Journée Thématique “Validation au plus tôt des choix d’Architecture Système par utilisation des modèles MBSE/MBSA”

Synchronization of heterogeneous models: a proof of concepts

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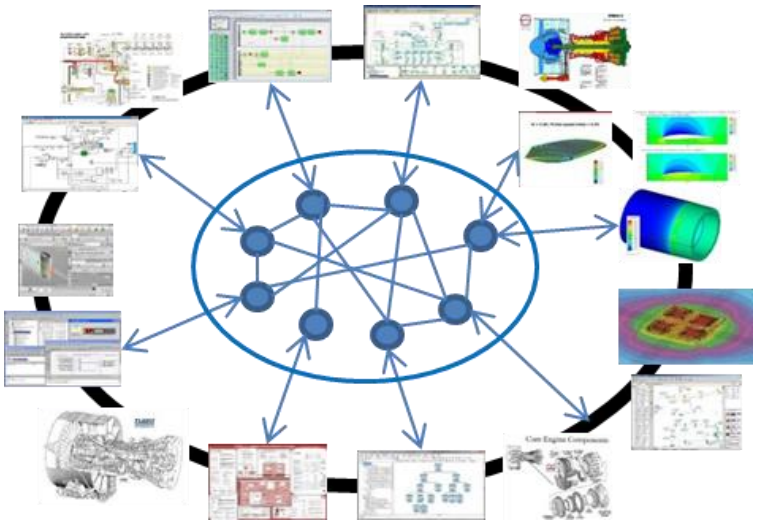
JT AFIS du 19 Juin 2019

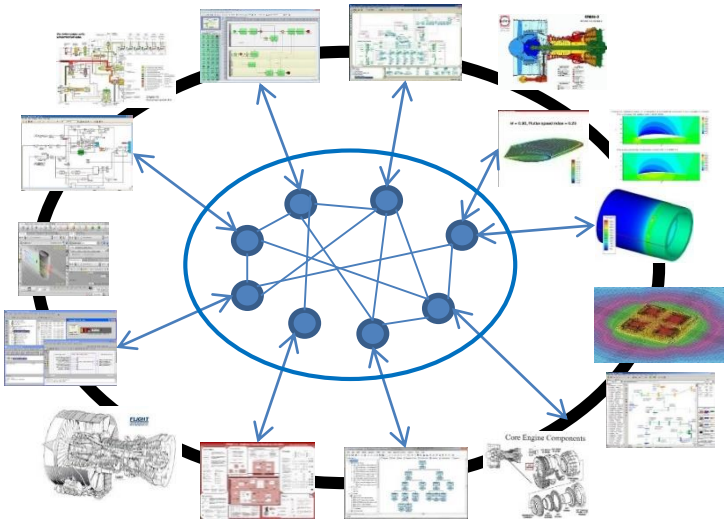


CONTEXT

Motivations: Integration of models

Today, a major challenge of industry is to **integrate the different systems engineering disciplines** (such as system architecture, control, multi-physics simulation, automatic code generation, safety and performances analyses…).

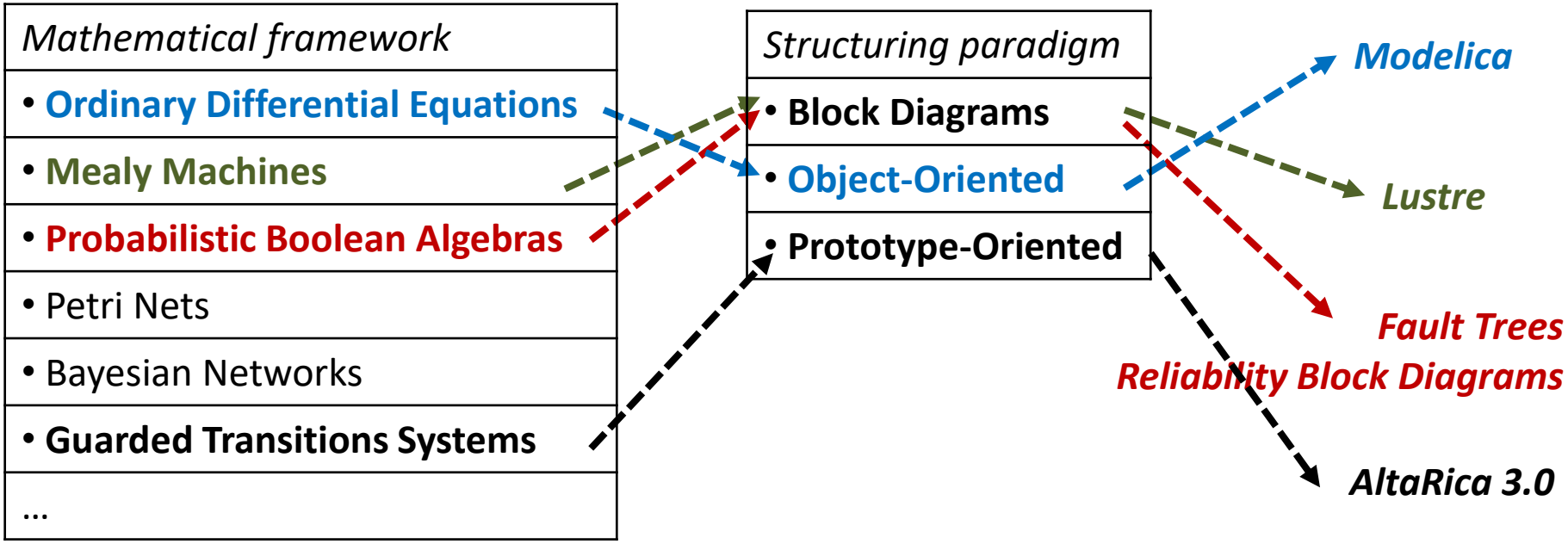
In all systems engineering disciplines, there is a growing interest for the so-called **Model-Based approach** (as opposed to Document-centric approach).



The integration of systems engineering disciplines goes through the integration of the artefacts, i.e. the models, they produce.

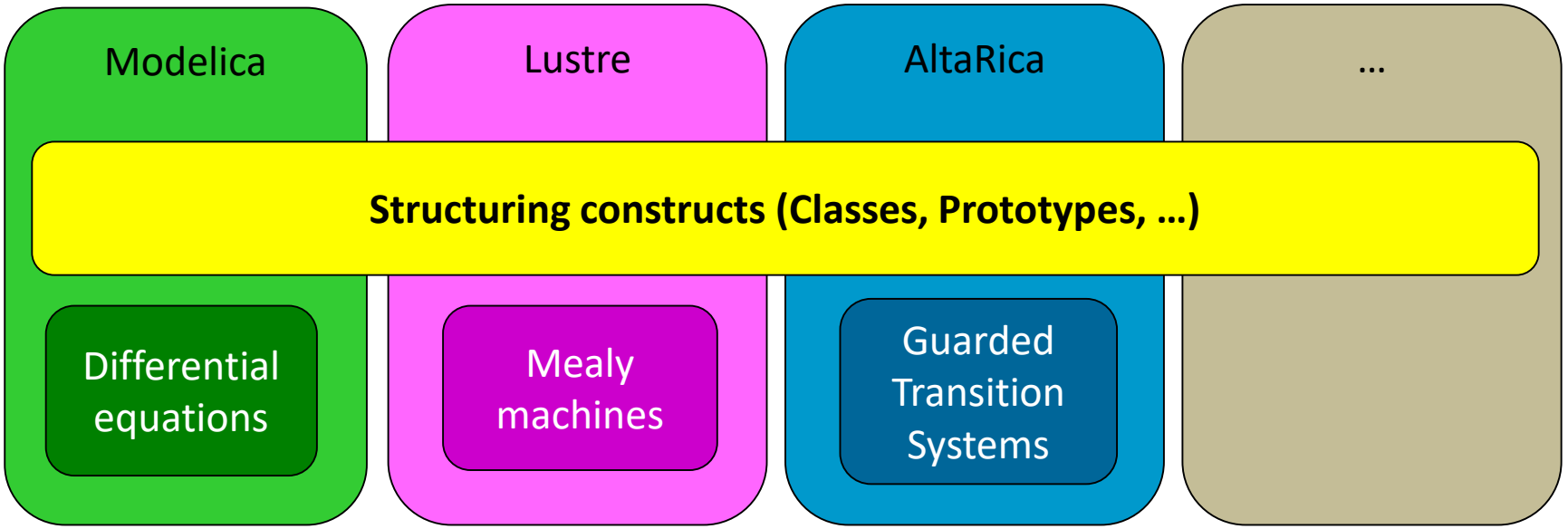
Central Thesis

Behaviors + Structures = Models



Commonalities between models stands in their structuring

Any **modeling language** is the **composition** of a **mathematical framework** and a set of **constructs to structure** models.



Structuring helps to design, to debug, to share, to maintain and to synchronize models.

The **structure of models** reflects the **structure of the system**, but only to a limited extent.

System Structure Modeling Language (S2ML)

- A set of **structuring constructs** that unifies the two dominant structuring paradigms for modeling languages, i.e. **object-orientation** and **prototype-orientation**.
- A **modeling language** on its own, dedicated to architecture description.

- Top-down model design
- System level
- Reuse of modeling patterns
- Prototype-Orientation

- Bottom-up model design
- Component level
- Reuse of modeling components
- Object-Orientation

system architecture

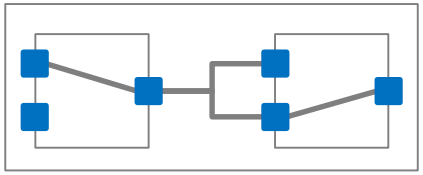
safety

Multiphysics simulation

S2ML: main concepts

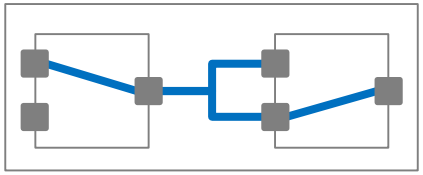
S2ML: a **structuring paradigm** that unifies **object-**and **prototype-orientation**.

Port



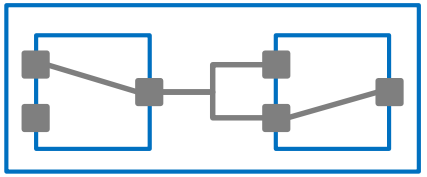
Variable, event…

Connection



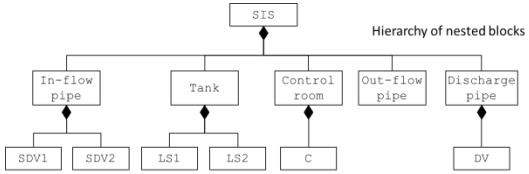
Equation, transition…

Container



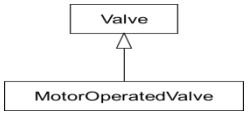
Model, component…

Composition



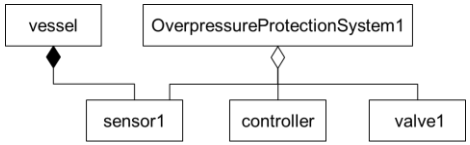
Is-part-of

Inheritance



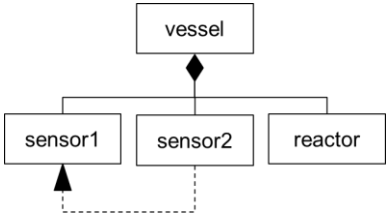
Is-a

Aggregation

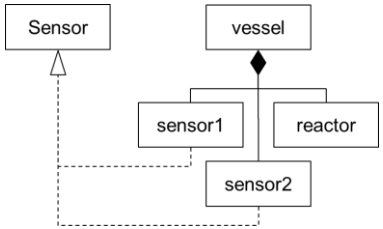


Uses

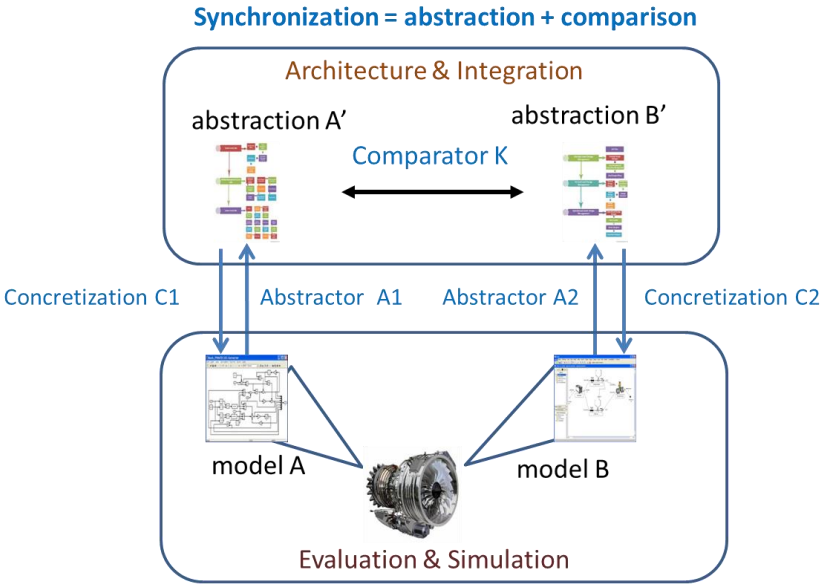
Prototype/Clone



Class/Instance



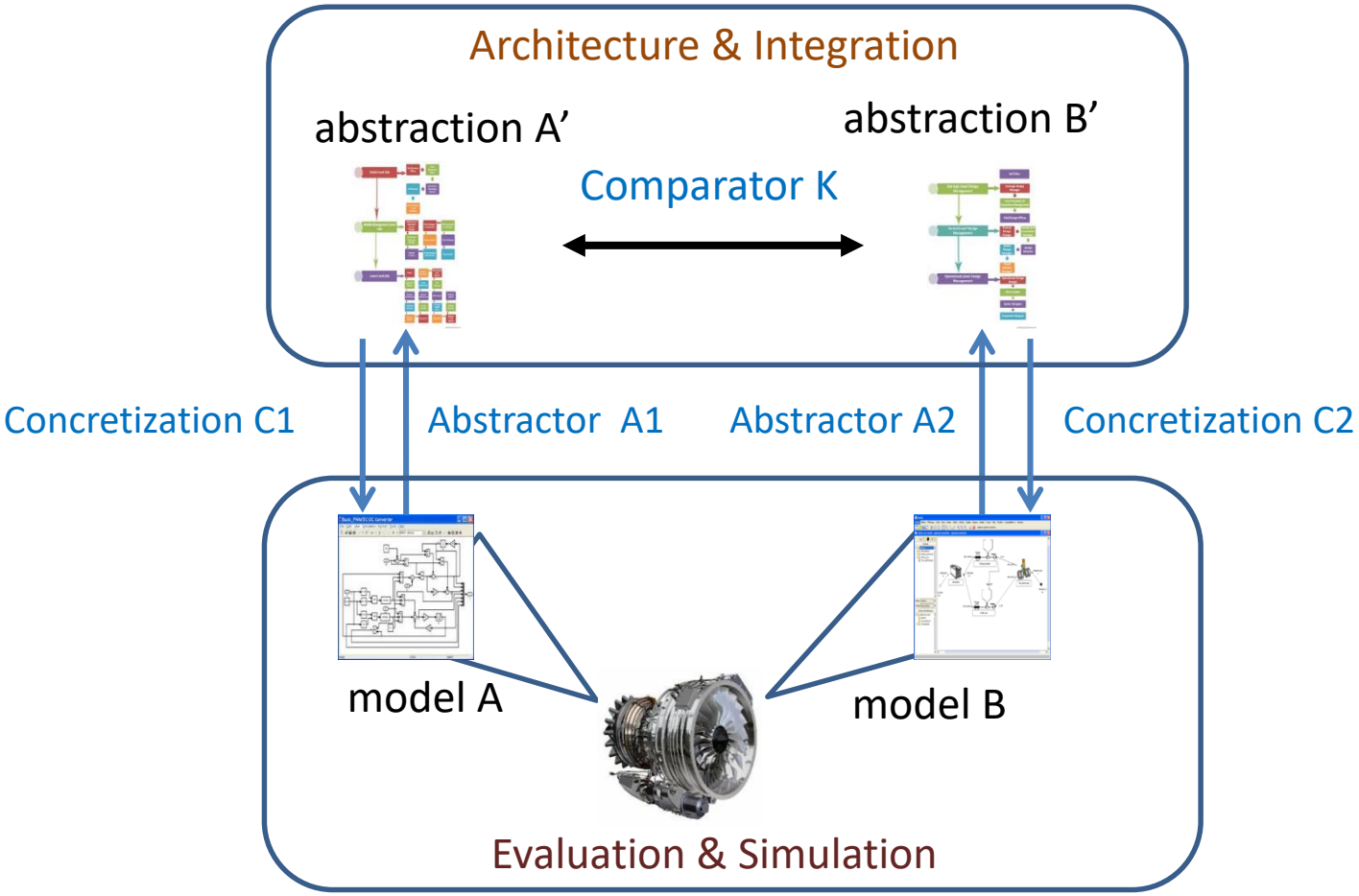
M. Batteux, T. Prosvirnova, A. Rauzy, « From models of structures to structures of models », 4th IEEE International Symposium on Systems Engineering, Rome, Italy, 2018. **Best paper award.**



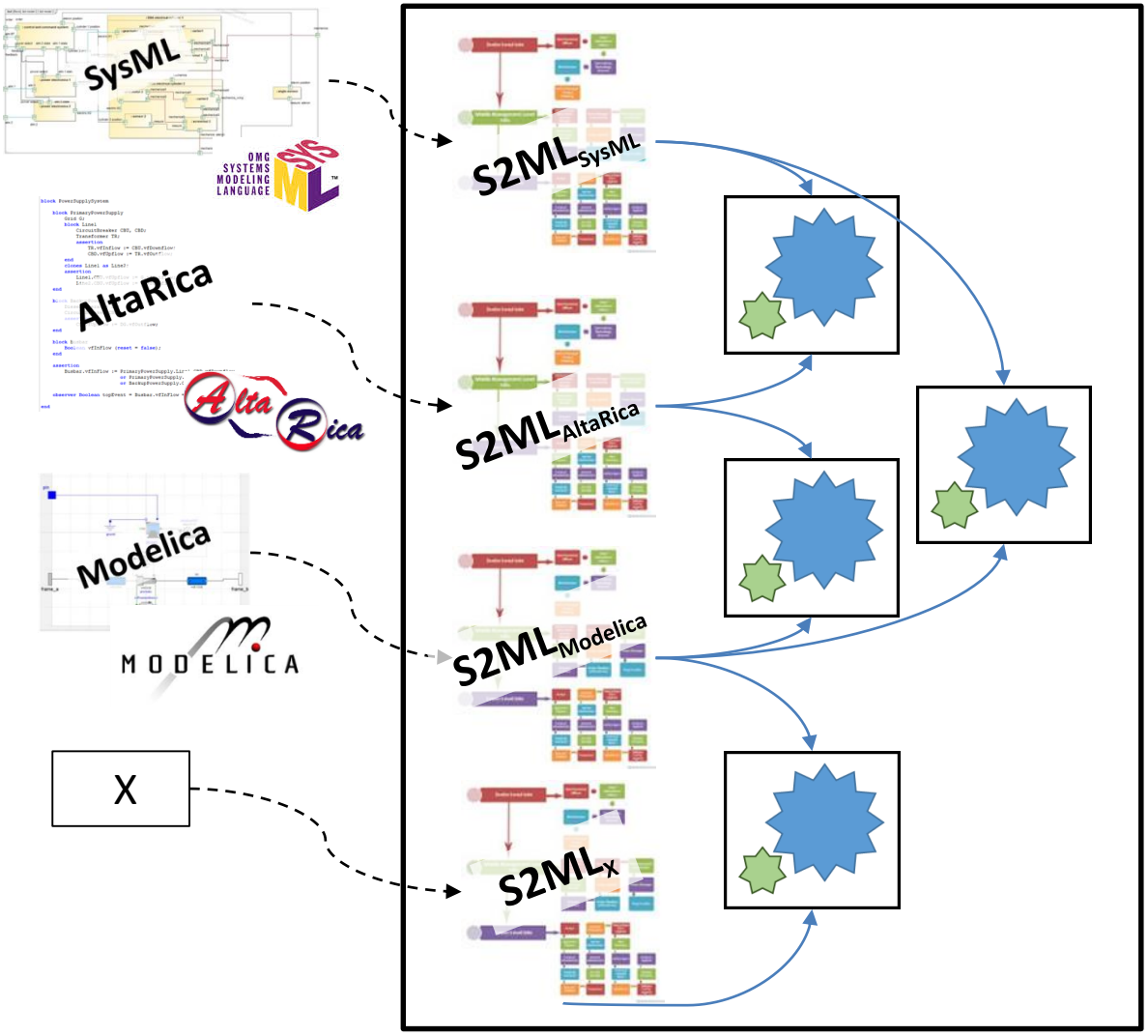
MODEL SYNCHRONIZATION

Model synchronization: principle

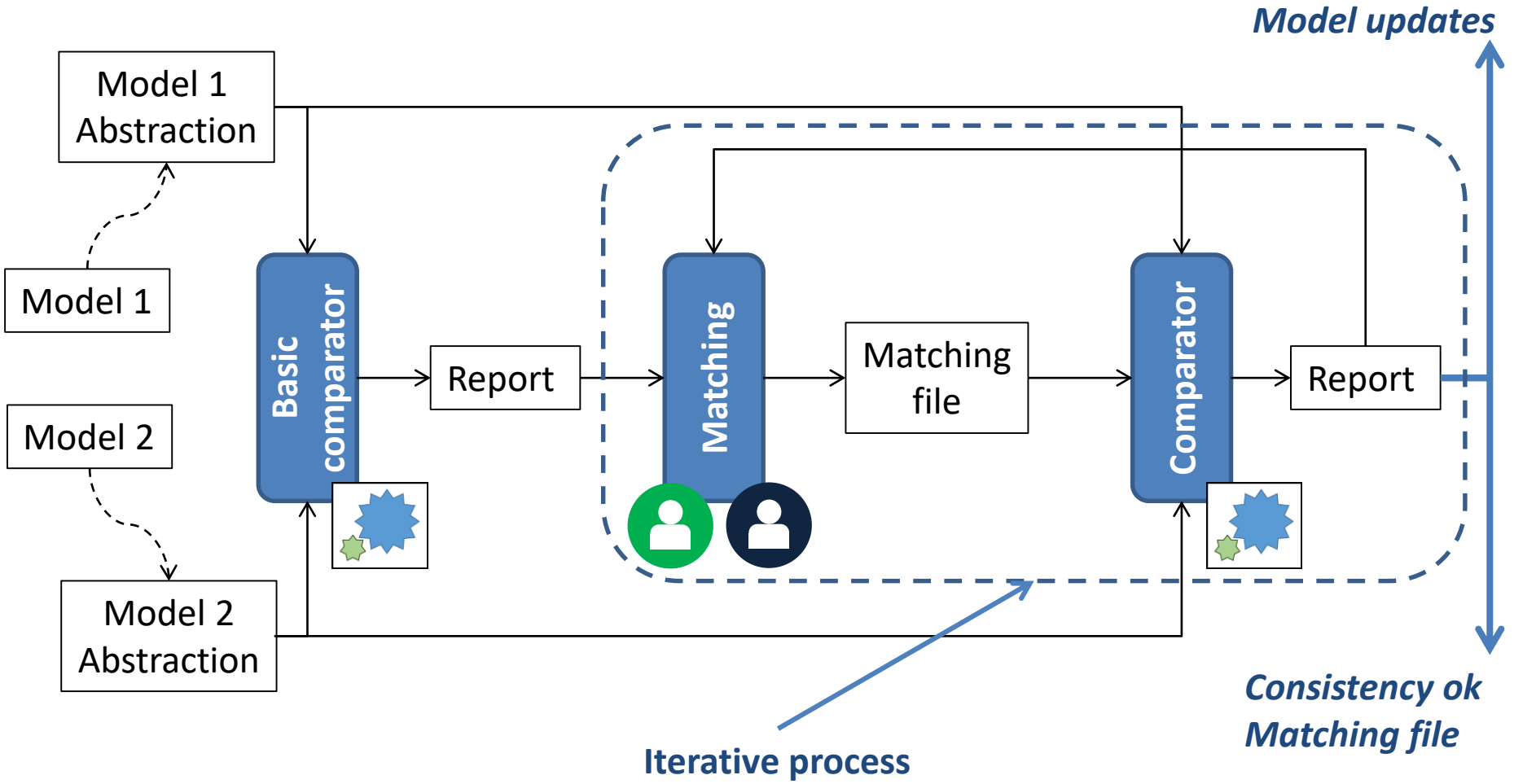
Synchronization = abstraction + comparison

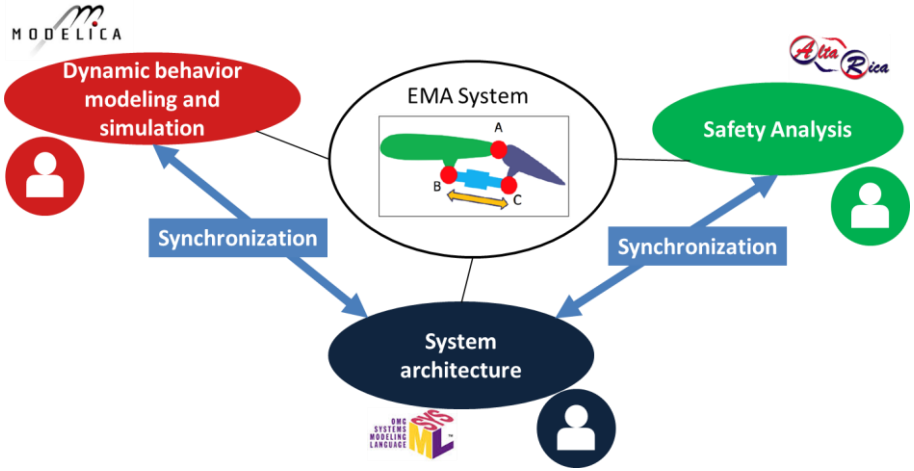


SmartSync platform



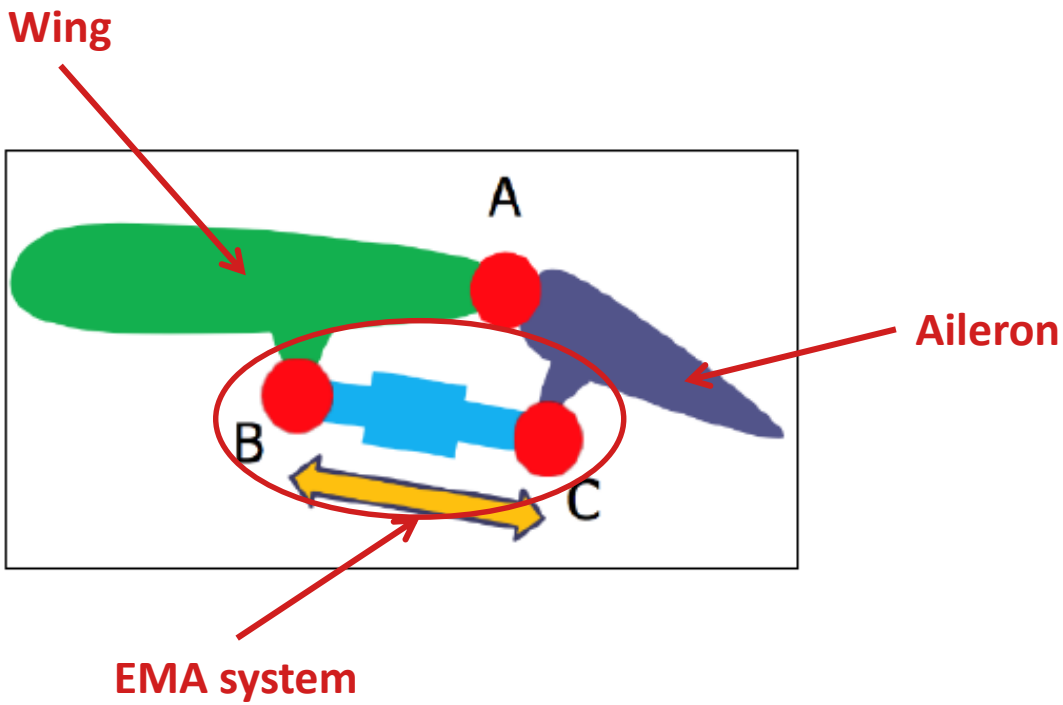
Model synchronization process





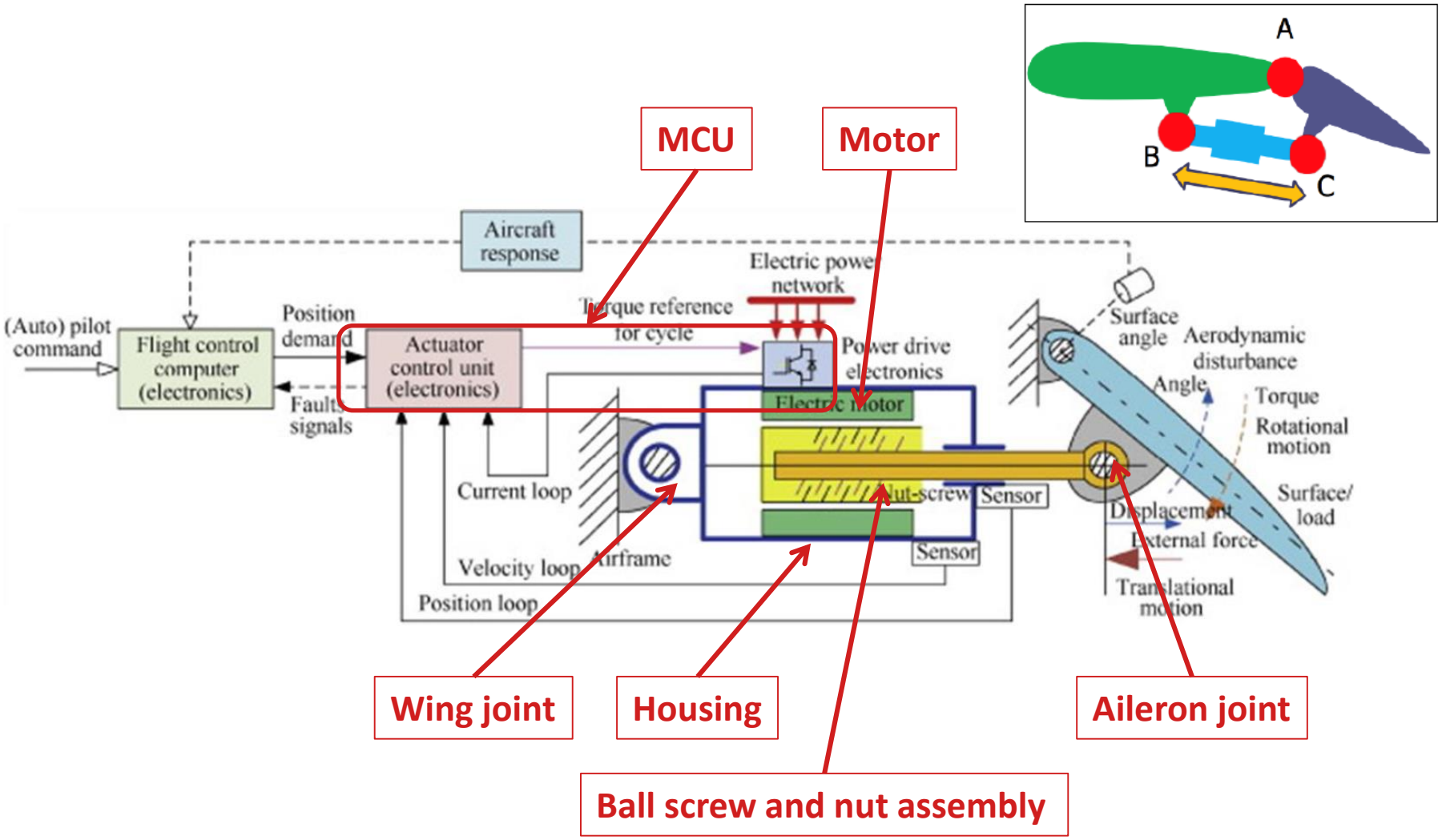
DEMONSTRATION

Electro-mechanical Actuator (EMA) for small aircraft



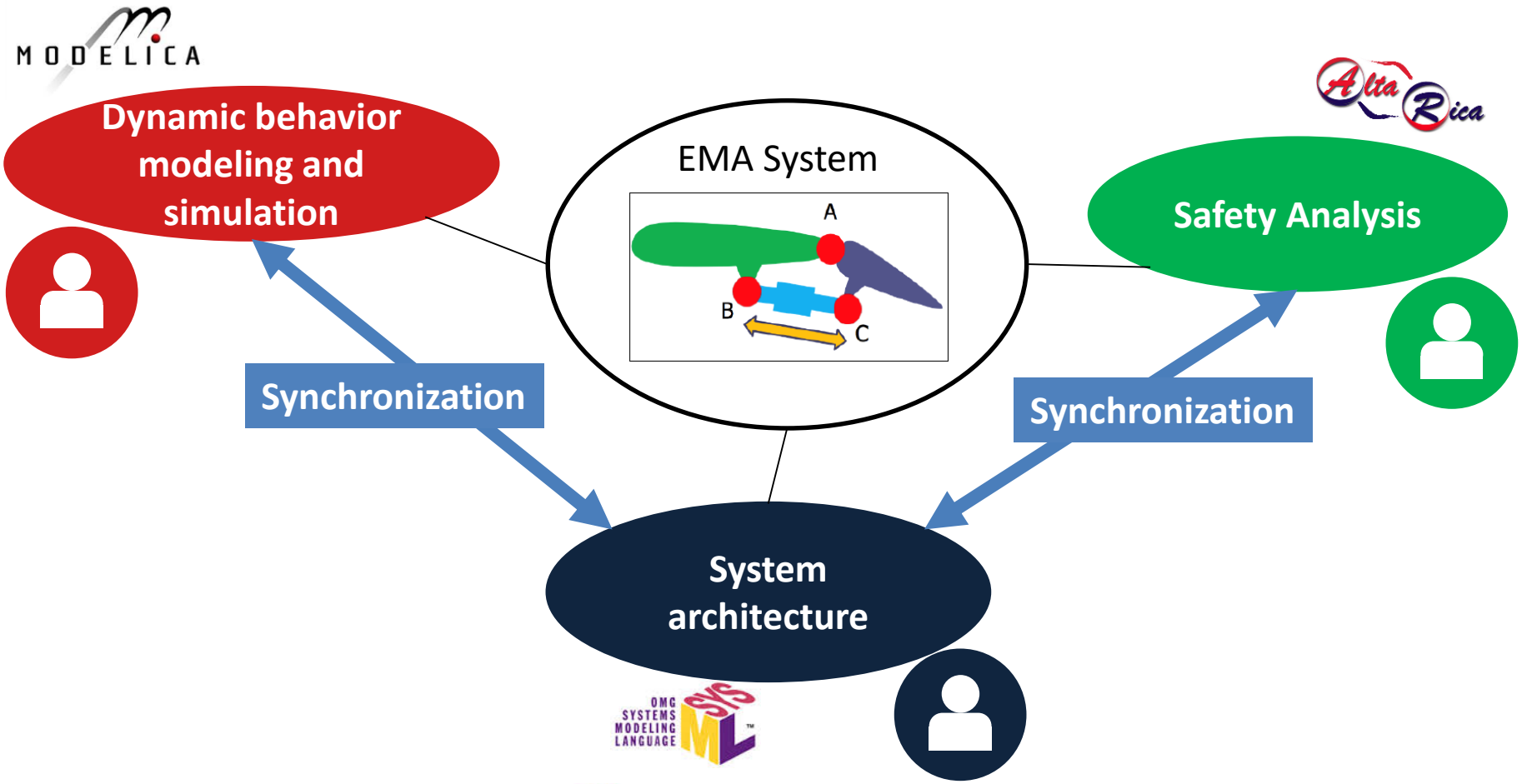
- EMA Drive Aileron System (Electro-Mechanical Actuator) for the Aileron Actuation of a Small Aircraft

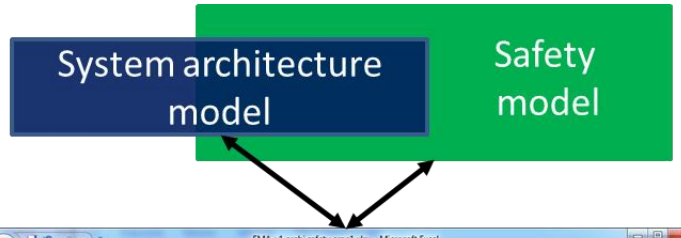
EMA mechanical and control system



Scenario: global picture

Verify and Validate Consistency between Multi-Domain System Models





EMA-v1.archi.safety.cmp1.xlsx - Microsoft Excel

C4: main.EMASystem_1.Instructions

	A	B	C
1	Type	Model1 (Architecture main.EMASystem_1)	Model2 (Safety main.EMASystem_1)
23	port	main.EMASystem_1.Housing.MechanicalActionHW	main.EMASystem_1.Housing.vfOut
24	port	ignore	main.EMASystem_1.Housing.evFailure
25	port	ignore	main.EMASystem_1.Housing.pLambda
26	port	ignore	main.EMASystem_1.Housing.vsWorking
27	port	main.EMASystem_1.MCU.ElectricalPower	main.EMASystem_1.MCU.vfFromElectricPower
28	port	main.EMASystem_1.MCU.InstructionAndFeedback	main.EMASystem_1.MCU.vfFromInstructions
29	port	main.EMASystem_1.MCU.Position	main.EMASystem_1.MCU.vfFromIncidenceSensor
30	port	main.EMASystem_1.MCU.RegulatedElectricalPower	main.EMASystem_1.MCU.vfToMotor
31	port	ignore	main.EMASystem_1.MCU.evFailure
32	port	ignore	main.EMASystem_1.MCU.pLambda
33	port	ignore	main.EMASystem_1.MCU.vsWorking
34	port	main.EMASystem_1.Motor.MechanicalAction	ignore
35	port	main.EMASystem_1.Motor.MechanicalRotPower	main.EMASystem_1.Motor.vfToGearbox
36	port	main.EMASystem_1.Motor.Position	main.EMASystem_1.IncidenceSensor
37	port	main.EMASystem_1.Motor.RegulatedElectricalPower	main.EMASystem_1.Motor.vfFromMCU
38	port	ignore	main.EMASystem_1.Motor.evFailure
39	port	ignore	main.EMASystem_1.Motor.pLambda
40	port	ignore	main.EMASystem_1.Motor.vsWorking
41	block	ignore	main.EMASystem_1.Observer

EMA-v1.archi.safety.cmp1

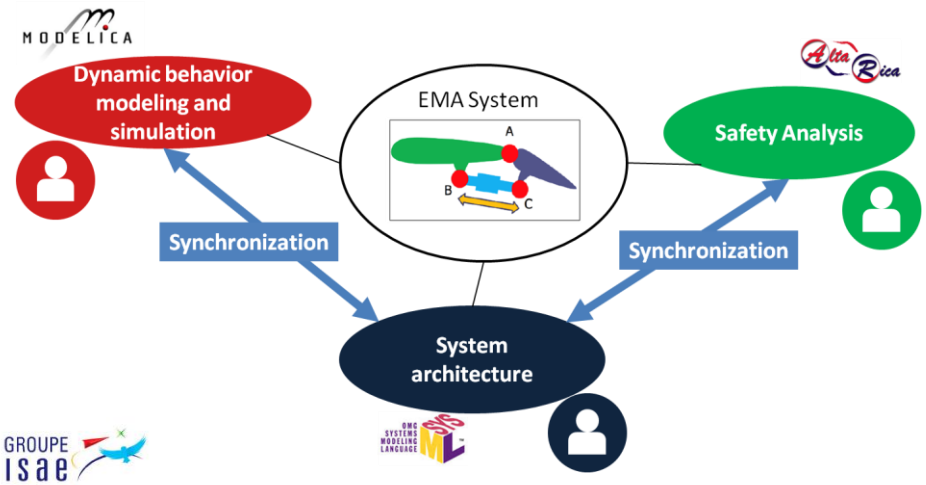
FINALLY

Conclusion

- Model synchronization enables to
  - Validate consistency
  - Detect modeling errors
- Matching structures/comparison of structures
  - Different naming of ports and blocks
  - Ports corresponding to blocks and vice-versa
  - Missing or additional elements
  - A block corresponding to several blocks in the other model

Conclusion

- Future works
  - Continue modeling and experiments with the EMA case study
  - Define and implement other comparators
    - Connections/ Topology
    - Matching proposals using matching files of previous versions



Thank you for your attention

?

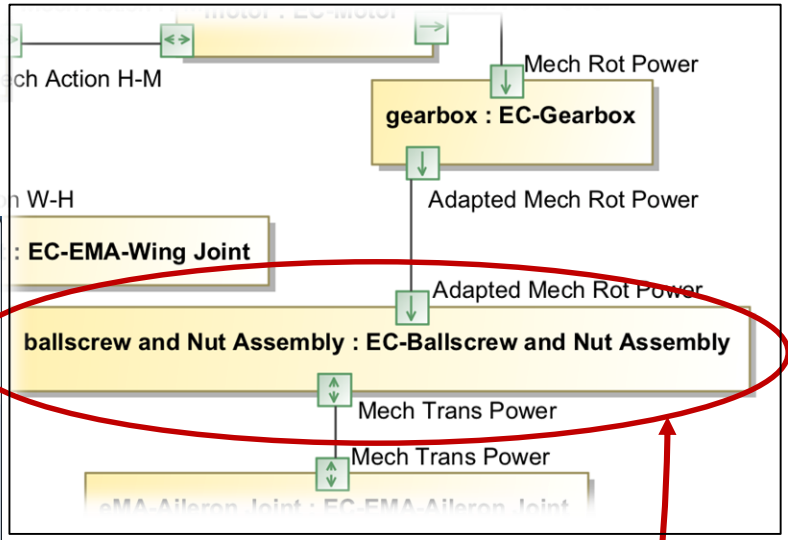
Back up

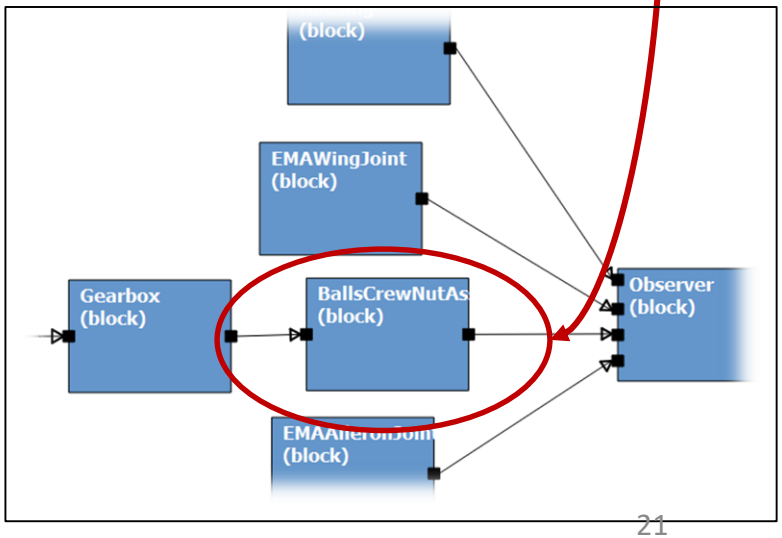
Comparison and matching (1/5)

Different naming of blocks

EMA-v1.archi.safety.cmp1.xlsx - Microsoft Excel

	A	B	C
1	**Type**	**Model1 (Architecture main.EMASystem_1)**	**Model2 (Safety main.EMASystem_1)**
5	port	main.EMASystem_1.WingMechanicalAction	
6	block	main.EMASystem_1.BallScrewAndNutAssembly	main.EMASystem_1.BallScrewNutAssembly
7	port	main.EMASystem_1.EMAAileronJoint.AileronMechanicalAction	
8	port	main.EMASystem_1.EMAAileronJoint.MechanicalTransmissionPower	
9	port		main.EMASystem_1.EMAAileronJoint.evFailure
10	port		main.EMASystem_1.EMAAileronJoint.pLambda
11	port		main.EMASystem_1.EMAAileronJoint.vfOut
12	port		main.EMASystem_1.EMAAileronJoint.vsWorking
13	port	main.EMASystem_1.EMAWingJoint.MechanicalActionHW	
14	port	main.EMASystem_1.EMAWingJoint.WingMechanicalAction	
15	port		main.EMASystem_1.EMAWingJoint.evFailure
16	port		main.EMASystem_1.EMAWingJoint.pLambda
17	port		main.EMASystem_1.EMAWingJoint.vfOut
18	port		main.EMASystem_1.EMAWingJoint.vsWorking
19	port	main.EMASystem_1.Gearbox.AdaptedMechanicalRotPower	
20	port	main.EMASystem_1.Gearbox.MechanicalRotPower	



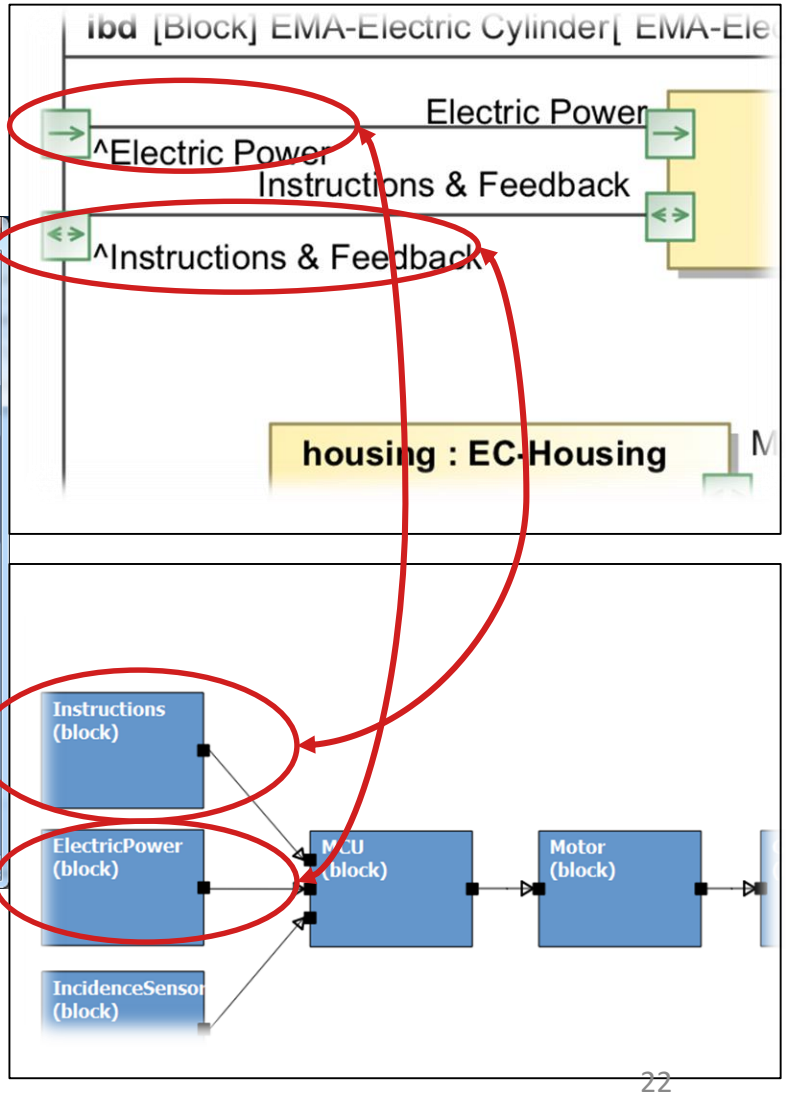


Comparison and matching (2/5)

Ports corresponding to blocks

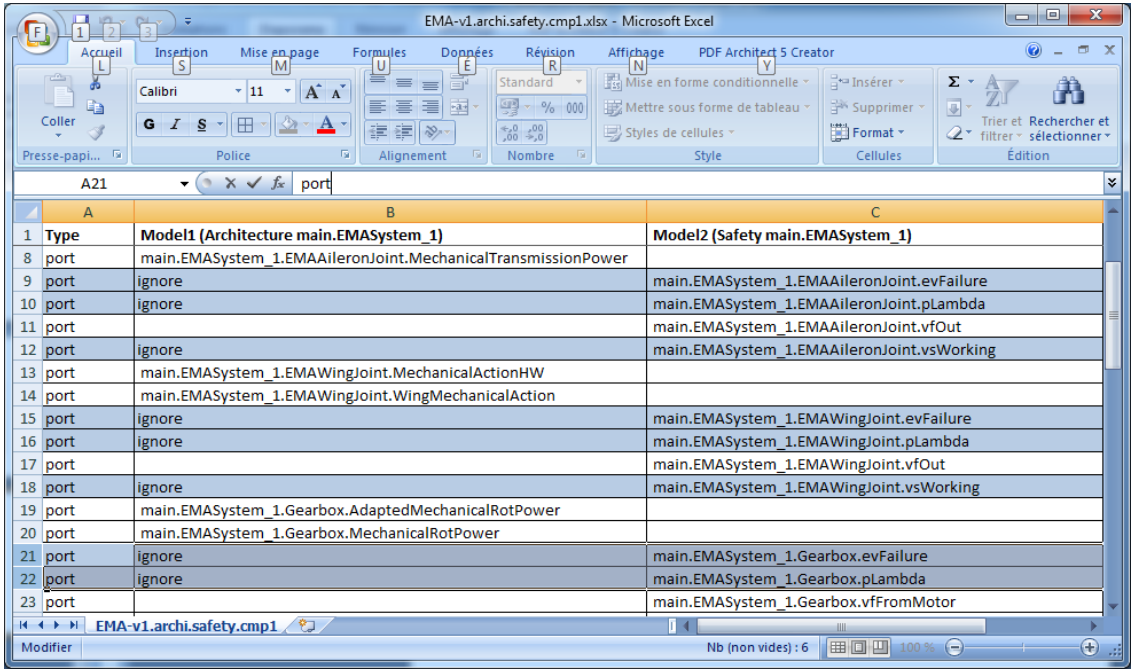
EMA-v1.archi.safety.cmp1.csv - Microsoft Excel

	A	B	C
1	**Type**	**Model1 (main.EMASystem_1)**	**Model2 (main.EMASystem_1)**
2	port	main.EMASystem_1.AileronMechanicalAction	
3	port	main.EMASystem_1.ElectricalPower	main.EMASystem_1.ElectricPower
4	port	main.EMASystem_1.InstructionAndFeedback	main.EMASystem_1.Instructions
5	port	main.EMASystem_1.WingMechanicalAction	
6	block	main.EMASystem_1.BallScrewAndNutAssembly	
7	port	main.EMASystem_1.EMAAileronJoint.AileronMechanicalAction	
8	port	main.EMASystem_1.EMAAileronJoint.MechanicalTransmissionPower	
9	port		main.EMASystem_1.EMAAileronJoint.evFailure
10	port		main.EMASystem_1.EMAAileronJoint.pLambda
11	port		main.EMASystem_1.EMAAileronJoint.vfOut
12	port		main.EMASystem_1.EMAAileronJoint.vsWorking
13	port	main.EMASystem_1.EMAWingJoint.MechanicalActionHW	
14	port	main.EMASystem_1.EMAWingJoint.WingMechanicalAction	
15	port		main.EMASystem_1.EMAWingJoint.evFailure
16	port		main.EMASystem_1.EMAWingJoint.pLambda
17	port		main.EMASystem_1.EMAWingJoint.vfOut



Comparison and matching (3/5)

Ports and/or blocks of the safety model not represented in the system model



	A	B	C
1	**Type**	**Model1 (Architecture main.EMASystem_1)**	**Model2 (Safety main.EMASystem_1)**
8	port	main.EMASystem_1.EMAAileronJoint.MechanicalTransmissionPower	
9	port	ignore	main.EMASystem_1.EMAAileronJoint.evFailure
10	port	ignore	main.EMASystem_1.EMAAileronJoint.pLambda
11	port		main.EMASystem_1.EMAAileronJoint.vfOut
12	port	ignore	main.EMASystem_1.EMAAileronJoint.vsWorking
13	port	main.EMASystem_1.EMAWingJoint.MechanicalActionHW	
14	port	main.EMASystem_1.EMAWingJoint.WingMechanicalAction	
15	port	ignore	main.EMASystem_1.EMAWingJoint.evFailure
16	port	ignore	main.EMASystem_1.EMAWingJoint.pLambda
17	port		main.EMASystem_1.EMAWingJoint.vfOut
18	port	ignore	main.EMASystem_1.EMAWingJoint.vsWorking
19	port	main.EMASystem_1.Gearbox.AdaptedMechanicalRotPower	
20	port	main.EMASystem_1.Gearbox.MechanicalRotPower	
21	port	ignore	main.EMASystem_1.Gearbox.evFailure
22	port	ignore	main.EMASystem_1.Gearbox.pLambda
23	port		main.EMASystem_1.Gearbox.vfFromMotor

- State variables, failure events, failure rates do not have any correspondence in the system architecture model
- They will be ignored in the next step of the comparison procedure

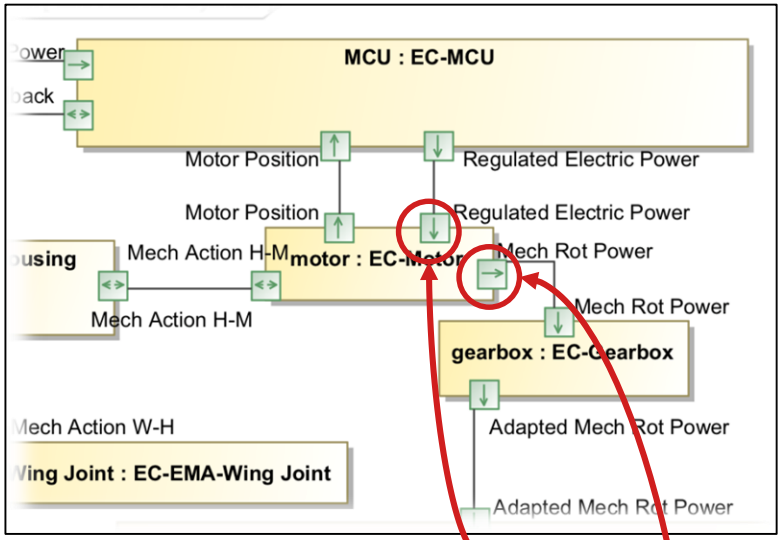
Comparison and matching (4/5)

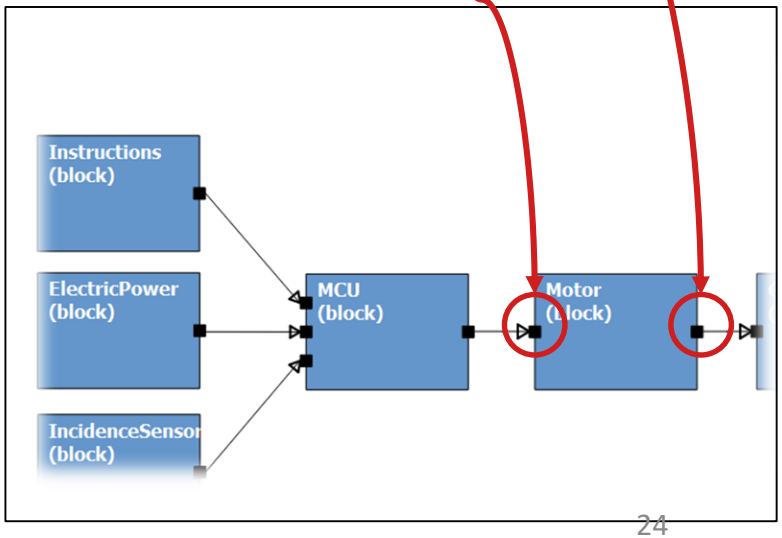
Different naming of ports

EMA-v1.archi.safety.cmp1.xlsx - Microsoft Excel

C4: main.EMASystem_1.Instructions

	A	B	C
1	**Type**	**Model1 (Architecture main.EMASystem_1)**	**Model2 (Safety main.EMASystem_1)**
23	port	main.EMASystem_1.Housing.MechanicalActionHW	main.EMASystem_1.Housing.vfOut
24	port	ignore	main.EMASystem_1.Housing.evFailure
25	port	ignore	main.EMASystem_1.Housing.pLambda
26	port	ignore	main.EMASystem_1.Housing.vsWorking
27	port	main.EMASystem_1.MCU.ElectricalPower	main.EMASystem_1.MCU.vfFromElectricPower
28	port	main.EMASystem_1.MCU.InstructionAndFeedback	main.EMASystem_1.MCU.vfFromInstructions
29	port	main.EMASystem_1.MCU.Position	main.EMASystem_1.MCU.vfFromIncidenceSensor
30	port	main.EMASystem_1.MCU.RegulatedElectricalPower	main.EMASystem_1.MCU.vfToMotor
31	port	ignore	main.EMASystem_1.MCU.evFailure
32	port	ignore	main.EMASystem_1.MCU.pLambda
33	port	ignore	main.EMASystem_1.MCU.vsWorking
34	port	main.EMASystem_1.Motor.MechanicalAction	ignore
35	port	main.EMASystem_1.Motor.MechanicalRotPower	main.EMASystem_1.Motor.vfToGearbox
36	port	main.EMASystem_1.Motor.Position	main.EMASystem_1.IncidenceSensor
37	port	main.EMASystem_1.Motor.RegulatedElectricalPower	main.EMASystem_1.Motor.vfFromMCU
38	port	ignore	main.EMASystem_1.Motor.evFailure
39	port	ignore	main.EMASystem_1.Motor.pLambda
40	port	ignore	main.EMASystem_1.Motor.vsWorking
41	block	ignore	main.EMASystem_1.Observer





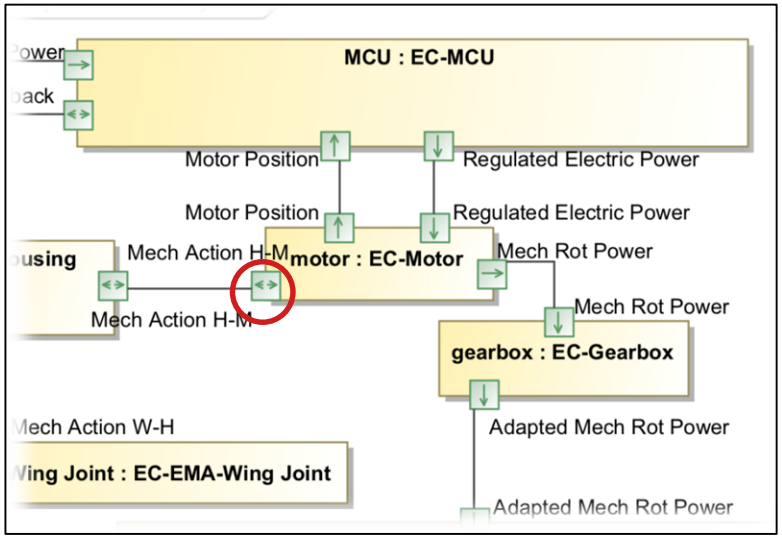
Comparison and matching (5/5)

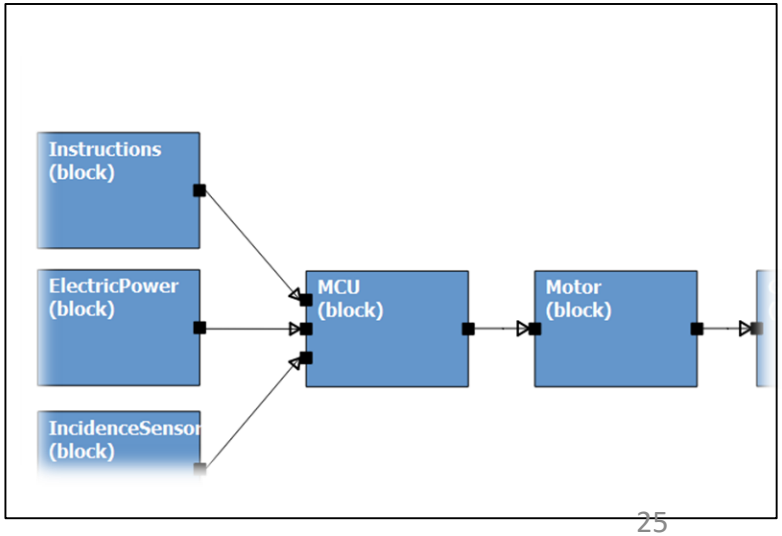
Ports and/or blocks of the system model not represented in the safety model

EMA-v1.archi.safety.cmp1.xlsx - Microsoft Excel

C4: main.EMASystem_1.Instructions

	A	B	C
1	**Type**	**Model1 (Architecture main.EMASystem_1)**	**Model2 (Safety main.EMASystem_1)**
2	port	main.EMASystem_1.AileronMechanicalAction	ignore
3	port	main.EMASystem_1.ElectricalPower	main.EMASystem_1.ElectricPower
4	port	main.EMASystem_1.InstructionAndFeedback	main.EMASystem_1.Instructions
5	port	main.EMASystem_1.WingMechanicalAction	ignore
6	block	main.EMASystem_1.BallScrewAndNutAssembly	main.EMASystem_1.BallScrewNutAssembly
7	port	main.EMASystem_1.EMAAileronJoint.AileronMechanicalAction	main.EMASystem_1.EMAAileronJoint.vfOut
8	port	main.EMASystem_1.EMAAileronJoint.MechanicalTransmissionPower	ignore
9	port	ignore	main.EMASystem_1.EMAAileronJoint.evFailure
10	port	ignore	main.EMASystem_1.EMAAileronJoint.pLambda
11	port	ignore	main.EMASystem_1.EMAAileronJoint.vsWorking
12	port	main.EMASystem_1.EMAWingJoint.MechanicalActionHW	ignore
13	port	main.EMASystem_1.EMAWingJoint.WingMechanicalAction	main.EMASystem_1.EMAWingJoint.vfOut
14	port	ignore	main.EMASystem_1.EMAWingJoint.evFailure
15	port	ignore	main.EMASystem_1.EMAWingJoint.pLambda
16	port	ignore	main.EMASystem_1.EMAWingJoint.vsWorking
17	port	main.EMASystem_1.Gearbox.AdaptedMechanicalRotPower	main.EMASystem_1.Gearbox.vfToBallScrewNutAssembly
18	port	main.EMASystem_1.Gearbox.MechanicalRotPower	main.EMASystem_1.Gearbox.vfFromMotor
19	port	ignore	main.EMASystem_1.Gearbox.evFailure
20	port	ignore	main.EMASystem_1.Gearbox.pLambda





Conclusion on comparison of system and safety models

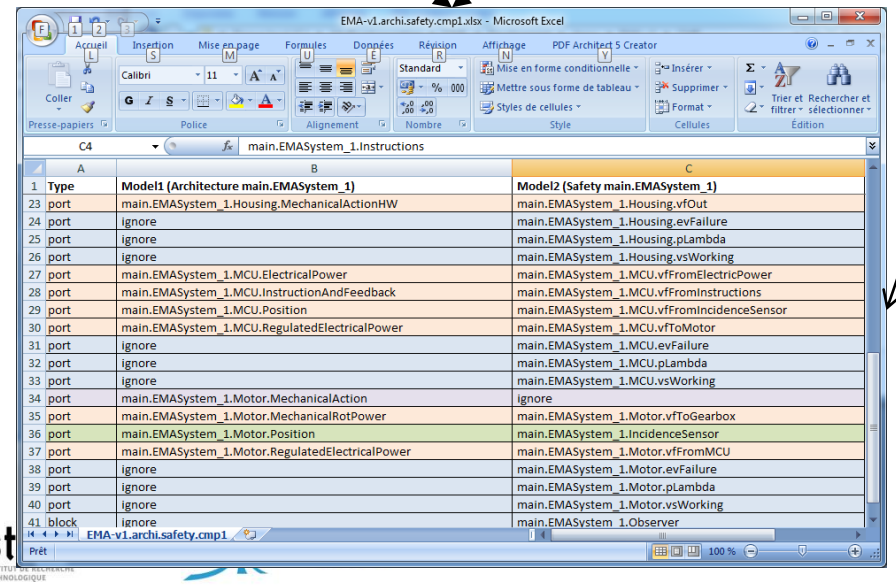
System architecture elements not represented in the safety model

Common structural part

System architecture model

Safety model

Additional safety related modeling elements



	A	B	C
1	Type	Model1 (Architecture main.EMASystem_1)	Model2 (Safety main.EMASystem_1)
23	port	main.EMASystem_1.Housing.MechanicalActionHW	main.EMASystem_1.Housing.vfOut
24	port	ignore	main.EMASystem_1.Housing.evFailure
25	port	ignore	main.EMASystem_1.Housing.pLambda
26	port	ignore	main.EMASystem_1.Housing.vsWorking
27	port	main.EMASystem_1.MCU.ElectricalPower	main.EMASystem_1.MCU.vfFromElectricPower
28	port	main.EMASystem_1.MCU.InstructionAndFeedback	main.EMASystem_1.MCU.vfFromInstructions
29	port	main.EMASystem_1.MCU.Position	main.EMASystem_1.MCU.vfFromIncidenceSensor
30	port	main.EMASystem_1.MCU.RegulatedElectricalPower	main.EMASystem_1.MCU.vfToMotor
31	port	ignore	main.EMASystem_1.MCU.evFailure
32	port	ignore	main.EMASystem_1.MCU.pLambda
33	port	ignore	main.EMASystem_1.MCU.vsWorking
34	port	main.EMASystem_1.Motor.MechanicalAction	ignore
35	port	main.EMASystem_1.Motor.MechanicalRotPower	main.EMASystem_1.Motor.vfToGearbox
36	port	main.EMASystem_1.Motor.Position	main.EMASystem_1.IncidenceSensor
37	port	main.EMASystem_1.Motor.RegulatedElectricalPower	main.EMASystem_1.Motor.vfFromMCU
38	port	ignore	main.EMASystem_1.Motor.evFailure
39	port	ignore	main.EMASystem_1.Motor.pLambda
40	port	ignore	main.EMASystem_1.Motor.vsWorking
41	block	ignore	main.EMASystem_1.Observer

Matching file between two models

Consistency checked and validated

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