An MDE-based Process for the Design, Implementation and Validation of Safety-Critical Systems

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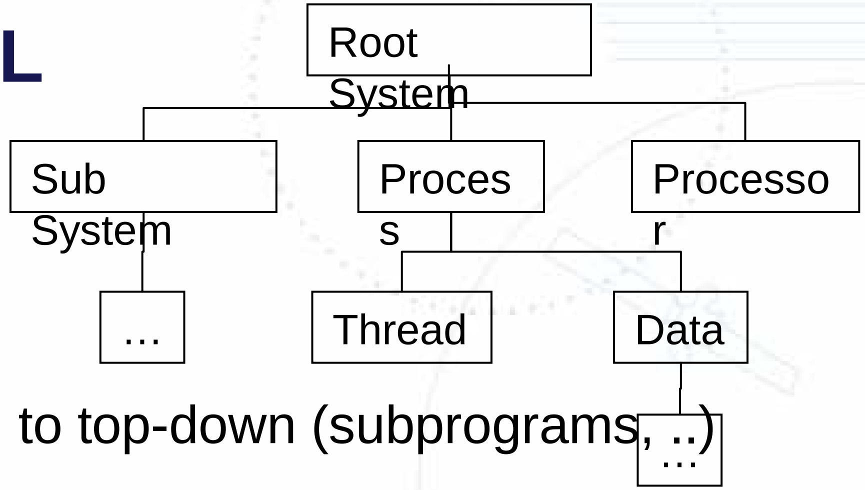
About the SAE AADL



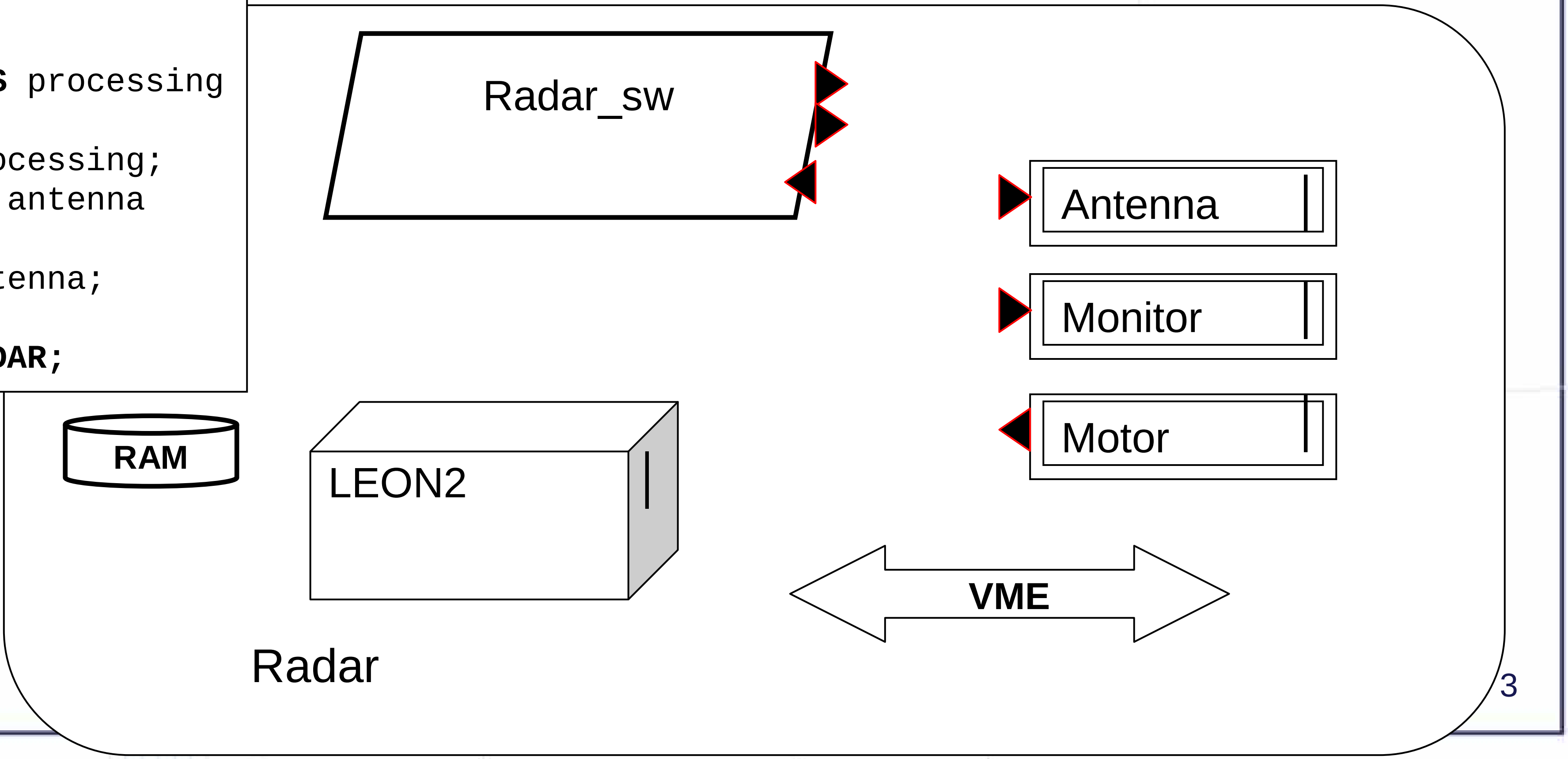
- **AADL model** :
  - A hierarchy from top-most (system) to top-down (subprograms, ..)
- **AADL components:**
  - **Component definition :** model of a software or hardware element, notion of type/interface, one or several implementations organized in package. A component implementation may have subcomponents.
  - **Component interactions :** features (part of the interface) + connections (access to data, to subprograms, ports, …)
  - **Component properties:** valued attributes to model non-functional property (priority, WCET, memory consumption, …)
- AADLv2 defines **both** textual and graphical representations
- UML/MARTE defines guidelines for modeling AADL

AADLv2 Radar example

```
PACKAGE radar
PUBLIC

PROCESS processing
-- …
END processing;
DEVICE antenna
-- …
END antenna;

END RADAR;
```



AADL and subprograms

- Default AADLv2 properties / AADL runtime allows one to bind user code to AADL model
  - ➢ This code is then executed e.g. when a thread is dispatched

```
subprogram Receiver_Spg
features
  receiver_out : out parameter Target_Distance;
  receiver_in : in parameter Target_Distance;
properties
  Source_Language => Ada95; -- defined in AADL_Project
  Source_Name => "radar.receiver";
end Receiver_Spg;
```

- Nothing prevents inclusion of models as “source code”, e.g. SDL, Scade, Simulink or Esterel
- **Issue:** how to perform this consistently ?

AADL and other modeling notations

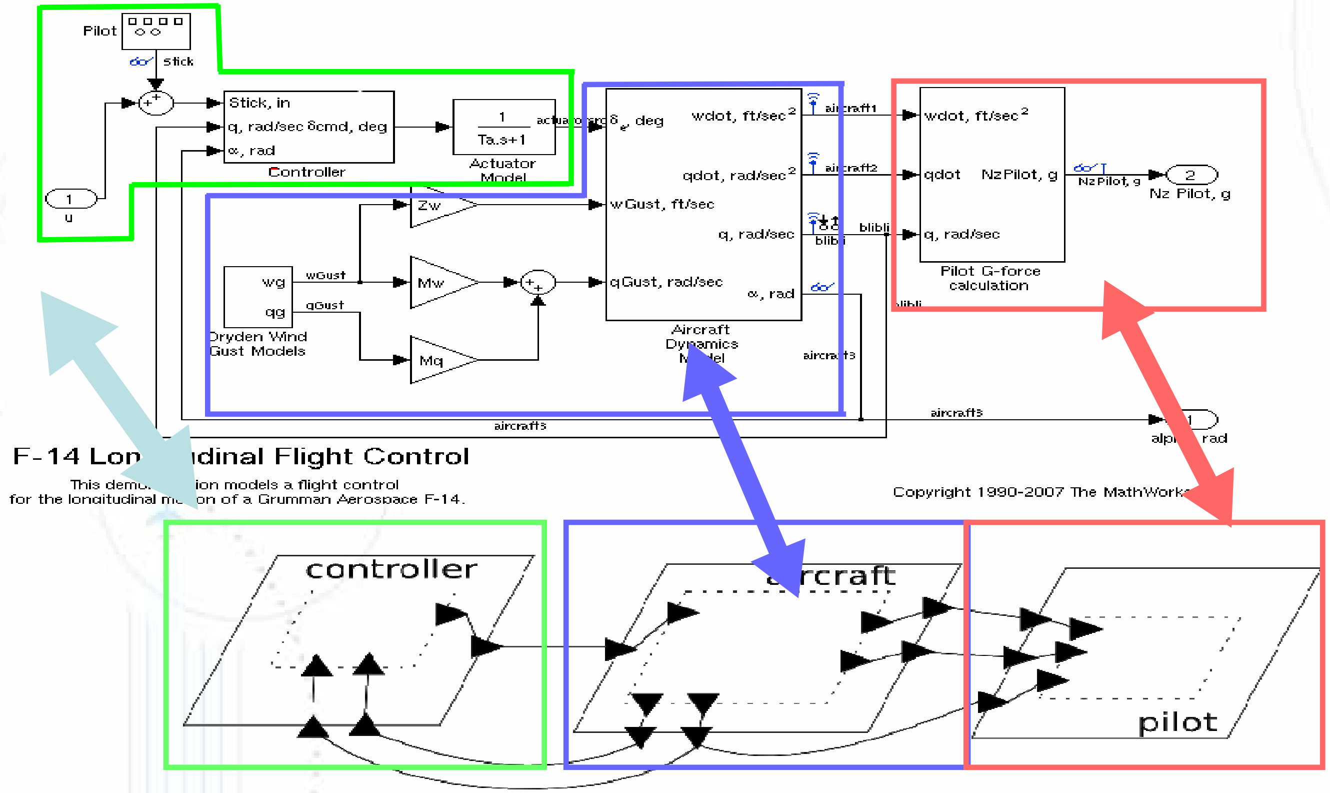
- AADL is an interesting framework to model architectures
  - ➢ Capture key aspects of design: hardware/software
  - ➢ Expression of some non functional properties: priority, resource consumption, latency, jitter, …
  - ➢ Enables: scheduling analysis, resource dimensioning, behavior analysis, mapping for formal methods, fault analysis, …
- Functional modeling notations (e.g. Simulink, SCADE, ..) describes precisely how the system should behave
  - ➢ Provides a high-level behavioral/computational view
  - ➢ Needs to be mapped onto hardware/software elements
- Natural complement to build systems with models
  - ➢ Without hand-written code

”Zero coding” paradigm

- Code generation from models is now a reality
  - Proposed by many tools
- Functional models
  - kcg: SCADE’s certified code generation
  - Real-Time Workshop: Simulink’s code generation
- Architectural models
  - Ocarina: AADL code generator for High-Integrity systems
- Foundations for a “zero coding” approach
  - Model, then integrate code generated from each view
- **Issue:** which integration process ?
  - Two approaches, driven by user demand

Application-driven process

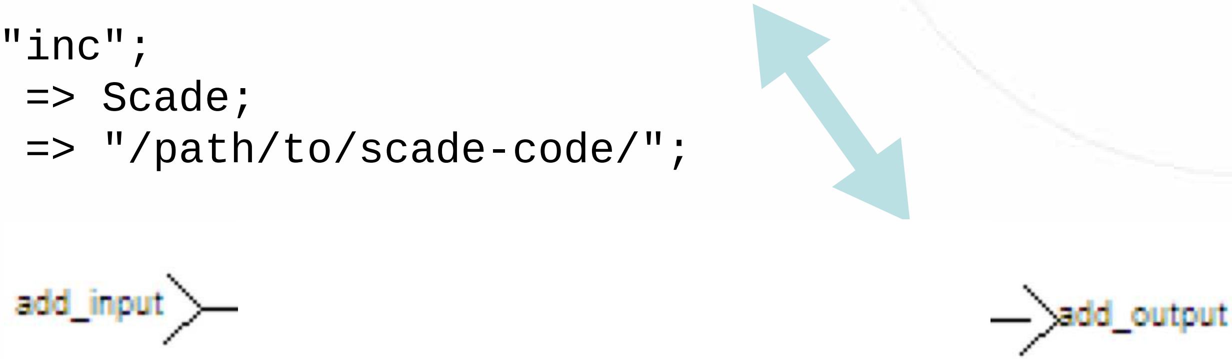
- Functions may be defined first, then refined to be bound to an existing architecture”



Architecture-driven process

- Reverse option: architecture is defined first, then a skeleton of the functional model is deduced, then implemented

```
subprogram spg_scade
features
input: in parameter integer {Source_Name => "add_input";};
output: out parameter integer {Source_Name => "add_output";};
properties
        source_name => "inc";
        source_language => Scade;
        source_location => "/path/to/scade-code/";
end spg_scade;
```



How to bind to AADL models ?

- In both cases, we rely on standard AADLv2 patterns
  - Source_Language <-> SCADE or Simulink
  - Source_Name <-> SCADE node or Simulink block
  - Source_Location <-> SCADE/Simulink generated code

- Smooth integration of AADL and other functional modeling
  - Providing only required information
  - While remaining 100% automatic

From AADL + X tocode

- Ocarina is an AADL-to-code generator
  - See http://aadl.telecom-paristech.fr
  - Joint work Telecom ParisTech, ENIS, ISAE
- Handles all code integration aspects
  - How to map AADL concepts to source code artefacts (POSIX threads, Ada tasks, mutexes, ...)
  - Handle portability concerns to several platforms, from bare to native
- + some knowledge on how a SCADE or Simulink models is mapped onto C code
  - So that integration is done by the code generator
  - No manual intervention required
- Supports **“zero coding”** approach

Code generation patterns

- Each functional framework relies on same foundations
  - ➢ Synchronous: discrete computation cycles
  - ➢ Asynchronous: function calls
- SCADE/Simulink/Esterel: a 3-step process
  - ➢ Fetch **in** parameters from AADL subprograms
  - ➢ Call the **reaction function** to compute output values
  - ➢ Send the output as **out** parameters of the AADL subprogram
- Architectural blocks are mapped onto programming language equivalent constructs
  - ➢ Ocarina relies on stringent coding guidelines to meet requirements for High-Integrity systems, validated though test harness by ESA, Thales, SEI, and their partners

Conclusion

- System are heterogeneous, so are models
- AADL clearly separates architecture from functional models
  - ➢ Allows reference from the architecture to function blocks
- **Our contribution:** integration of AADL and SCADE or Simulink in two processes to perform full generation of systems
- Advantages
  - ➢ “Zero coding” paradigm to ease integration work
  - ➢ Quality of code generated for both functions and architecture
  - ➢ Opens the path towards qualification/certification of complex embedded systems at model-level