VERIFICATION & VALIDATION OF LAUNCHER FLIGHT SOFTWARE

Ada-Europe

International Conference on Reliable Software Technologies

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Julien GRAND

ARIANE 5

Quite expensive

Limited versatility

NOT ADAPTED TO CURRENT MARKET

ARIANE 6

40% cost decrease

High versatility

OBJECTIVE OF HIGH COST EFFICIENCY

➢ More complex and cheaper flight software

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ARIANE 6 FLIGHT SOFTWARE

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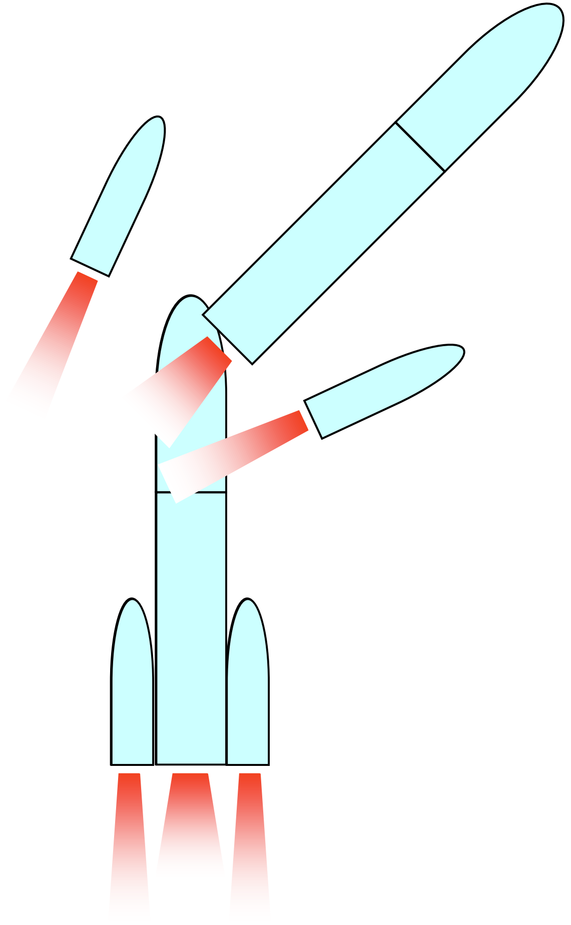
Functions

- **Engines control**
- **Trajectory control**
- **Manage the sequential events (e.g. stage release)**
- **Attitude control**
- **…**



ARIANE 6 FLIGHT SOFTWARE

Specificities

Embedded

- The software is embedded into the launcher computer. This implies limited CPU and memory resources
  - *Example: Few megabytes of memory available*

Real-Time

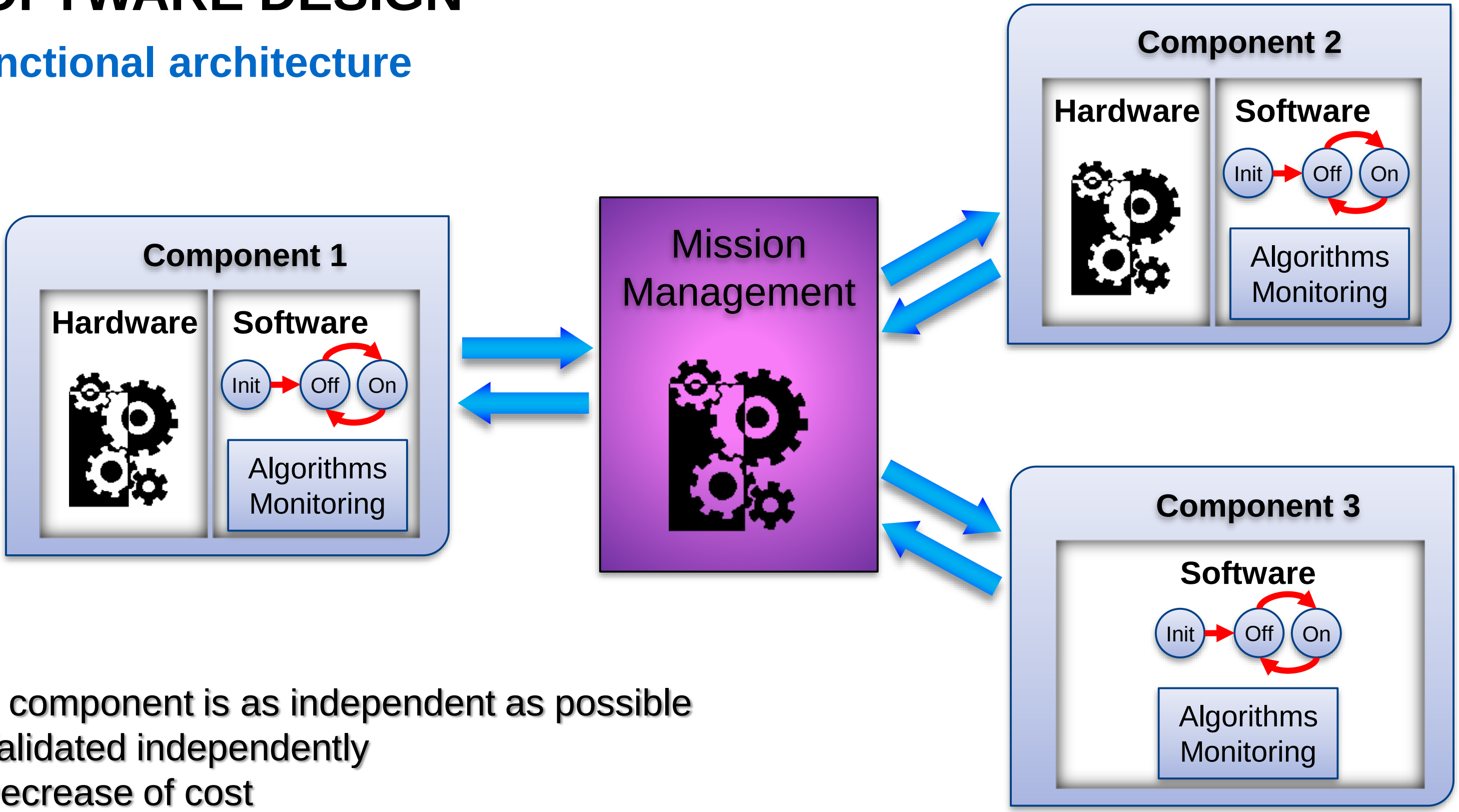
- The software is constrained by time. It shall deliver correct results in imposed deadlines
  - *Example: Reactivity of a few milliseconds*

Critical

- Failure of the software might have huge material damages
  - *Example: Failure may result in the launcher destruction*

SOFTWARE DESIGN

Functional architecture



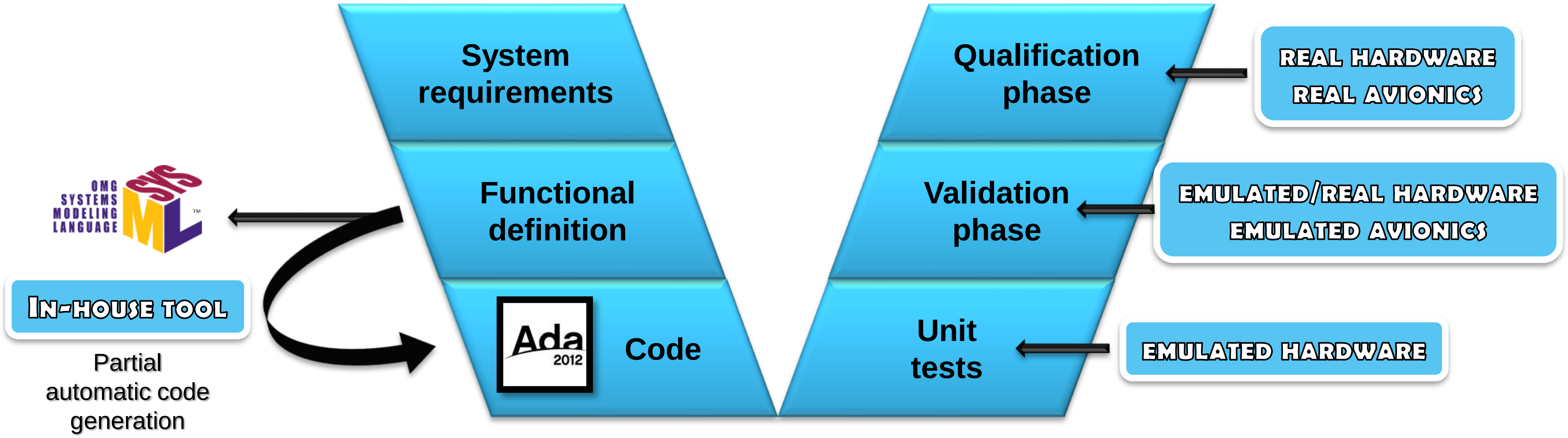
Each component is as independent as possible

⇒ Validated independently

⇒ Decrease of cost

DEVELOPMENT METHOD

V-Cycle

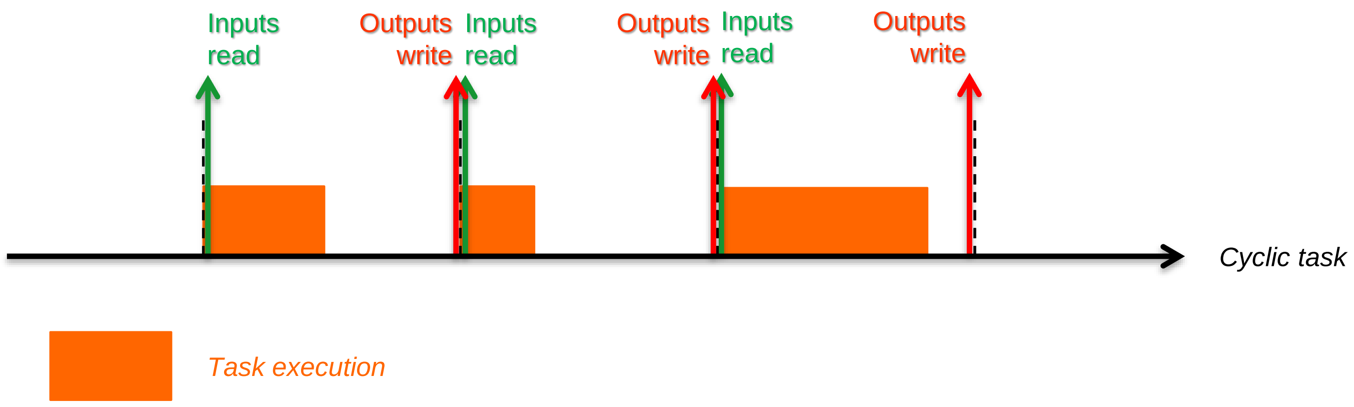


✓ GO FOR LAUNCH

DESIGN PRINCIPLES

Synchronous approach

Cyclic software



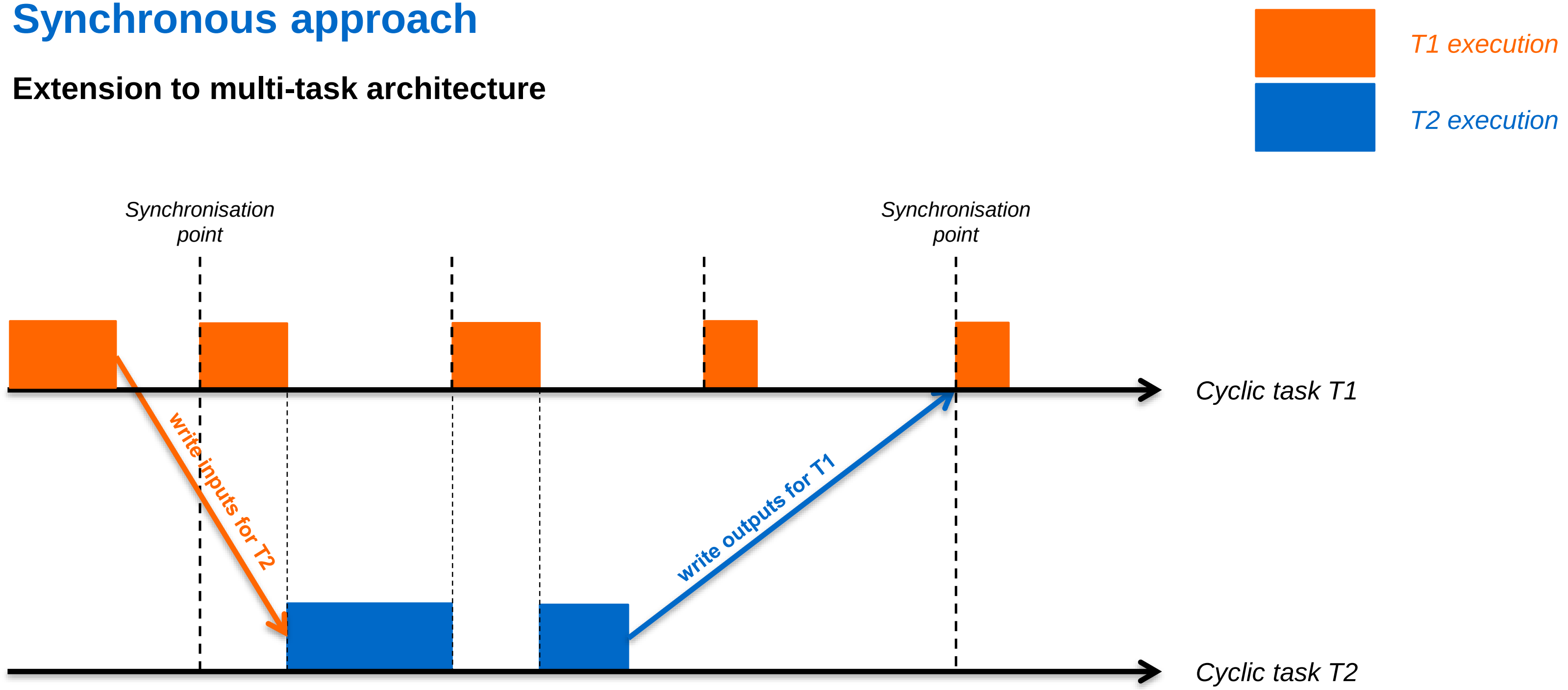
⇒ Functional and Real-Time behaviour independent from WCET

WCET: Worst Case Execution Time

DESIGN PRINCIPLES

Synchronous approach

Extension to multi-task architecture

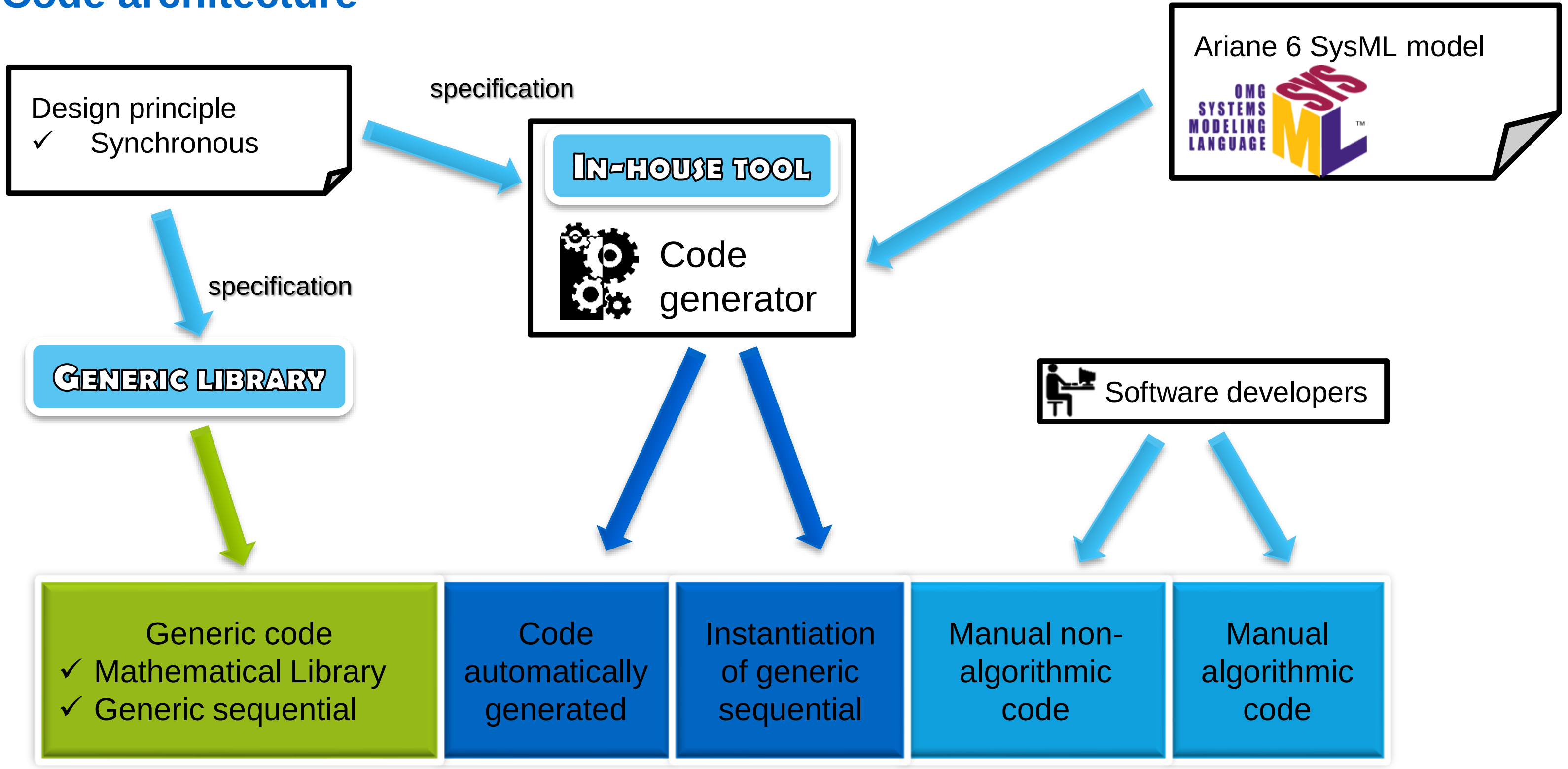


⇒ Functional and Real-Time behaviour independent from WCET

WCET: Worst Case Execution Time

SOFTWARE DESIGN

Code architecture



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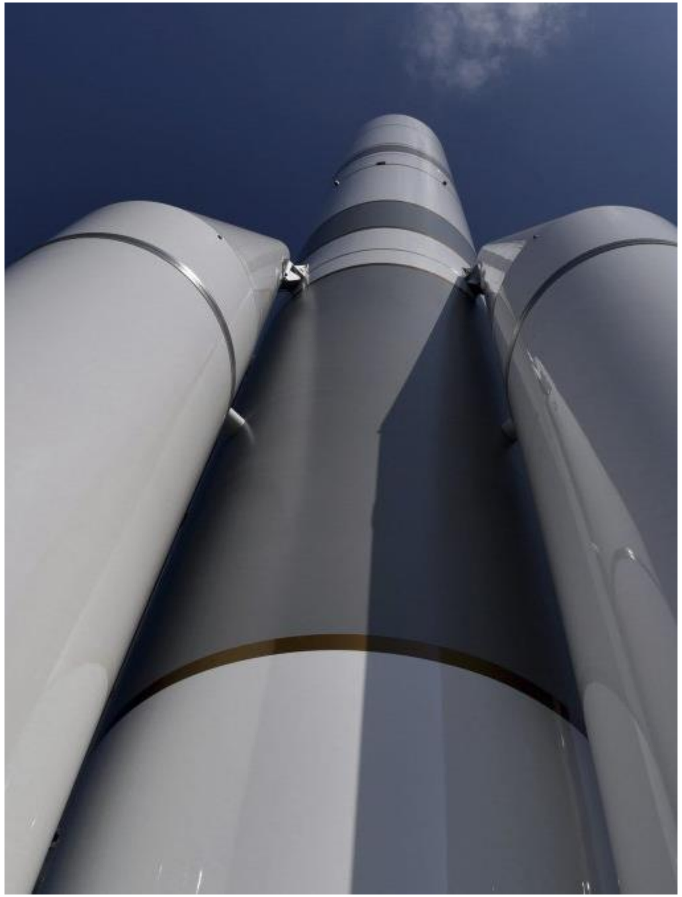
VALIDATION METHODS

VALIDATION METHODS

Objectives:

- **ensure the correctness of the flight software**
- **decrease the validation costs**



VALIDATION METHODS

Means to perform the validation

- **Emulated hardware**

✓ Faster than real on-board computer
✓ Easier debugging

⇒ Used for tests preparation

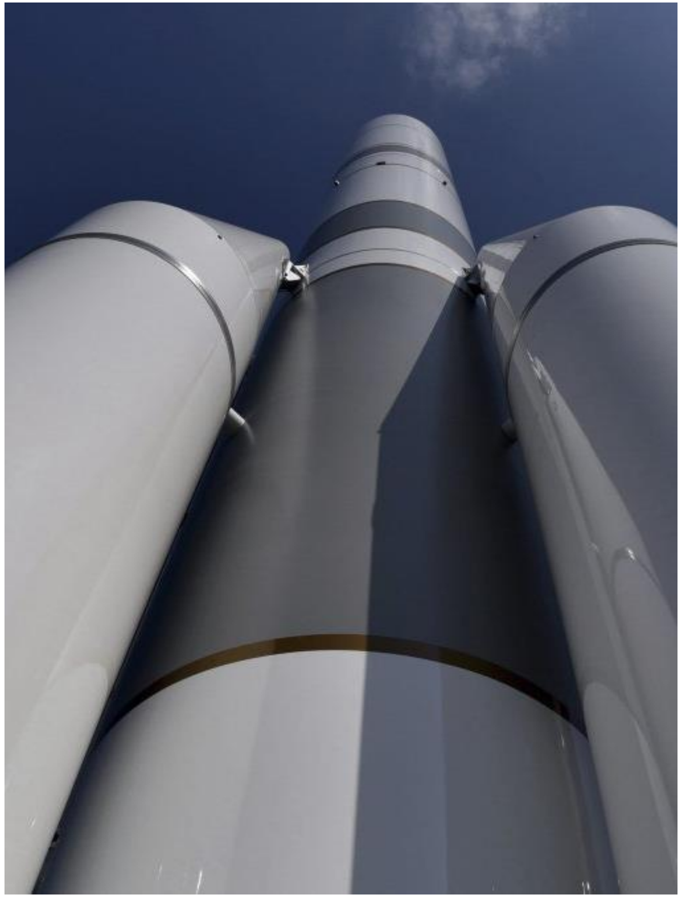
- **Real hardware**

✓ Fully representative of the flight

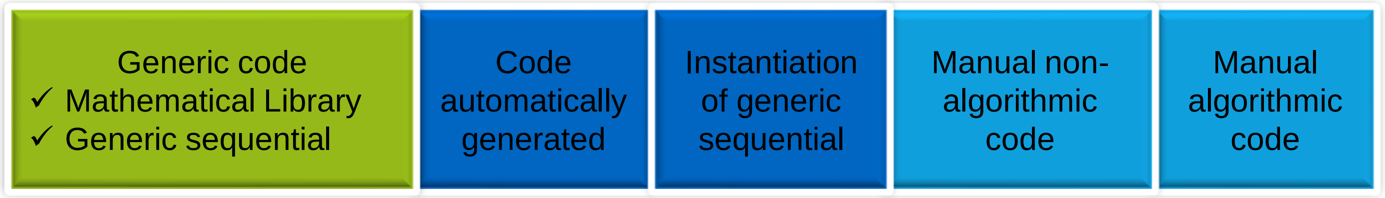
⇒ Used for formal tests

Synchronous principle
⇒ **Identical behaviour on real and emulated hardware when WCET are met**

WCET: Worst Case Execution Time



GENERIC CODE VALIDATION


Generic code
✓ Mathematical Library
✓ Generic sequential
Code automatically generated
Instantiation of generic sequential
Manual non-algorithmic code
Manual algorithmic code

Flight software code architecture

GENERIC CODE VALIDATION

Validation on representative instantiations of the generic code

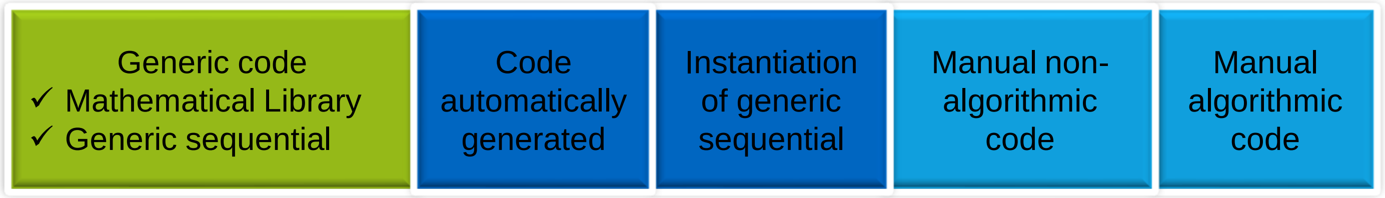
Example of the mathematical library

- Generic code for matrix operations

⇒ Validation on instantiations for matrix of sizes:

- 1x1 (specific case)
- 3x1 (column matrix)
- 1x3 (row matrix)
- 5x3

GENERATED CODE VALIDATION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Flight software code architecture

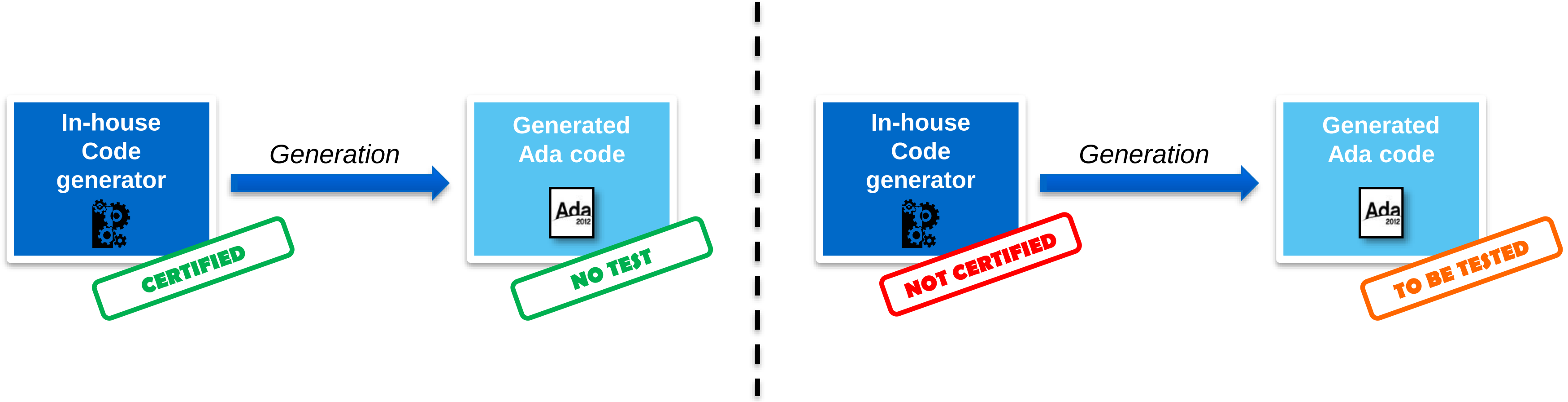
GENERATED CODE VALIDATION

Flight software criticality: B

In-house code generator criticality: D

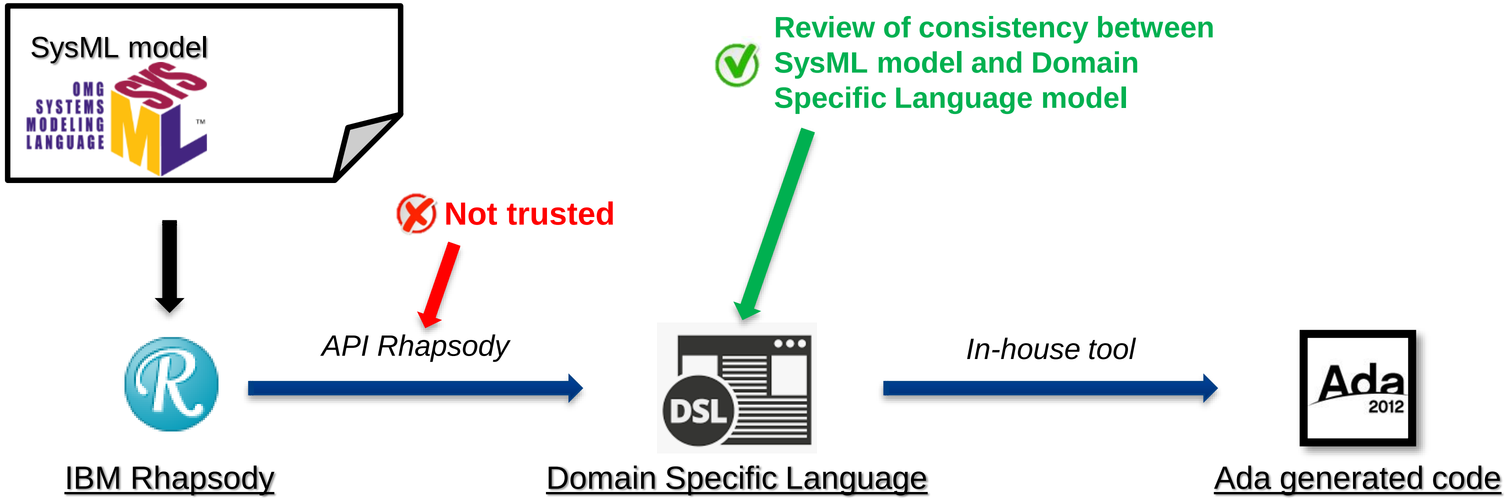
⇒ **To decrease the cost**

⇒ **The generated code shall be validated**



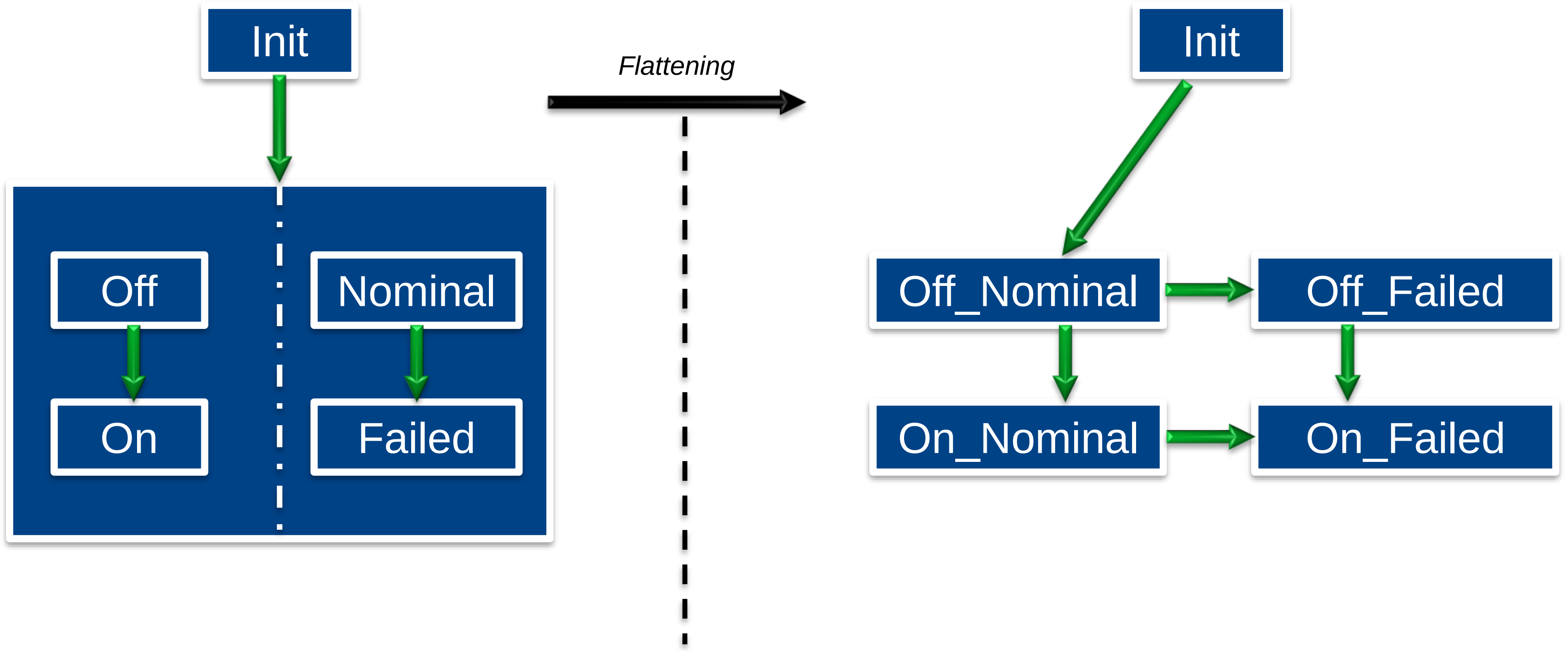
GENERATED CODE VALIDATION

Code generation principle



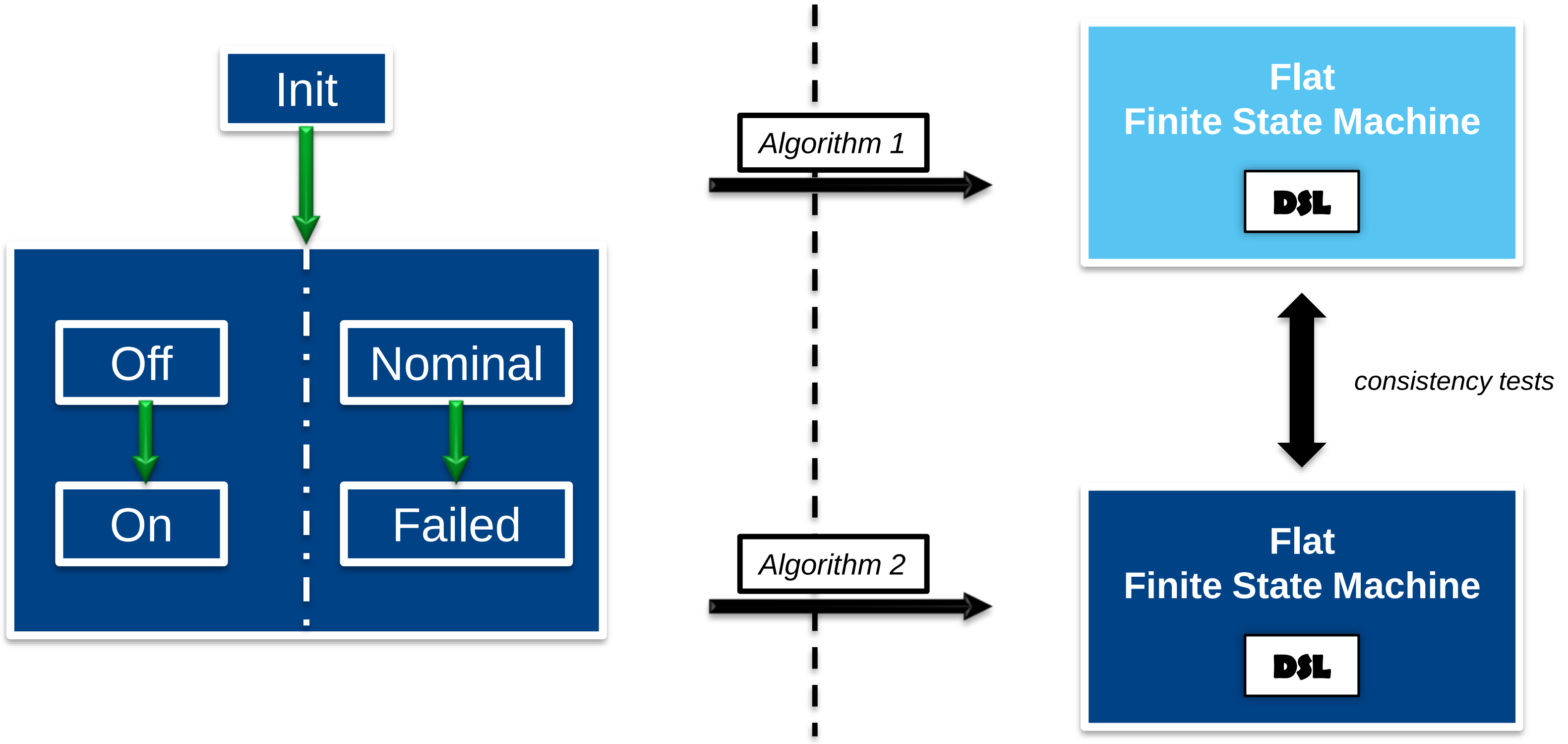
GENERATED CODE VALIDATION

Finite State Machines



GENERATED CODE VALIDATION

Finite State Machines



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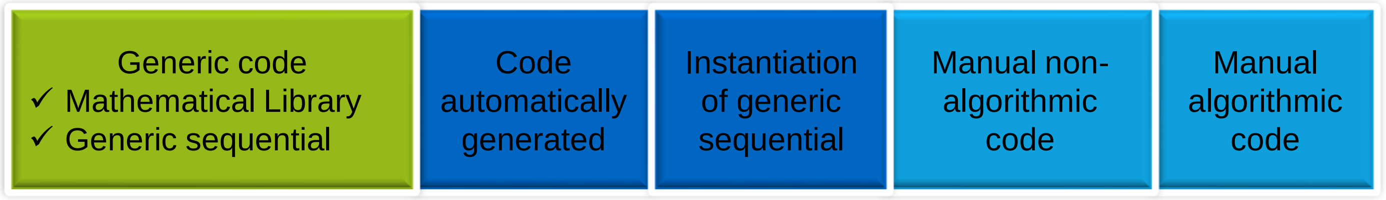
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<ins>Flight software code architecture</ins>

GENERATED CODE VALIDATION

Sequential events validation

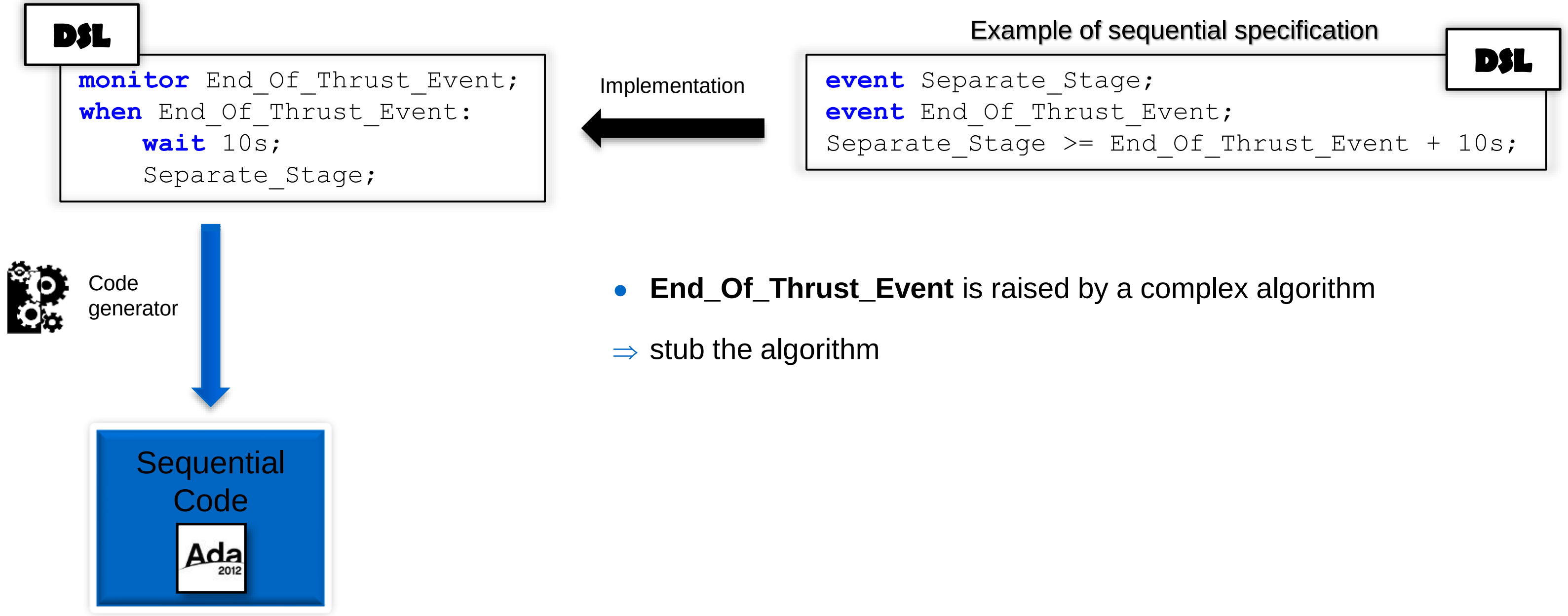
Examples of sequential events: stage release, fault management…

- Specification: timed constraints on sequential events

- Validation by simulation

GENERATED CODE VALIDATION

Sequential events validation



```
monitor End_Of_Thrust_Event;
when End_Of_Thrust_Event:
    wait 10s;
    Separate_Stage;
```

Example of sequential specification

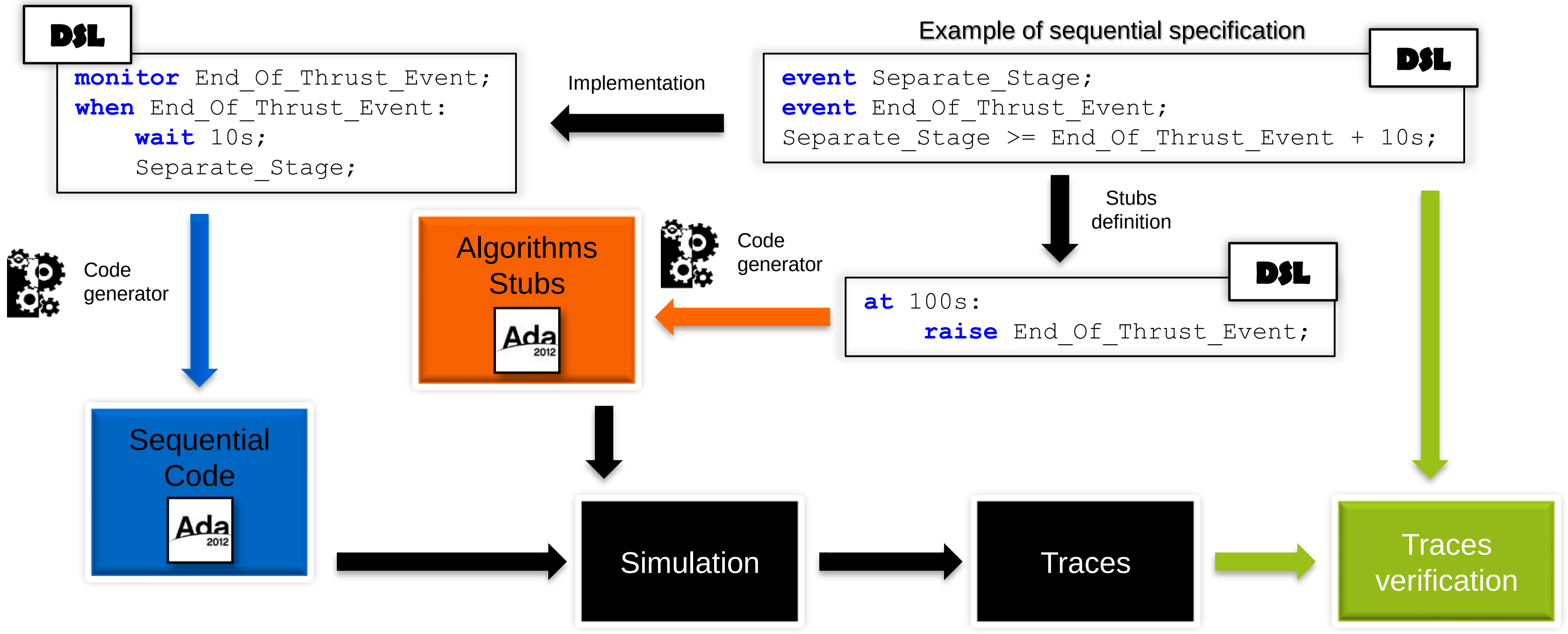
```
event Separate_Stage;
event End_Of_Thrust_Event;
Separate_Stage >= End_Of_Thrust_Event + 10s;
```

- **End_Of_Thrust_Event** is raised by a complex algorithm

⇒ stub the algorithm

GENERATED CODE VALIDATION

Sequential events validation



Example of sequential specification

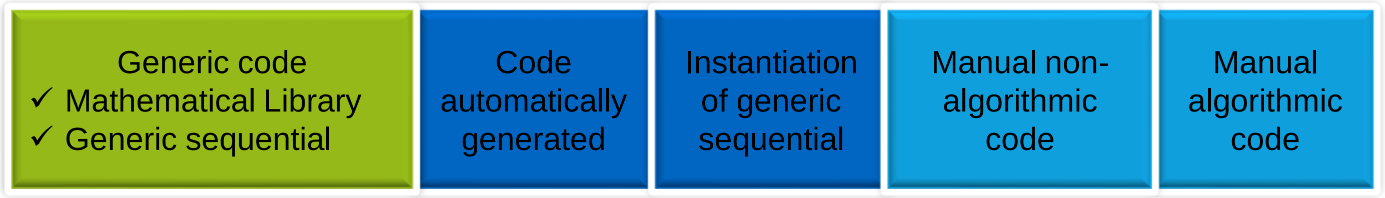
```
event Separate_Stage;
event End_Of_Thrust_Event;
Separate_Stage >= End_Of_Thrust_Event + 10s;
```

```
monitor End_Of_Thrust_Event;
when End_Of_Thrust_Event:
    wait 10s;
    Separate_Stage;
```

```
at 100s:
    raise End_Of_Thrust_Event;
```

MANUAL CODE VALIDATION

Non-algorithmic code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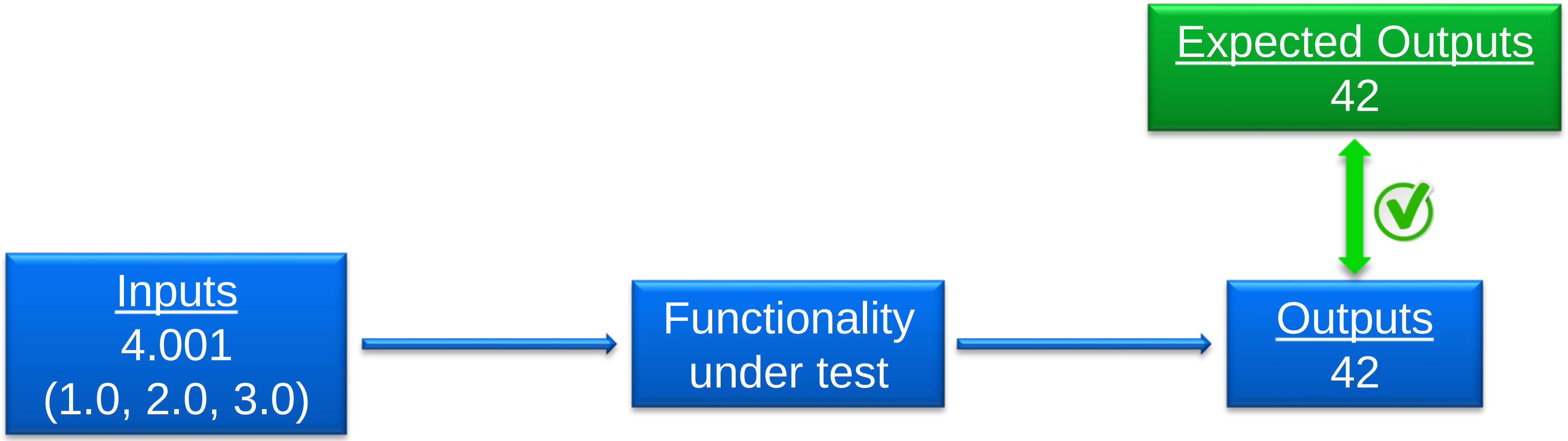
<u>Flight software code architecture</u>

MANUAL CODE VALIDATION

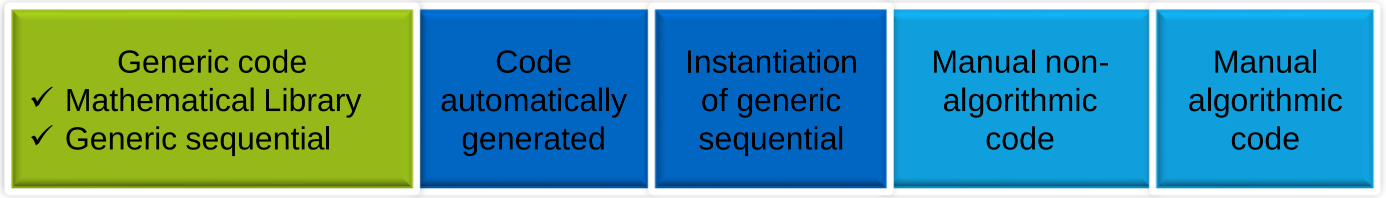
Non-algorithmic code

⇒ **Open-Loop approach**



MANUAL CODE VALIDATION

Algorithmic code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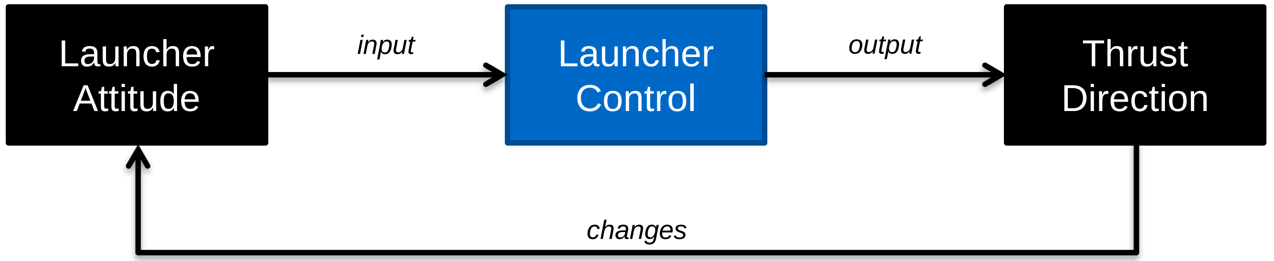
<u>Flight software code architecture</u>

MANUAL CODE VALIDATION

Algorithmic code

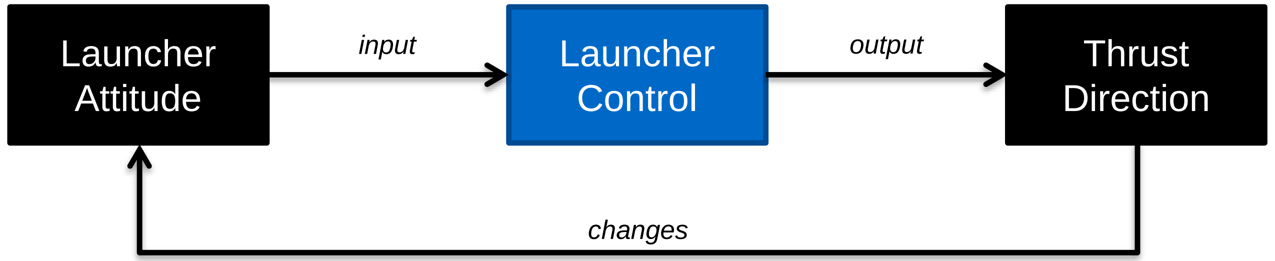
A classical open-loop approach is not possible for algorithmic code



MANUAL CODE VALIDATION

Algorithmic code

A classical open-loop approach is not possible for algorithmic code

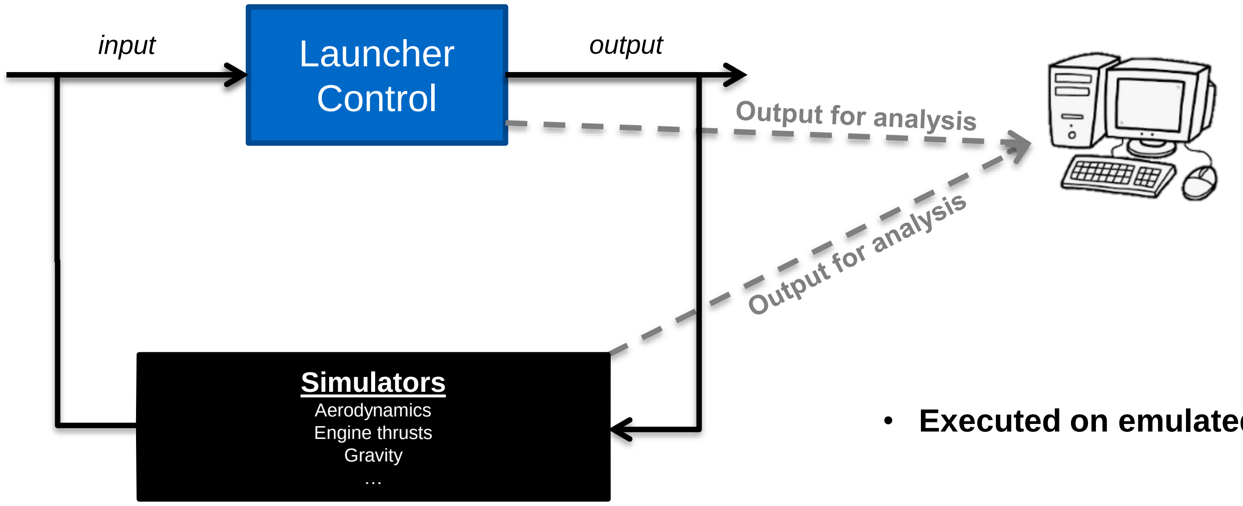


Simulators
Aerodynamics
Engine thrusts
Gravity
…

MANUAL CODE VALIDATION

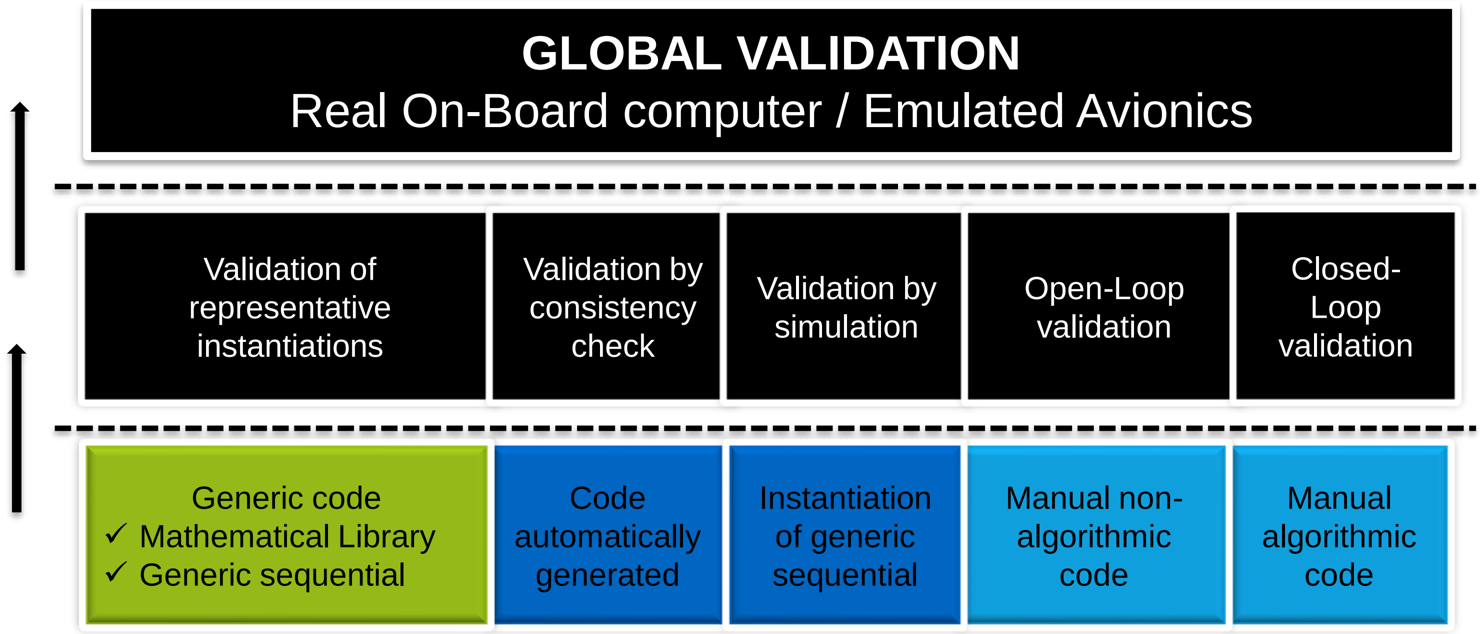
Algorithmic code

Closed-Loop approach



- **Executed on emulated hardware**

GLOBAL VALIDATION


GLOBAL VALIDATION
Real On-Board computer / Emulated Avionics
Validation of representative instantiations
Validation by consistency check
Validation by simulation
Open-Loop validation
Closed-Loop validation
Generic code
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✓ Generic sequential
Code automatically generated
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Manual algorithmic code

CONCLUSION

- **Different kinds of code**
- **Adaptation of validation methods**
- **Decrease of costs**

OBJECTIVE ACHIEVED

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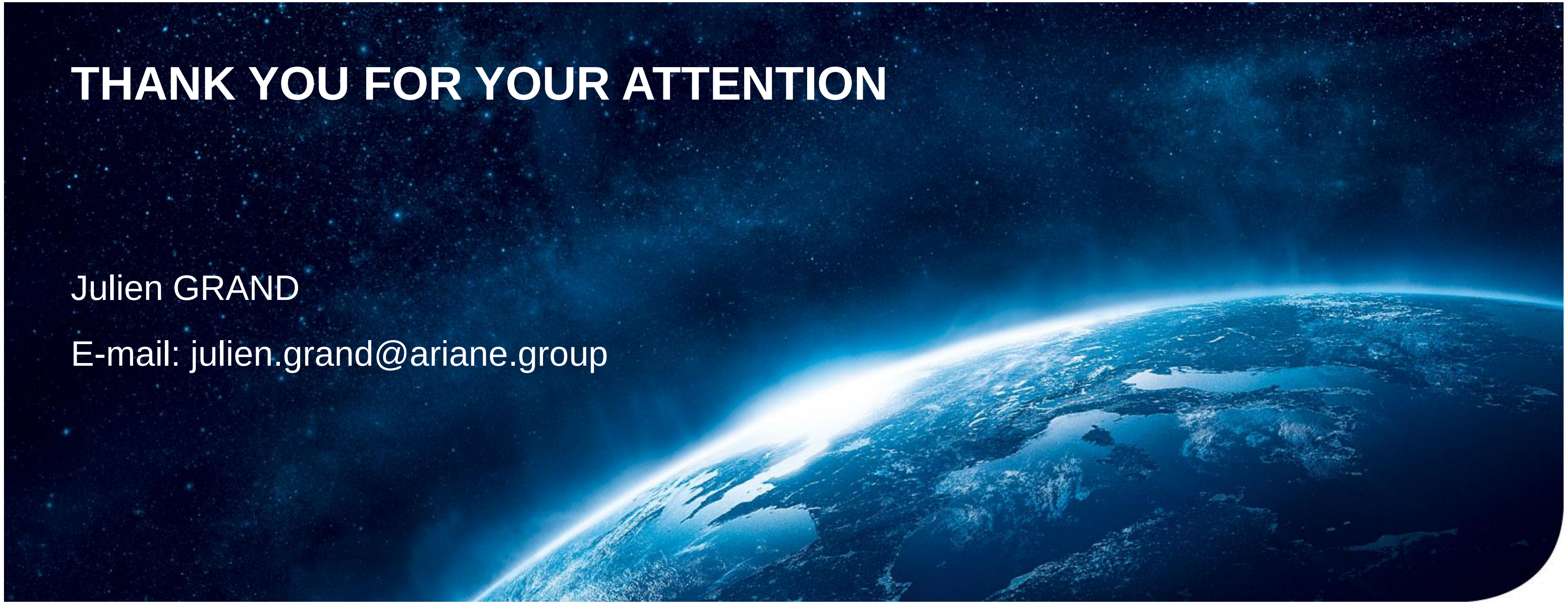

THANK YOU FOR YOUR ATTENTION

Julien GRAND

E-mail: julien.grand@ariane.group