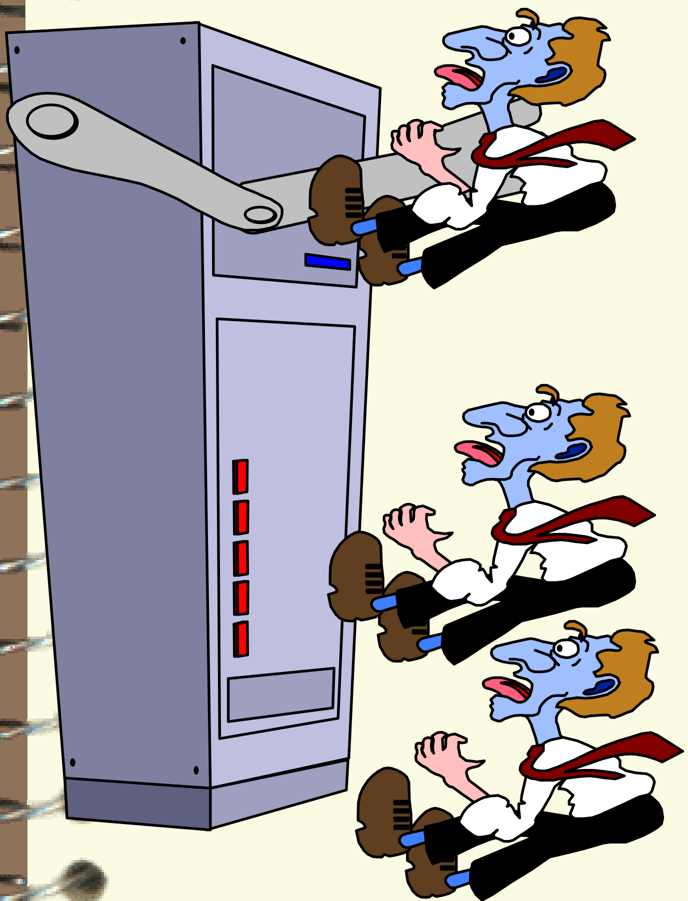
```
requeue Entry_Name [with abort];
```

7 The *requeue* allows a call to an entry to be placed back in the queue for later processing.

7 Without the *with abort* option, the requeued entry is protected against cancellation.



Requeue Statement



```
protected Event is
        entry Wait;
        entry Signal;
private
        entry Reset;
        Occurred : Boolean := False;
end Event;
protected body Event is
        entry Wait when Occurred is
        begin
                null;           -- note null body
        end Wait;
        entry Signal when True is
                -- barrier is always true
        begin
                if Wait'Count > 0 then
                        Occurred := True;
                        requeue Reset;
                end if;
        end Signal;
        entry Reset when Wait'Count = 0 is
        begin
                Occurred := False;
        end Reset;
end Event;
```

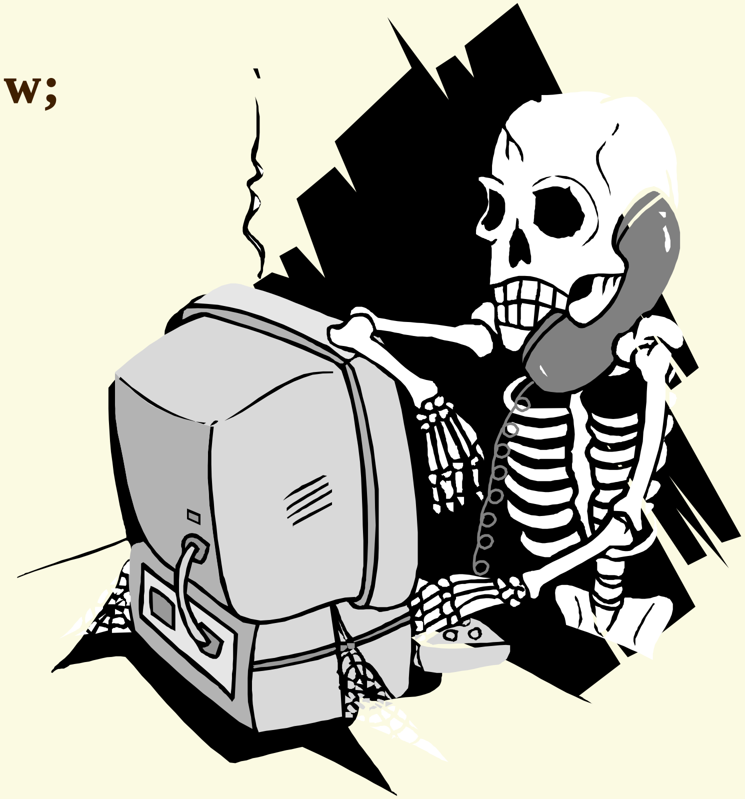
Delay and Until Statements

delay Next_Time - Calendar.Now;

-- suspended for at least the duration specified

delay until Next_time;

-- specifies an absolute time rather than a time interval



The *until* <u>does not</u> provide a guaranteed delay interval, but it does prevent inaccuracies due to swapping out between the “delay interval calculation” and the delay statement

Delay Statement

```
task body Poll_Device is
    Poll_Time    : Real_Time.Time                   :=
    time_to_start_polling;
    Period       : constant Real_Time.Interval  := 10 * Milliseconds;
  begin
    loop
        delay until Poll_Time;
        .         -- sequence of statements
        .         -- to
        .         -- Poll the device

        Poll_Time := Poll_Time + Period;
    end loop;
end Poll_Device;
```

Poll_Device task polls the device every 10 milliseconds starting at the initial value of Poll_Time. The period will not drift.

Killing a Task

Aborting a task

- The "ABORT" statement can not only kill a task, but can have catastrophic effects upon the entire system.

- Any program unit that has "visibility" to a task object can "abort" the task thru the abort statement.

```
abort TASK_NAME;
```

Aborting a task

- This causes the task to become "abnormal"
- If the task is "blocked" or "ready", it just becomes complete
- If not, it must become completed prior to any action affecting another task

Aborting a Task

- A task may “complete” in the middle of IO, updating a record, an assignment, etc.
- Any entry in the tasks’ queues (or a “client” that was in rendezvous) now have a TASKING_ERROR raised
- A task may kill itself to quickly terminate execution cleanly!!

Aborting a Task

- “An abort statement should be used only in extremely severe situations requiring unconditional termination”
- Any abort statement (other than a task aborting itself) should only be used as a last resort if the task is non-responsive or a “rogue” task!! Steps must be taken to ensure data and file integrity and recovery!!

Real-time Features Required

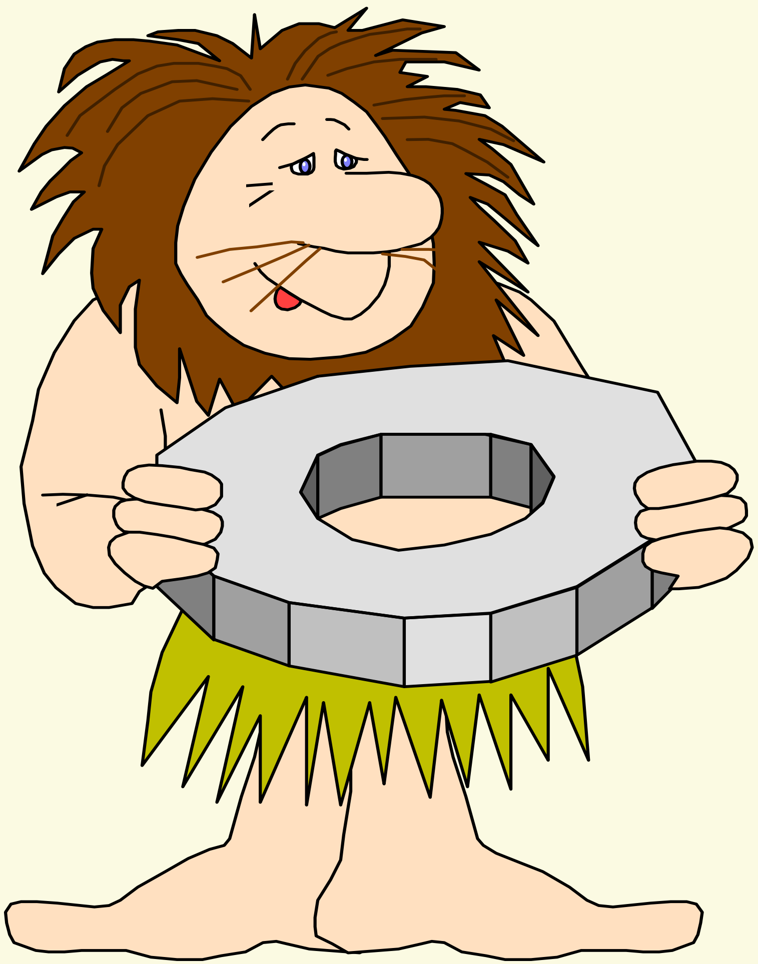
for low-level, real-time, embedded, and distributed systems

Systems Programming Annex Annex C

Real-Time Annex Annex D

The Real-Time Annex requires the Systems Programming Annex for support

Systems Programming Annex
Annex C

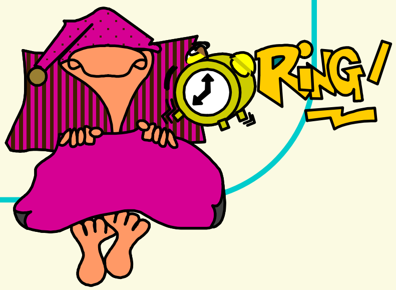


Capabilities (Systems Programming)

- Access to Machine Operations (machine dependent)
  - Must have assembler (if available)
  - Memory addressing and offsets must be specified
  - Overhead with inline vs. subprogram calls documented
  - Pragmas for interfacing assembler and Ada must be supplied
- Access to Interrupt Support
  - pragma Interrupt-Handler (defines parameterless procedure that can be later attached to an interrupts)
  - pragma Attach_Handler (can be used to specify attachment of pararmeterless procedure to a specific interrupt at initialization time). This pragma can be replaced by a dynamic procedure call to Attach_Handler that accomplish the same thing

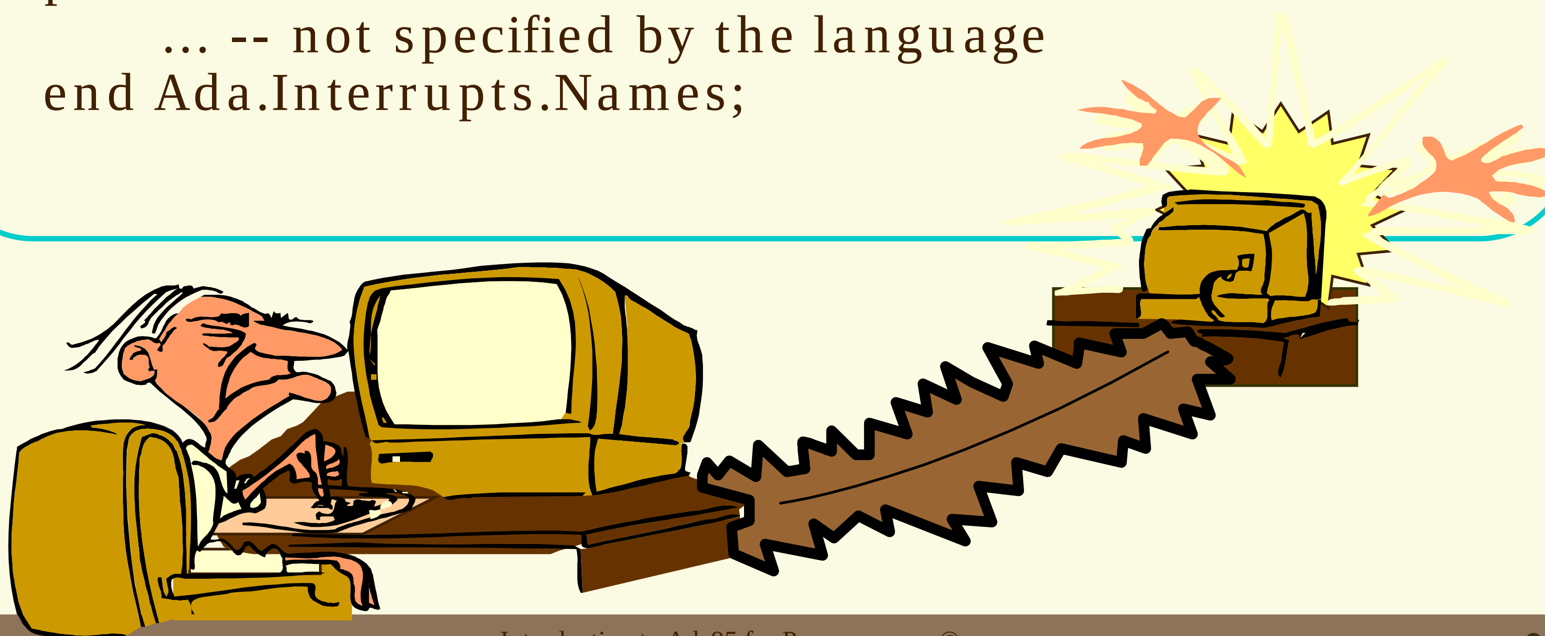
Interrupt Package

```
package Ada.Interrupts is
   type Interrupt_Id is implementation_defined;
   type Parameterless_Handler is access protected procedure;

     function Is_Reserved (Interrupt : Interrupt_Id)  return Boolean;

     function Is_Attached (Interrupt : Interrupt_Id)  return Boolean;

      function Current_Handler (Interrupt :Interrupt_Id) return
                                               Parameterless_Handler;

      procedure Attach_Handler (New_Handler : Parameterless_Handler;
                          Interrupt   : Interrupt_Id);

      procedure Exchange_Handler  (Old_Handler : out
             Parameterless_Handler;   New_Handler :
             Parameterless_Handler; Interrupt   : Interrupt_Id);

      procedure Detach_Handler (Interrupt : Interrupt_Id);

      function Reference (Interrupt: Interrupt_Id)  return Address;

       private
         ... -- not specified by the language
       end Ada.Interrupts;
```



Interrupt Package - Cont

```
package Ada.Interrupts.Names is
   implementation_defined : constant Interrupt_Id :=
                                implementation_defined;
         . . .
   implementation_defined : constant Interrupt_Id :=
                                implementation_defined;

 private
      ... -- not specified by the language
 end Ada.Interrupts.Names;
```

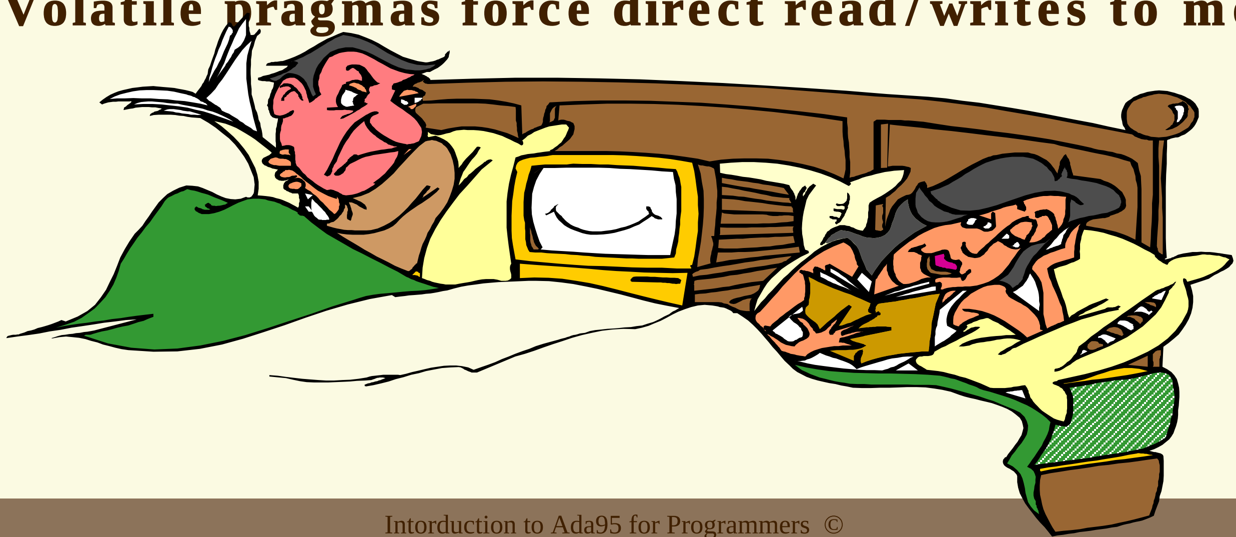


Shared Variable Control

- **Pragma Atomic (applies to objects, components, or types)**
- **Pragma Atomic_Components (applies to arrays)**
- **Pragma Volatile (applies to objects, components, or types)**
- **Pragma Volatile_Components (applies to arrays)**

The Atomic pragmas force indivisible read/write operations.

The Volatile pragmas force direct read/writes to memory



Task Identification

```
package Ada.Task_Identification is
   type Task_Id is private;
   Null_Task_Id : constant Task_Id;
   function  "=" (Left, Right: Task_Id) return Boolean;
   function  Image       (T: Task_Id) return String;
   function  Current_Task return Task_Id;
   procedure Abort_Task   (T : in out Task_Id);

   function  Is_Terminated(T : Task_ID) return Boolean;
   function  Is_Callable  (T : Task_ID) return Boolean;
private
   ... -- not specified by the language
end Ada.Task_Identification;
```

Image returns an implementation-defined string that identifies a task
Current_Task returns a value that identifies the task

Task Attributes

```
with Ada.Task_Identification;
generic
   type Attribute is private;
   Initial_Value : Attribute;
package Ada.Task_Attributes is
   type Attribute_Handle is access all Attribute;

   function Value
        (T: Task_Identification.Task_Id :=
      Task_Identification.Current_Task)
                                          return Attribute;
   function Reference
        (T : Task_Identification.Task_Id :=
             Task_Identification.Current_Task)
                                          return Attribute_Handle;
   procedure Set_Value   (Val : Attribute;
            T : Task_Identification.Task_Id :=
            Task_Identification.Current_Task);
   procedure Reinitialize
         (T : Task_Identification.Task_Id :=
      Task_Identification.Current_Task);

end Ada.Task_Attributes;
```

Real-Time Annex

Specifies additional characteristics of Ada implementations intended for real-time systems software.

To conform to this annex, an implementation must also conform to the Systems Programming Annex.

Most of this annex consists of documentation requirements. An implementation must document the values of the annex-defined metrics for at least one hardware/system configuration.

Task Priorities

pragma Priority (expression);

pragma Interrupt_Priority (optional expression);

The range of System.Interrupt_Priority shall include at least one value.

The range of System.Priority must have at least 30 values.

Interrupt_Priority is defined as being greater than Priority.

The following declarations exist in package System

subtype Any_Priority **is** Integer **range** *implementation-defined***;**

subtype Priority **is** Any_Priority **range** Any_Priority'first**..***implementation-defined***;**

subtype Interupt_Priority **is** Any_Priority **range** Priority'last+1**..**Any_Priority'last**;**

Default_Priority **: constant** Priority **:=** (Priority'first + Priority'last) / 2;

Default_Interupt_Priority **: constant** Interupt_Priority **:=** Interupt_Priority'last;

Priority Scheduling

pragma Task_Dispatching_Policy (policy_identifier);

where FIFO_Within_Priorities is the only required policy. Other implementation-dependent policies may be defined

An implementation must document

- the maximum priority inversion a user task can experience
- whether execution of a task can be preempted by the implementation processing of delay expirations for lower priority tasks (and, if so, for how long)

Priority Scheduling

The Ceiling_Locking policy (which specifies interactions between priority task scheduling and protected object ceilings) must be in effect for FIFO_Within_Priorities.

pragma Locking_Policy (policy_identifier);

where Ceiling_Locking is a predefined policy. Other policies may be implementation-defined.

Priority Ceiling Locking

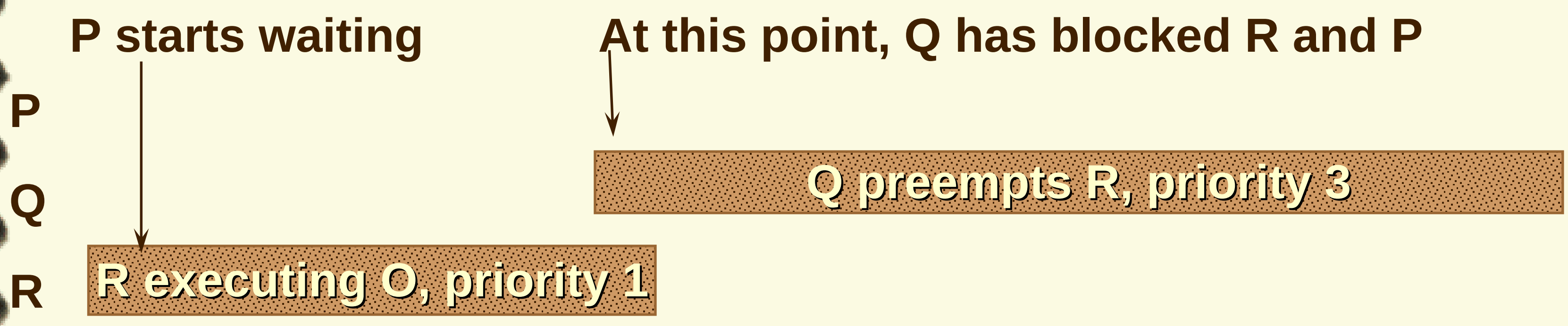
An example WITHOUT Ceiling Locking

Three tasks

- •P of priority 5
- •Q of priority 3
- •R of priority 1

Also, there is a protected object (O).

Task R is executing a procedure in O. P later requires access to the same procedure in O, but R must finish first. Q can preempt R.



(R must complete exclusive write access to O before P can preempt R)

Priority Ceiling Locking

Solution - Have the protected object O automatically execute at a “ceiling”.

Every protected object has a ceiling priority (set by either Priority or Interrupt_Priority pragma).

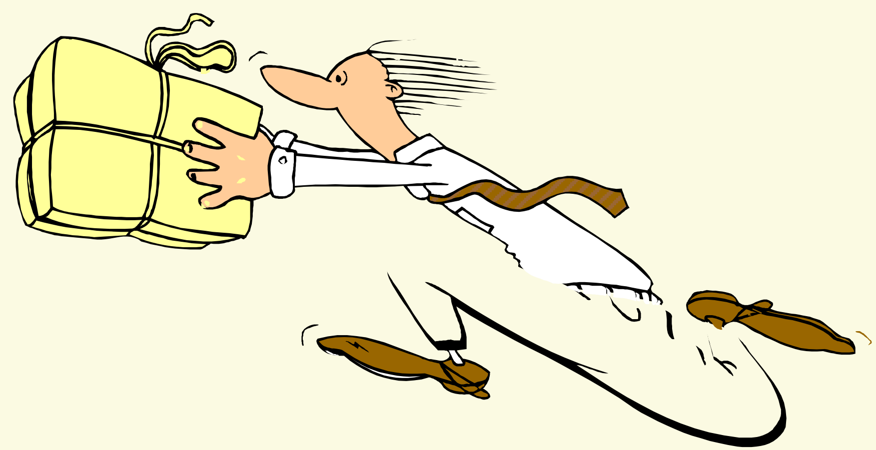
When a task executes a protected operation, it inherits the ceiling priority of the corresponding protected object.

If the active priority of the task is higher than the ceiling of the protected operation, a Program_Error is raised.

Expiration of Time Delay and elective Accepts

If two or more selective accepts are present with the different priorities, then the highest priority is executed.

If two or more expired delays or selective accepts are present with the same priority, the first in textual order is executed / selected.



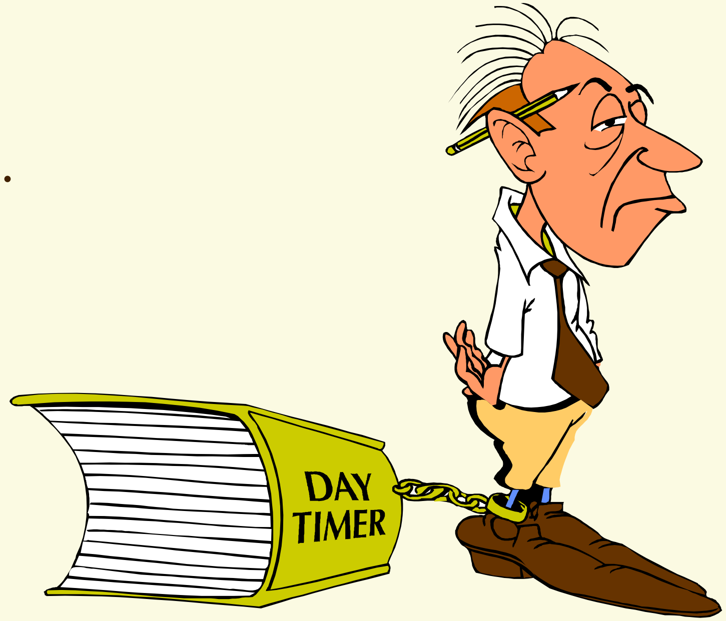
Entry Queuing Policies

This specifies how the calls to a single entry point are queued up.

pragma Queuing_Policy (policy_identifier);

where FIFO_Queuing and Priority_Queuing are predefined. Other implementation-defined policies may exist.

FIFO_Queuing is the default.



Dynamic Priorities

Allows the priority of a task to be modified or queried at run time

```
with System;
with Ada.Task_Identification; -- See G.6.1
   package Ada.Dynamic_Priorities is

      procedure Set_Priority(Priority : System.Any_Priority;
                             T : Ada.Task_Identification.Task_Id :=
                             Ada.Task_Identification.Current_Task);

       function Get_Priority (T : Ada.Task_Identification.Task_Id :=
                             Ada.Task_Identification.Current_Task)
                              return System.Any_Priority;

      private
        ... -- not specified by the language
     end Ada.Dynamic_Priorities;
```

Preemptive Abort

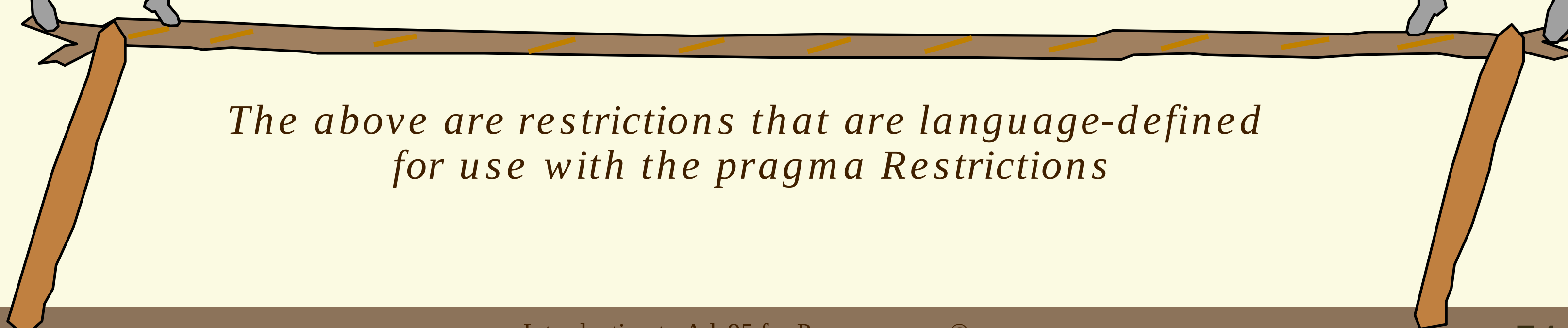
Implementations must document

Execution time (in processor clock cycles) that it takes for an abort_statement to cause completion

- On multiprocessors, the upper bound (in seconds) on the time that the completion of an aborted task can be delayed beyond the point that is required for a single processor
- An upper bound on the execution time of an asynchronous_select

Tasking Restrictions

- No_Task_Hierarchy
- No_Nested_Finalization
- No_Abort_Statement
- No_Terminate_Alternatives
- No_Task_Allocators
- No_Implicit_Heap_Allocation
- No_Dynamic_Priorities
- No_Asynchronous_Control
- Max_Select_Alternatives
- Max_Task_Entries
- Max_Protected_Entries
- Max_Storage_At_Blocking
- Max_Asynchronous_Select_Nesting
- Max_Tasks



The above are restrictions that are language-defined for use with the pragma Restrictions

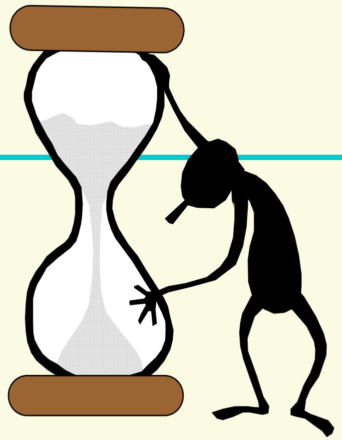
Monotonic Time

This clause specifies a high-resolution, monotonic clock package

```
package Ada.Real_Time is

  type Time is private;
  Time_First: constant Time;
  Time_Last: constant Time;
  Time_Unit: constant := implementation_defined_real_number;


  type Time_Span is private;
  Time_Span_First: constant Time_Span;
  Time_Span_Last: constant Time_Span;
  Time_Span_Zero: constant Time_Span;
  Time_Span_Unit: constant Time_Span;

  Tick: constant Time_Span;
  function Clock return Time;
```

Monotonic Time Cont.

```
type Seconds_Count is range implementation-defined;

procedure Split (T : in Time; SC: out Seconds_Count;
                 TS : out Time_Span);

function Time_Of (SC: Seconds_Count; TS: Time_Span)
                 return Time;

private
 ... -- not specified by the language
end Ada.Real_Time;
```



Monotonic Time Limits

The range of Time shall be sufficient to represent real ranges up to 50 years later.

Tick shall be no greater than 1 millisecond.

Time_Unit shall be less than or equal to 20 micro seconds.

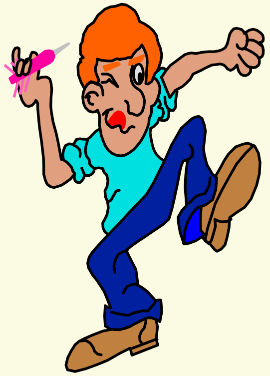
Time_Span_First shall be no Greater than -3600 seconds and Time_Span_Last no less than 3600 seconds.

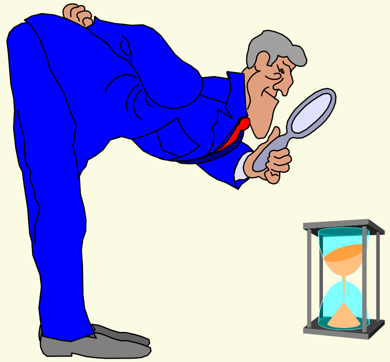
The actual values of Time_First, Time_Last, Time_Span_First, Time_Span_Last , Time_Span_Unit and Tick shall be documented.

Delay Accuracy

An implementation shall document the following

- **An upper bound on the execution time (in processor clock cycles) of a delay_relative_statement whose requested values is less than or equal to zero.**
- **An upper bound of the execution time of a delay_until_statement whose requested value of the delay expression is less than or equal to the value of the Real_Time.Clock and Calendar.Clock.**
- **An upper bound on the lateness of a delay_relative_statement for a positive values of the delay (and delay_until_statement), in a situation where the task has sufficient priority to preempt the processor as soon as it becomes ready.**





Synchronous Task Control

Describes a language-defined private semaphore (suspension object)

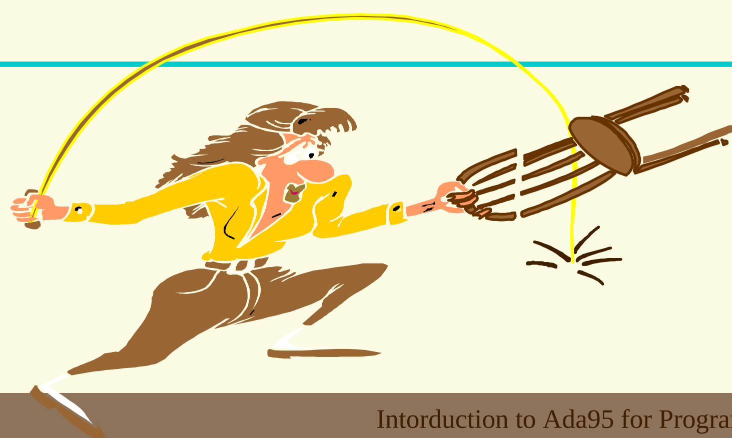
```
package Ada.Synchronous_Task_Control is
   type Suspension_Object is limited private;
   procedure Set_True(S : in out Suspension_Object);
   procedure Set_False(S : in out Suspension_Object);
   function Current_State (S : Suspension_Object) return Boolean;
   procedure Suspend_Until_True (S: in out Suspension_Object);
 private
      ... -- not specified by the language
 end Ada.Synchronous_Task_Control;
```

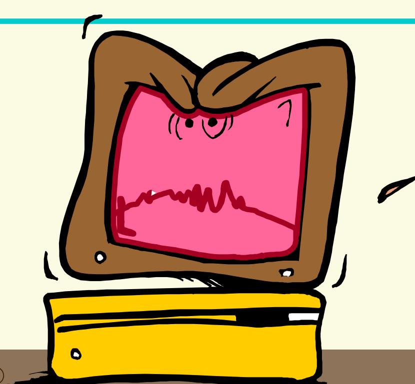
- An object of type Suspension_Object has two states: True and False
- Set_True and Set_False are atomic with respect to each other
- Suspend_Until_True blocks the calling task until the state is True, Program_Error is raised if another task is already waiting
- Current_State returns the current state of the object.

Asynchronous Task Control

This clause introduces a language-defined package to do asynchronous suspend/resume on tasks.

```
with Ada.Task_Identification;
package Ada.Asynchronous_Task_Control is
  procedure Hold(T : Ada.Task_Identification.Task_Id);
  procedure Continue(T :
Ada.Task_Identification.Task_Id);
  function Is_Held(T : Ada.Task_Identification.Task_Id)
   return Boolean;
private
   ... -- not specified by the language
end Ada.Asynchronous_Task_Control;
```

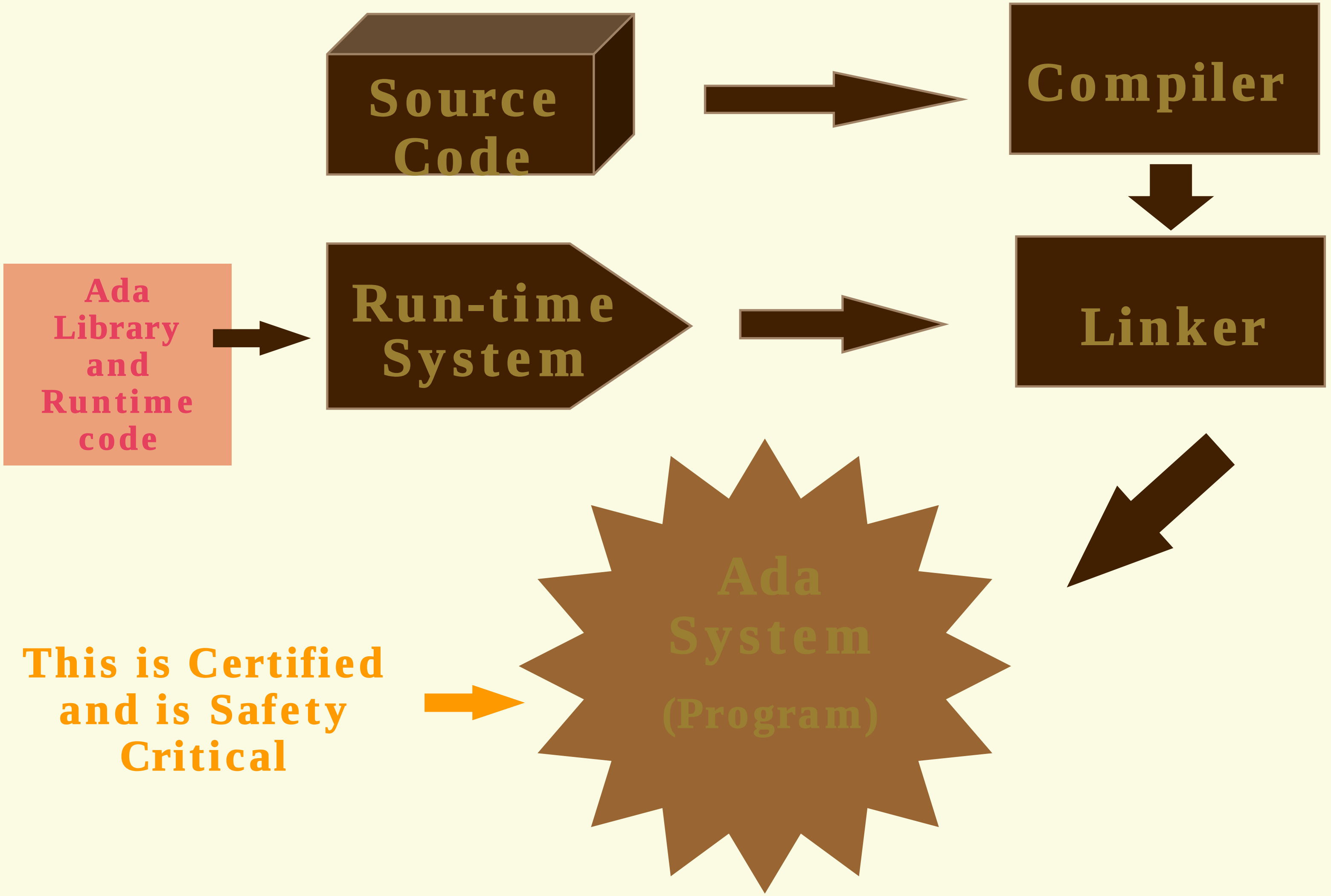




Asynchronous Task Control

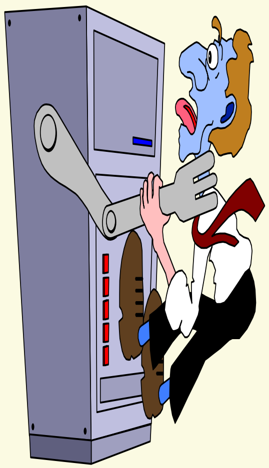
- **After the Hold operation, the task becomes "held". There is a conceptual "idle task" whose priority is below System.Any_Priority'First. The held task is set to a "held priority" below the "idle task".**
- **For a held task, it's base priority no longer constitutes an inheritance source. Instead, the "held priority" is the new inheritance source.**
- **A Continue operation resets the state to not-held, and the priority is now reevaluated.**

More than just the Source Code must be Certified

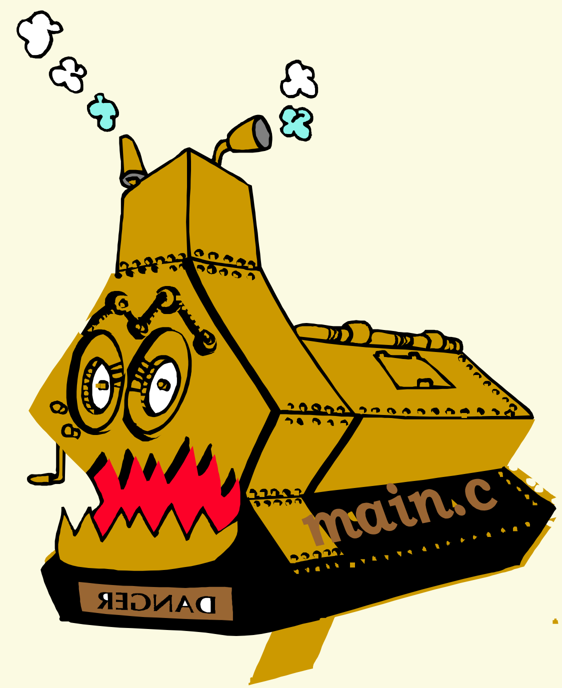


Lack of Experience

Lack of experience in Ada programming causes poor code performance.



Lack of experience in “C/C++” causes code errors.



Low Level Features

- Importing & Exporting other languages
- Callbacks
- Representation Clauses

Standard Interfaces

pragma Import

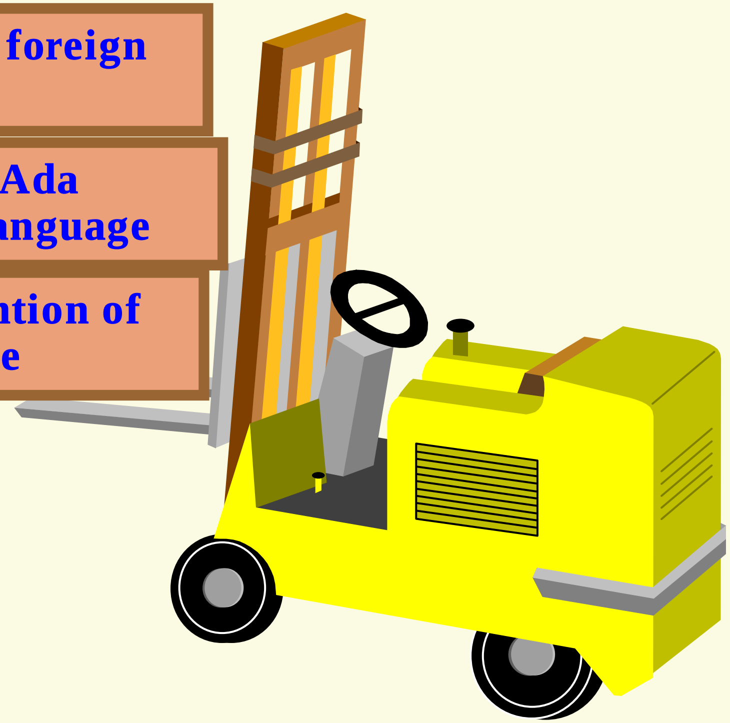
-- used to import a foreign language into Ada

pragma Export

-- used to export an Ada entity to a foreign language

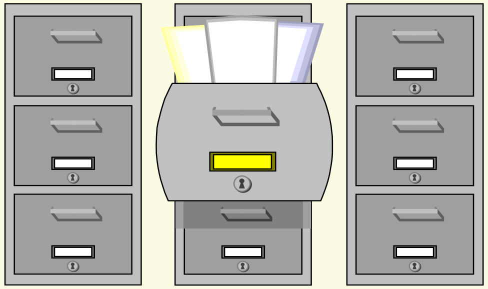
pragma Convention

-- use the convention of another language



Standard Interfaces

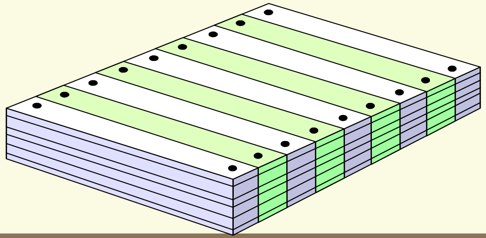
The following packages are REQUIRED by the standard:



- **package Interface.C -- interface to C**

- **package Interface.COBOL -- interface for COBOL**

- **package Interface.FORTRAN - interface for FORTRAN**



"Nothing is more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order, this luke-warmness arising partly from... the incredulity of mankind, who do not truly believe in anything new until they have had actual experience in it".

-- Niccolo Machiavelli, from The Prince

How Not To Do Systems Engineering And The Sinking Of The Largest Offshore Oil Platform

March 2001

Disclaimer: Slides Received From Unknown Author


For those of you who may be involved in the engineering of systems

Please read this quote from a Petrobras executive,

extolling the benefits of cutting quality assurance and inspection costs,

on the project that sunk into the Atlantic Ocean off the coast of Brazil in March 2001.


"Petrobras has established new global benchmarks
for the generation of exceptional shareholder wealth

through an aggressive and innovative programme of cost cutting on its P36 production facility.

Conventional constraints have been successfully challenged


and replaced with new paradigms appropriate to the globalised corporate market place.

Through an integrated network of facilitated workshops,

the project successfully rejected the established constricting and negative influences of prescriptive engineering,

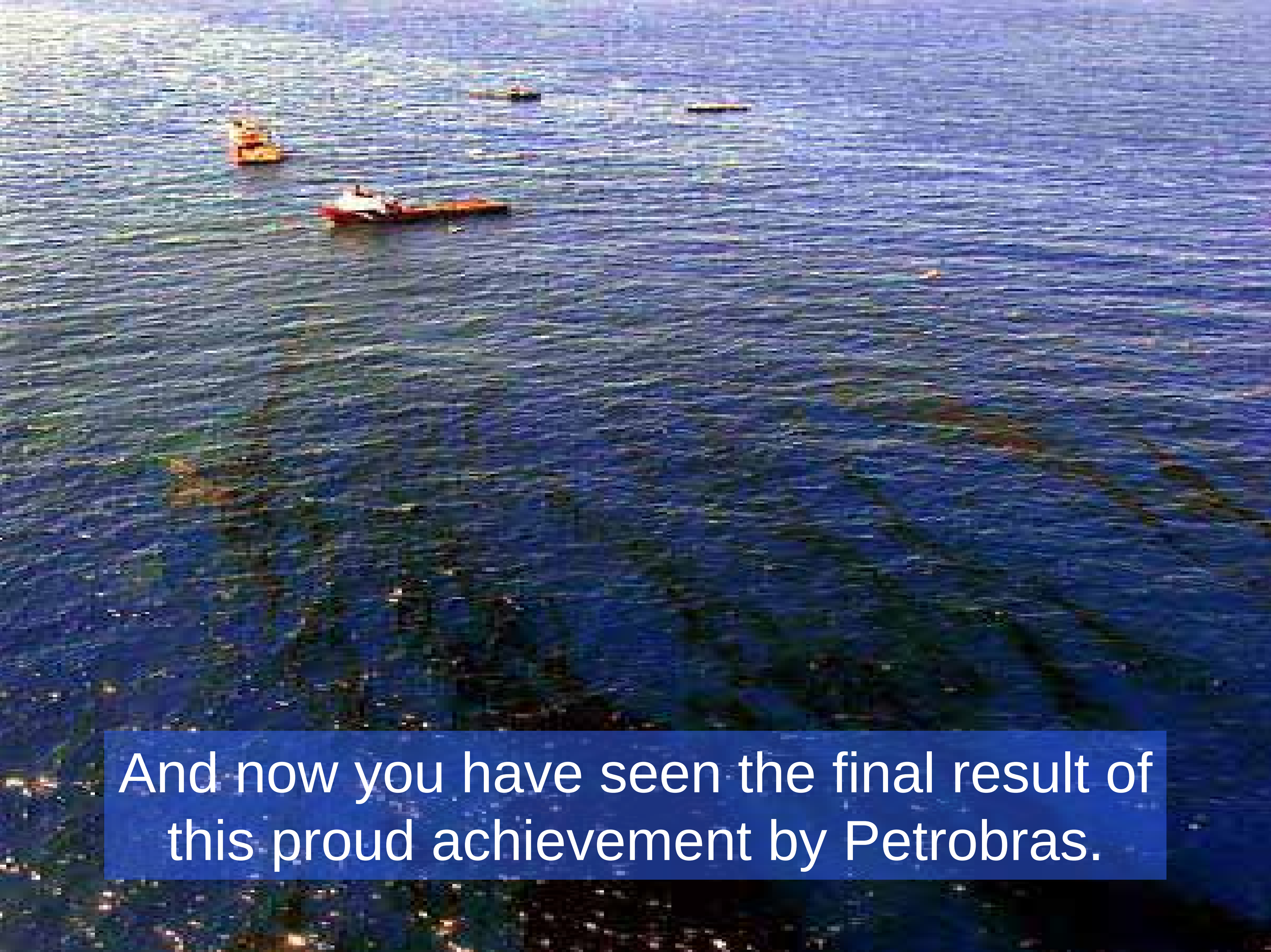
onerous quality requirements, and outdated concepts of inspection and client control.

Elimination of these unnecessary straitjackets has empowered the project's suppliers and contractors to propose highly economical solutions,

with the win-win bonus of enhanced profitability margins for themselves.

The P36 platform shows the shape of things to come


in unregulated global market economy of the 21st Century.”


And now you have seen the final result of
this proud achievement by Petrobras.

Ada Engineered Products (1)

LAMPS SH-60R ASW Helicopter

Ada Engineered Products (2)
Boeing 777 Commercial Aviation

- Airbus 320
- Airbus 330
- Airbus 340
- Beechjet 400A
- Beech Starship I
- Beriev BE-200
- Boeing 737
- Boeing 747
- Boeing 757
- Boeing 767
- Boeing 777
- Canadair Regional Jet
- Embraer CBA-123
- Embraer CBA-145
- Fokker F-100
- Ilyushin 96M
- LM Hercules
- Saab 2000
- Tupolev TU-204

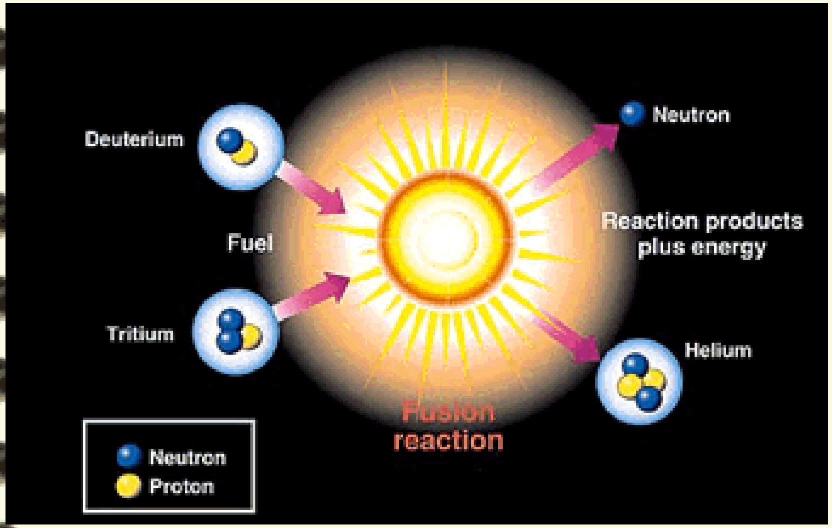
Ada Engineered Products (3)
Canal+ Interactive Television

CANAL+ TECHNOLOGIES is the world's leading provider of digital broadcasting and interactive TV software solutions. Its field-proven systems are being used by more than 20 different digital operators and over 4.5 million set-top boxes based on its technologies are currently deployed.

Ada Engineered Products (4) Hertz Neverlost

Ada Engineered Products (5)
70’Kingcat M270 Luxury Power Catamaran

Ada Engineered Products (6)
National Ignition Facility



- Inertial Confinement Fusion
- 192 Lasers (510 Meters Path)
- 1.8 megajoules
- Tiny Target – 600 µm diameter
- At Lawrence Livermore National Laboratory

Common Characteristics of Ada Applications

- Reliability is a real concern
- Control safety or mission critical applications
- Control hard real-time or near real-time application
- Reliability is a real concern
- Control highly distributed systems
- Control systems with multiple interfaces
- Reliability is a real concern

Achieved via a sound systems engineering approach

With the Ada Language as a Key Technology

If Architects used programming languages ...

Design and Implementation with SE & Ada 95

Design(?) and Implementation without SE

The End