INFORMATION TECHNOLOGY FOR EUROPEAN ADVANCEMENT

D6.2.2 – Intermediate and final report on multi-core compilation

WP 6.2: Efficient operation and simulation on multi-core platforms

Work Package 6: Modelling and simulation services

MODRIO (11004)

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Summary

Executive summary

The objective of this work-package was to speed-up the simulation of large models.

Detailed requirements have been detailed within the deliverable D6.2.1 [R02]. This document provides results of tests of multi-core compilation and simulation of Modelica model.

1. SUMMARY

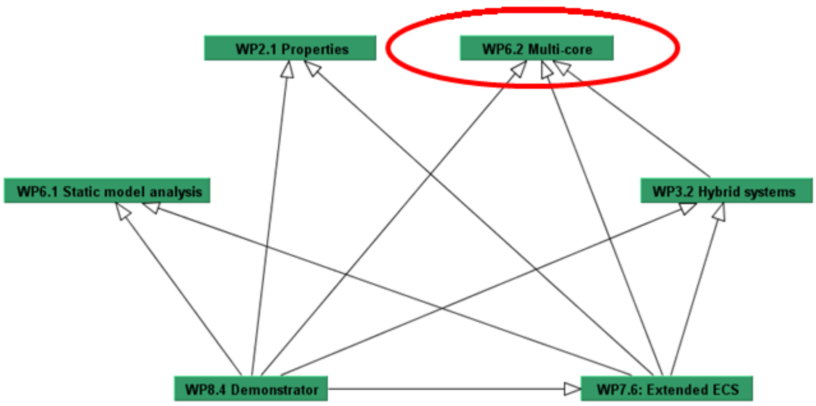
The objective of this work-package was to speed-up the simulation of large models.

Detailed requirements have been detailed within the deliverable D6.2.1 [R02]. This document provides results of tests of multi-core compilation and simulation of Modelica model.

For Dassault-Aviation, the main challenge of Modrio is to be able to make fast, accurate and selective diagnostics from data measurement made on the aircraft. It is also to improve the current status concerning simulation of large models during the design phase.

The purpose of this work-package is to focus on features required to fulfill the overall objectives: enable sufficiently fast systems simulations to make system design and diagnosis from comparison between aircraft measurements and models simulations.

Dependencies with other Work-Package:



1.1 Acronyms

- BCV : Brake Control Valve
- BLEED : Bleed Air System
- BIZJET : Business aircraft
- DMU : Digital Mock-Up
- ECS : Environmental Control System
- FMI/FMU : Functional Mock-up Interface / Unit
- LTS : Liebherr Aerospace Toulouse
- TOICA : Project FP7 TOICA (Thermal Overall Integrated Concept of Aircraft)
- WAI : Wing Anti-Icing

2. APPLICATION OF MULTI-CORE CAPABILITIES

The multi-cores capabilities have been tested mainly with Dassault Systèmes Dymola. In Dymola the multi-cores feature exists from Dymola 2015FD01. It is an automatic feature enabled by setting a flag (Advanced.ParallelizeCode) to true.

Dymola automatically inquires the number of available cores, including Hyper-threading.

According to the last available Dymola documentation (Dymola 2017):

“• The compiler used must support OpenMP. For Visual Studio this means that you must

use Visual Studio Professional 2010 or later, or Visual Studio Express 2012 or later.

On Windows, the GCC versions that Dymola supports, also support OpenMP.

• Multi-core simulation is currently only supported for dassl, lsodar, euler and rkfix,

when neither using DLL nor embedded server (DDE, OPC).”

The following paragraphs describe tests that have been performed with this new feature.

2.1 Test on an aircraft braking system

The multi-core capability has been applied on a braking system which normally requires nearly 1100s (20 min) to simulate 15s of real time.

2.1.1 Model description

The system is composed of hydraulic circuit composed of detailed models servo valves (BCV), braking blocks (with detailed hydraulics and mechanical components) and piping elements (rigid and flexible pipes, bents ...). The following figure represents the top level representation of the braking system.

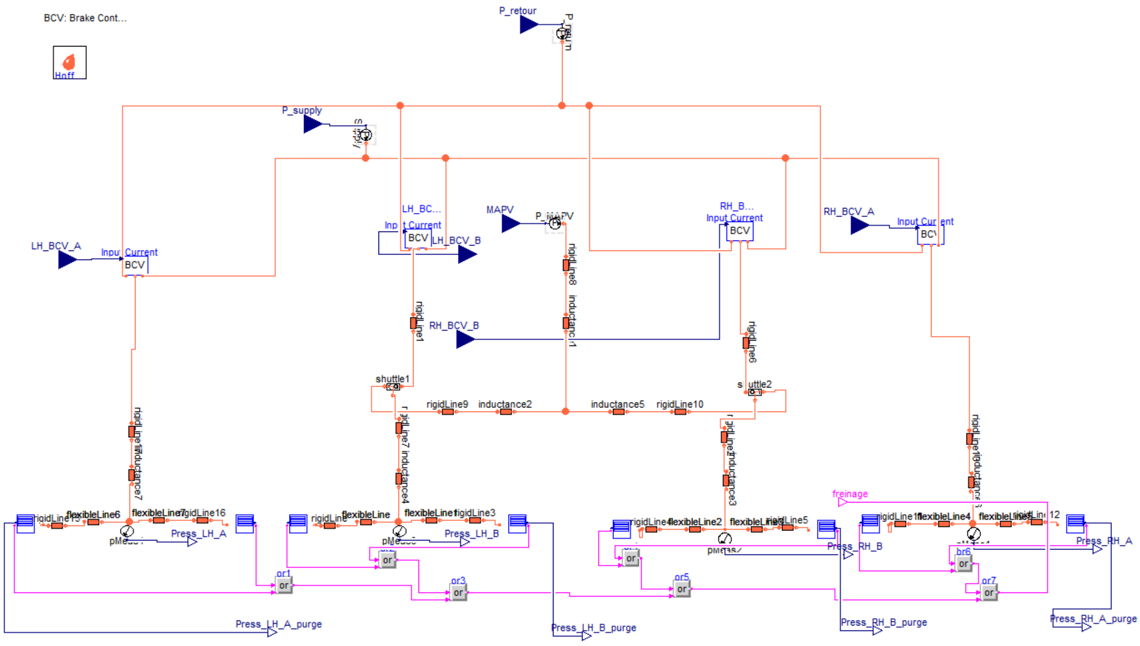


Figure 1 : CPU time with and without multicore feature

2.1.2 Model particularities

The DAE has **20730 scalar unknowns and scalar equations**.

Statistics after translation:

- Constants: 8768 scalars
- Free parameters: 5503 scalars
- Parameter depending: 5046 scalars
- **Continuous time states: 345 scalars**
- **Time-varying variables: 7139 scalars**
- Alias variables: 8451 scalars
- Assumed default initial conditions: 296
- **Number of mixed real/discrete systems of equations: 36**

2.1.3 Simulation particularities

2.1.3.1 Simulation platform

Hardware:
- Computer : HP Z420 Workstation
- Processor : Intel® Xeon® CPU ES-1620 0 @ 3.60 GHz
- RAM : 16.0 Go

Software:
- Tool : Dymola 2015x, 2016x, 2017
- Solver: DASSL

2.1.4 Tests

Only by setting Advanced.ParallelizeCode = true, we obtain the following result:

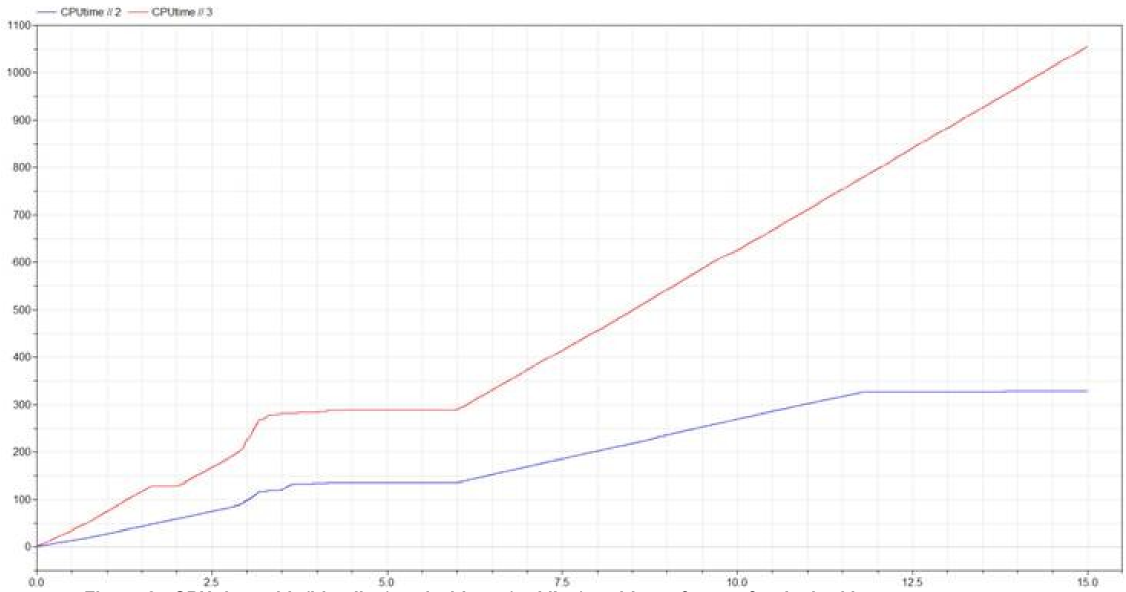


Figure 2 : CPU time with (blue line) and without (red line) multicore feature for the braking system use-case

2.2 Test on a wing anti-Icing system

The multi-core capability has been applied on a part of the complex model of a wing anti-icing system which normally requires nearly 2500s to simulate about 200s of real time.

2.2.1 Model description

The complete model is composed of 2 main parts:

- (1) A thermal and thermal fluid part, modeled with 1D Modelica components
- (2) A 2D/3D thermal-aerodynamic model

These two models are normally coupled using FMI.

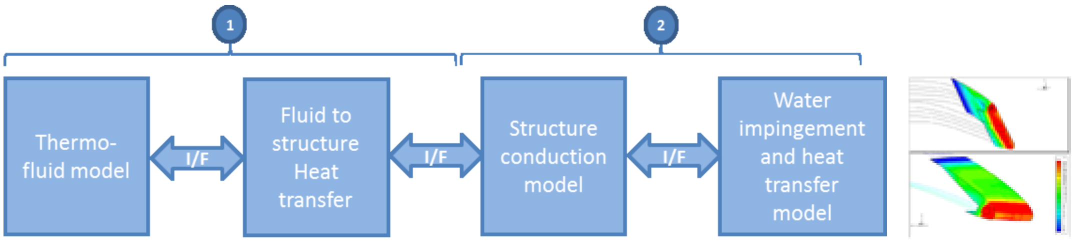


Figure 3 : Process regarding Preliminary Design and System

In this use case, part (2) is modeled only as constant boundary conditions, with no special initializations.

Part 1 is composed of:

- A thermal part which automatically create components (several hundreds of components) at translation which bind the 3D part to the 1D thermal-fluid part; and set parameters of the components (thousands of parameters defined from de 3D Digital Mock-Up)
- A 1D thermal-fluid part which reproduces the internal piping flow within the wing structure, divided into three slats.

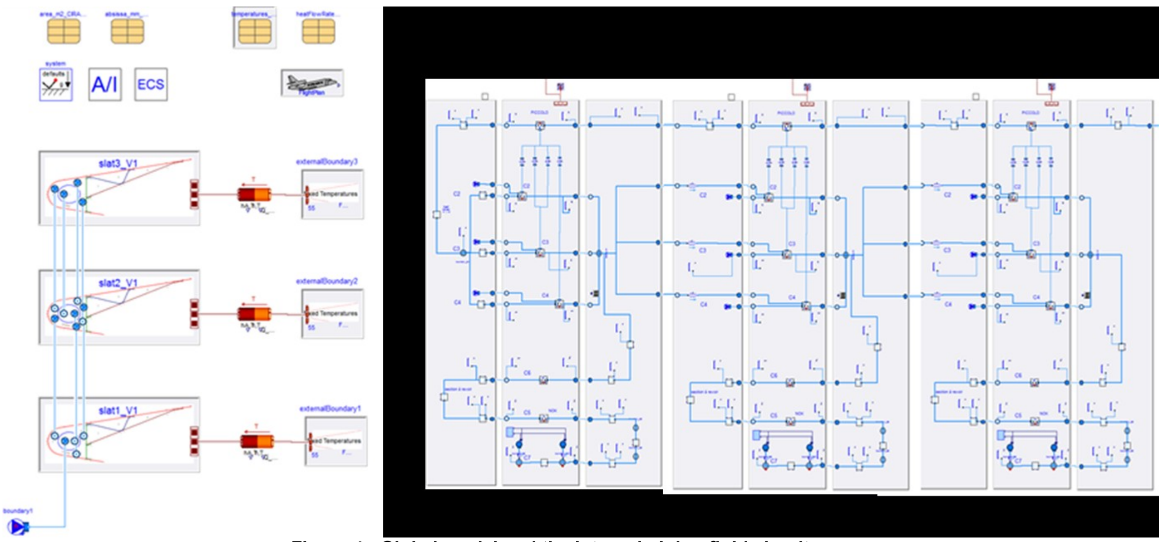


Figure 4 : Global model and the internal piping fluid circuit

2.2.2 Model particularities

The DAE has **71577 scalar unknowns and scalar equations**.

Statistics after translation:

- Constants: 77032 scalars
- Parameter depending: 131 scalars
- Outputs: 2 scalars
- **Continuous time states: 1295 scalars**
- **Time-varying variables: 19221 scalars**
- Alias variables: 30040 scalars
- Assumed default initial conditions: 839
- **Number of mixed real/discrete systems of equations: 0**

2.2.3 Simulation particularities

Hardware:

- Computer : HP Z420 Workstation
- Processor : Intel® Xeon® CPU ES-1620 0 @ 3.60 GHz
- RAM : 24.0 Go

Software:

- Tools : Dymola 2015x, 2016x, 2017
- Solvers : RADAU IIa, DASSL

Note: as the DAE system is stiff at the beginning of the simulation, the usual solver used for such simulation is often RADAU IIa. As it is not yet compatible with the multicore feature of Dymola, DASSL has been used instead, even if it is often less efficient than RADAU IIa.

2.2.4 Tests

Only by setting Advanced.ParallelizeCode = true, we obtain the following result:

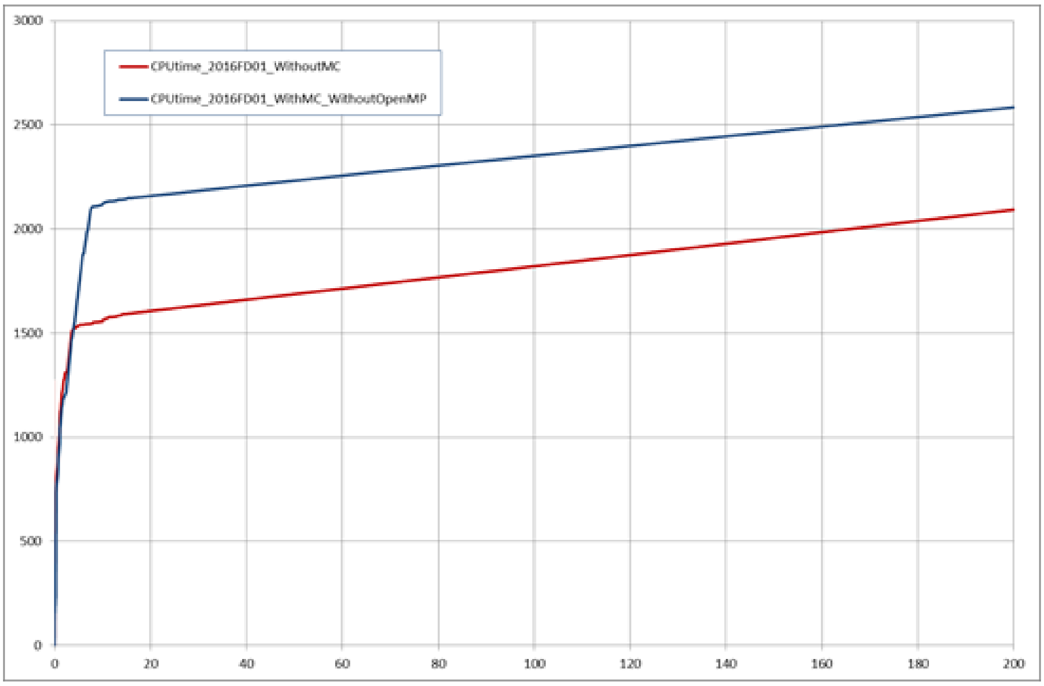


Figure 5 : CPU time with and without multicore feature for the WAI use-case

2.3 Test on an multi-systems use-case

The multi-core capability has been applied on the multi-systems use case of the project FP7 TOICA (see [R01]).

2.3.1 Model description

The system is composed of multiple which may have different level of details. They can be Modelica models or FMUs. In the case of the use case the systems BLEED and ECS at the center of the next figure when FMUs provided by a design partner. The simulated model is then very representative of a model used for operational architecture assessment, optimization or trade-off (as defined within the project FP7 TOICA, see figure 7, and the base of the demonstrator [R03]).

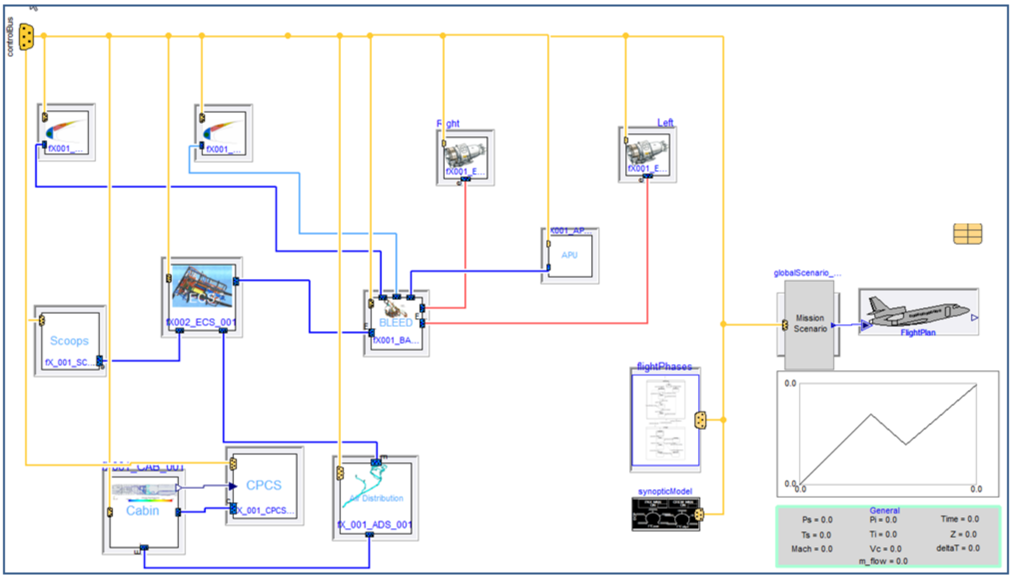


Figure 6 : Global multi-system model, including FMUs

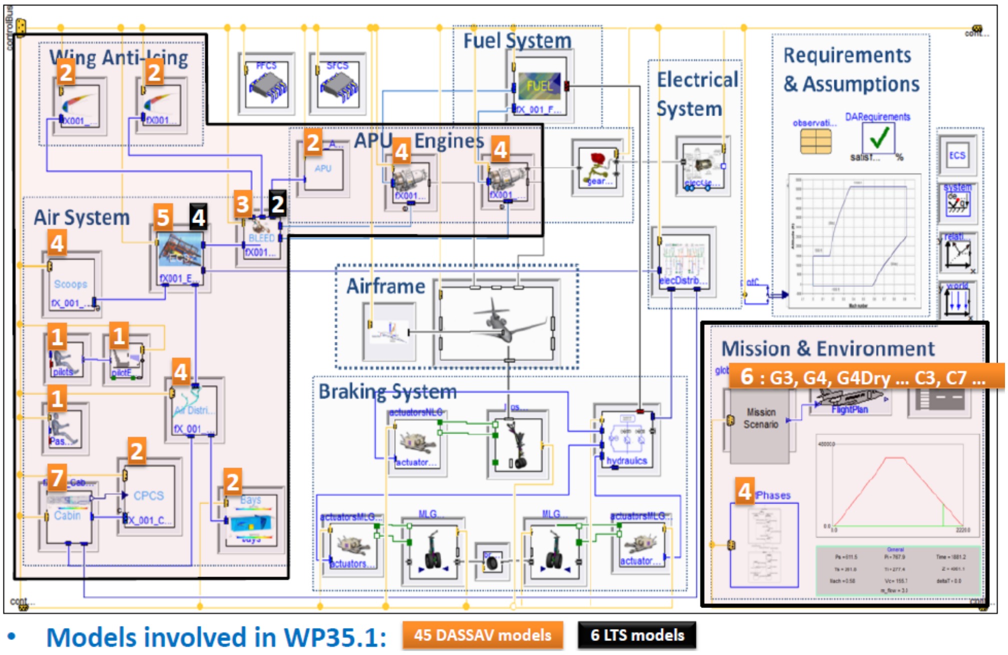


Figure 7 : Example of a global multi-system, with multi-levels models, as defined into the project FP7 TOICA

2.3.2 Model particularities

The DAE has **10916 scalar unknowns and scalar equations**.

Statistics after translation:

- Constants: 13671 scalars
- Parameter depending: 160 scalars
- Outputs: 2 scalars
- **Continuous time states: 174 scalars**
- **Time-varying variables: 1922 scalars**
- Alias variables: 6869 scalars
- **Number of mixed real/discrete systems of equations: 0**

2.3.3 Model particularities

Hardware:

- Computer : HP Z420 Workstation
- Processor : Intel® Xeon® CPU ES-1620 0 @ 3.60 GHz
- RAM : 24.0 Go

Software:

- Tools : Dymola 2015x, 2016x, 2017
- Solver: DASSL

2.3.4 Tests

Only bay setting Advanced.ParallelizeCode = true, we obtain the following result:

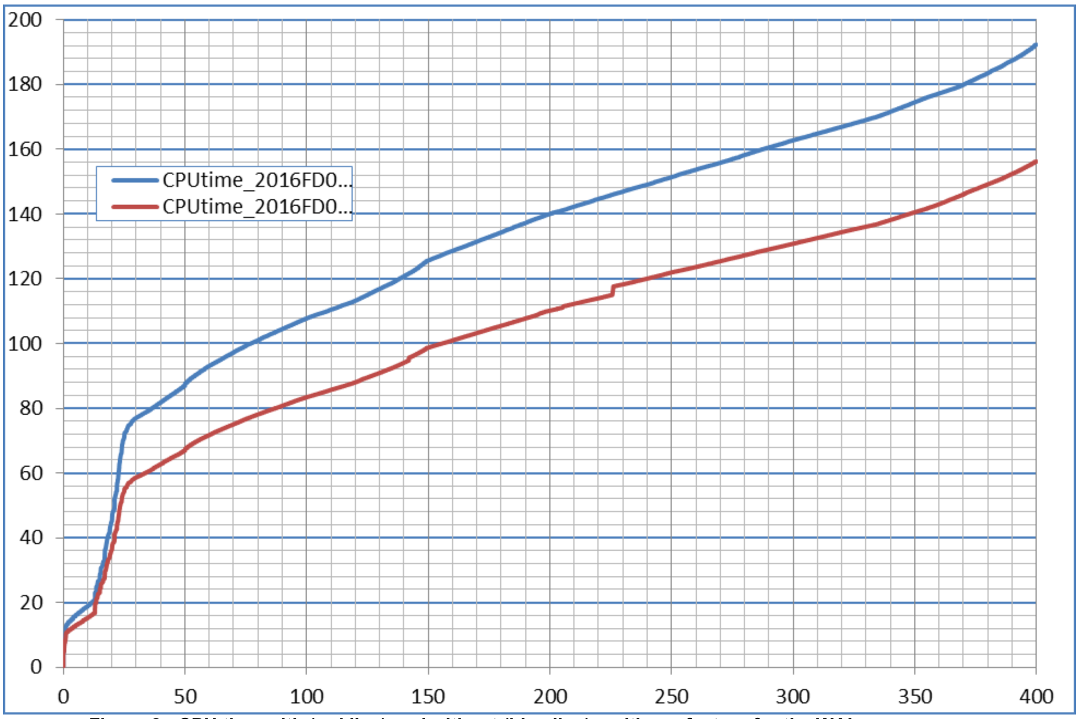


Figure 8 : CPU time with (red line) and without (blue line) multicore feature for the WAI use-case

3. CONCLUSIONS

- The multi-cores feature is activated with different flags in Dymola.
    - Generally, simulation speed is increased by a positive factor (from +20% to 3 according to the tests performed) without modifying the models.
    - But, sometimes, it doesn't work without knowing why.
- All solvers are not supported, in particular Radau IIa (order 5) which is often used for stiff models.

4. REFERENCES

[R01] Modelica Conference 2015: "Towards Enhanced Process and Tools for Aircraft Systems Assessments during very Early Design Phase" Eric Thomas[1] Olivier Thomas[1] Raphael Bianconi[1] Matthieu Crespo[2] Julien Daumas[2]
[1]Dassault Aviation, France, [2]Liebherr Aerospace, France

[R02] WP6.2 / D6.2.1-DGT139136-Requirements for multi-core compilation

[R03] WP8.4 / D8.4.2-DGT153570-Business aircraft Demonstrator