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A Model-Based Systems Engineering (MBSE) Framework for Aerospace Applications

Presentation · September 2018

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Modelling and Simulation Tools for Systems Integration on Aircraft

Clean Sky 2 – WP 100.3

Demonstration of the MISSION framework

Technology Readiness Level 5 – Towards workflow integration

Clean Sky 2 MISSION – WP100.3

Scope

„**m**odelling & **s**imulation tools for **s**ystems **i**ntegration on aircraft”



MISSION will provide a **software toolchain** supporting the whole aerospace product design workflow from **Requirements** to **Certification**



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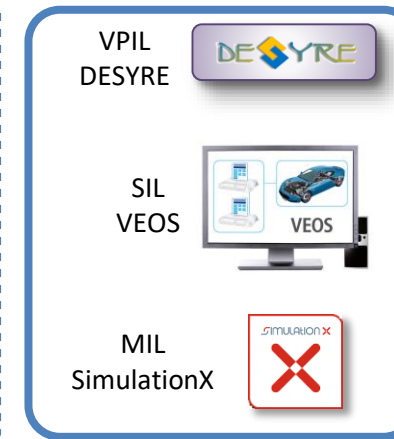
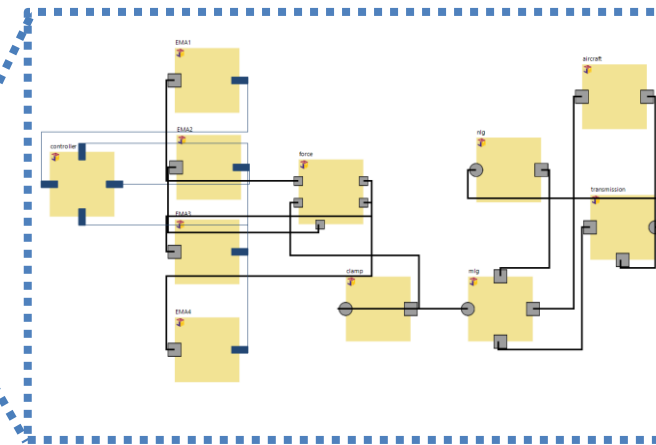
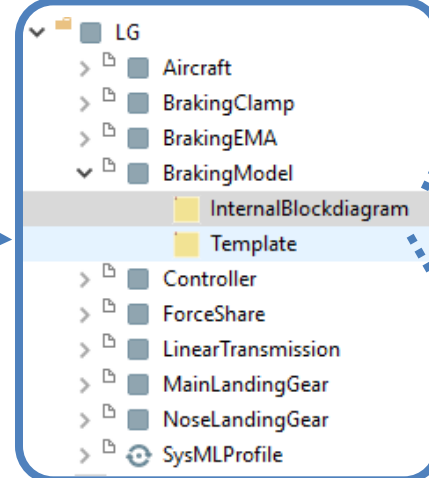
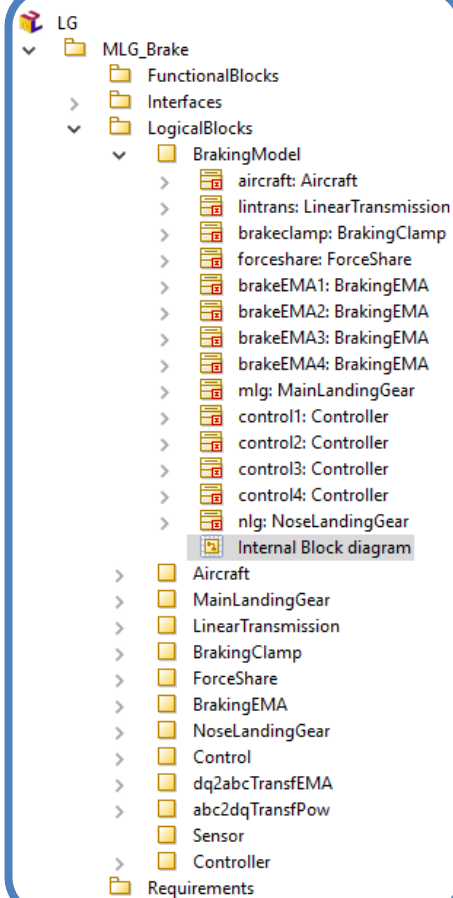
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Open Framework integrating Design and Verification

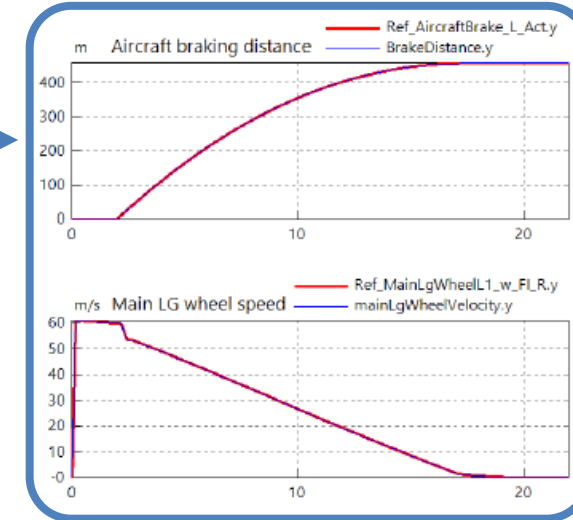
From Requirements... To Systems Engineering...



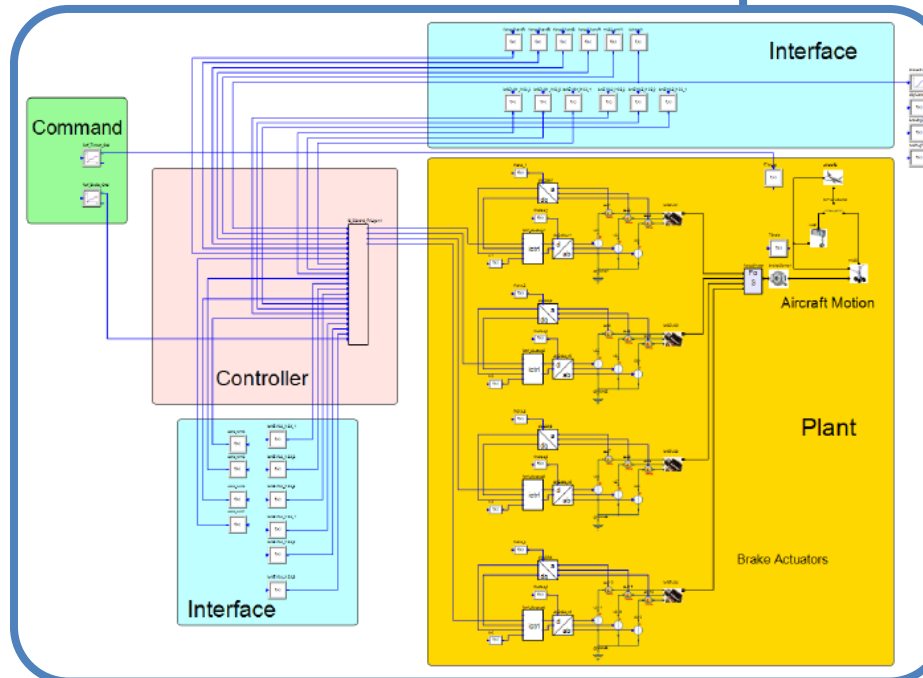
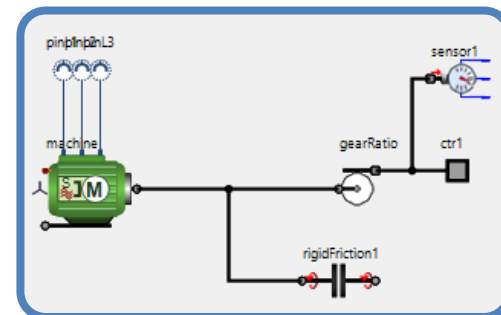
IBM Rational
DOORS



To Virtual Systems Verification



To Components Design and Integration...



Highlights:

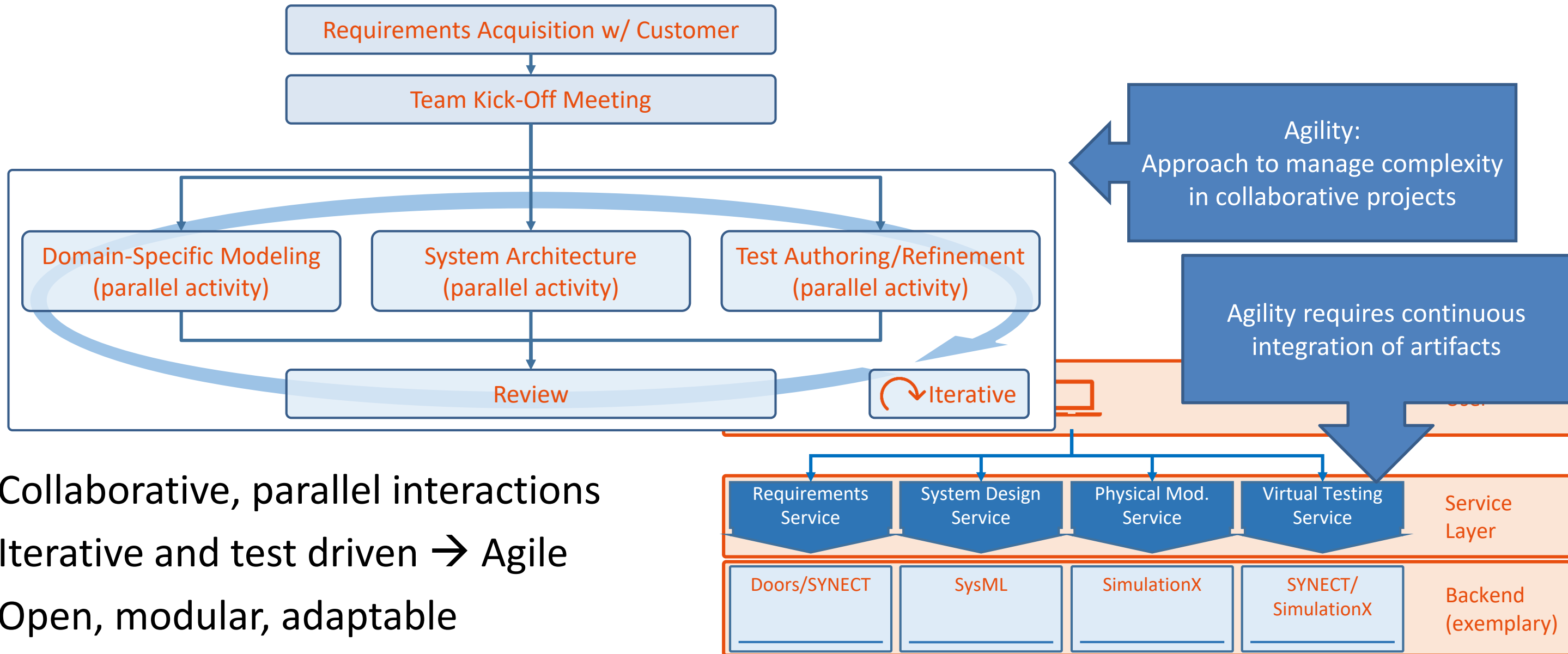
- Open, modular framework
- Linked data and automatism



RTO: ✓

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Apply novel Workflow Aspects to Aerospace Design



- Collaborative, parallel interactions
- Iterative and test driven → Agile
- Open, modular, adaptable



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Software Technology Readiness Level 5

Demonstration of Integration Framework

Design and Verification of a Landing Gear Brake Actuator

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Requirements definition and provision

'Requirements' current 0.0 in /LandingGearRequirements (Formal module) - DOORS

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View Standard view All levels

Requirements

- 1 Aircraft-level requirements
- 2 Functional requirements
- 3 Performance requirements
- 4 Electrical interface requirements
- 5 Data interface requirements
- 6 Built-in-tests

ID	
1	1 Aircraft-level requirements
2	The aircraft has left and right landing gear
4	Left and right landing gear have two wheels each
5	Four EMA actuators per wheel
6	The aircraft shall be able to brake in 1.5 km [20] in wet conditions at sea level (normal TO)
7	The aircraft shall be able to brake in 600 m (40% of runway [21]) in dry [25] conditions (RTO). Thermal requirements and tyre integrity do not apply in this situation
8	2 Functional requirements
12	Max braking force per wheel shall be 50 kN
11	Anti-skid is deactivated when ground speed is less than 20 knots (10.3 m/s)
10	The anti-skid can be turned off and on from the cockpit
9	When active, the anti-skid system shall order brake release when the speed of a wheel drops below 0.87 times the aircraft speed
14	3 Performance requirements
15	The drive maximum current shall be 15 A
17	All control loops shall have a 6 dB gain margin and a 45° phase margin
18	Current loop bandwidth 200 Hz
19	Anti-skid loop bandwidth 2 Hz
60	Actuator maximum stroke shall be 60mm in the most extended position
61	Actuator shall be designed for maximum rate of 12mm/s at max load of 5000daN
64	The BSCU controller shall run at 1ms rate
63	The EBAC controllers shall run at 1ms rate
20	4 Electrical interface requirements
21	Nominal supply voltage 28 Vdc
22	The actuator shall operate according to the requirements with a supply ranging from 22 Vdc to 30.3 Vdc
23	5 Data interface requirements
24	The actuator shall include a load cell to measure applied force on the brake pad
25	The accuracy of the measured force is +/-5 %
26	The actuator shall include a resolver to measure motor speed
27	A 12-bit resolver shall be used
28	The wheel shall include a tachometer to measure wheel speed
29	The accuracy of the tachometer is 500 cycles per revolution
30	The actuator shall include a hall current sensor per each phase of the motor
31	The accuracy of the current sensor is +/-1% rated current
32	The BSCU shall receive as inputs wheel speed, braking torque and temperature from respective sensors in each brake
33	The BSCU shall receive brake command signals from the left and right brake pedal transducers included in the cockpit of the aircraft, manual brake release, and aircraft speed
34	The BSCU shall send to the cockpit the anti-skid status, the braking force applied to wheel, the braking system fault and the brake overtemperature
35	Communication delay between cockpit and BSCU (brake system control unit) is 20 ms
36	Communication between BSCU and both EBACs shall be transmitted via fieldbus with a bus cycle time of 10ms or faster

DOORS

ReqIF

SYNECT

SYNECT - [System Requirements - Landing Gear System]

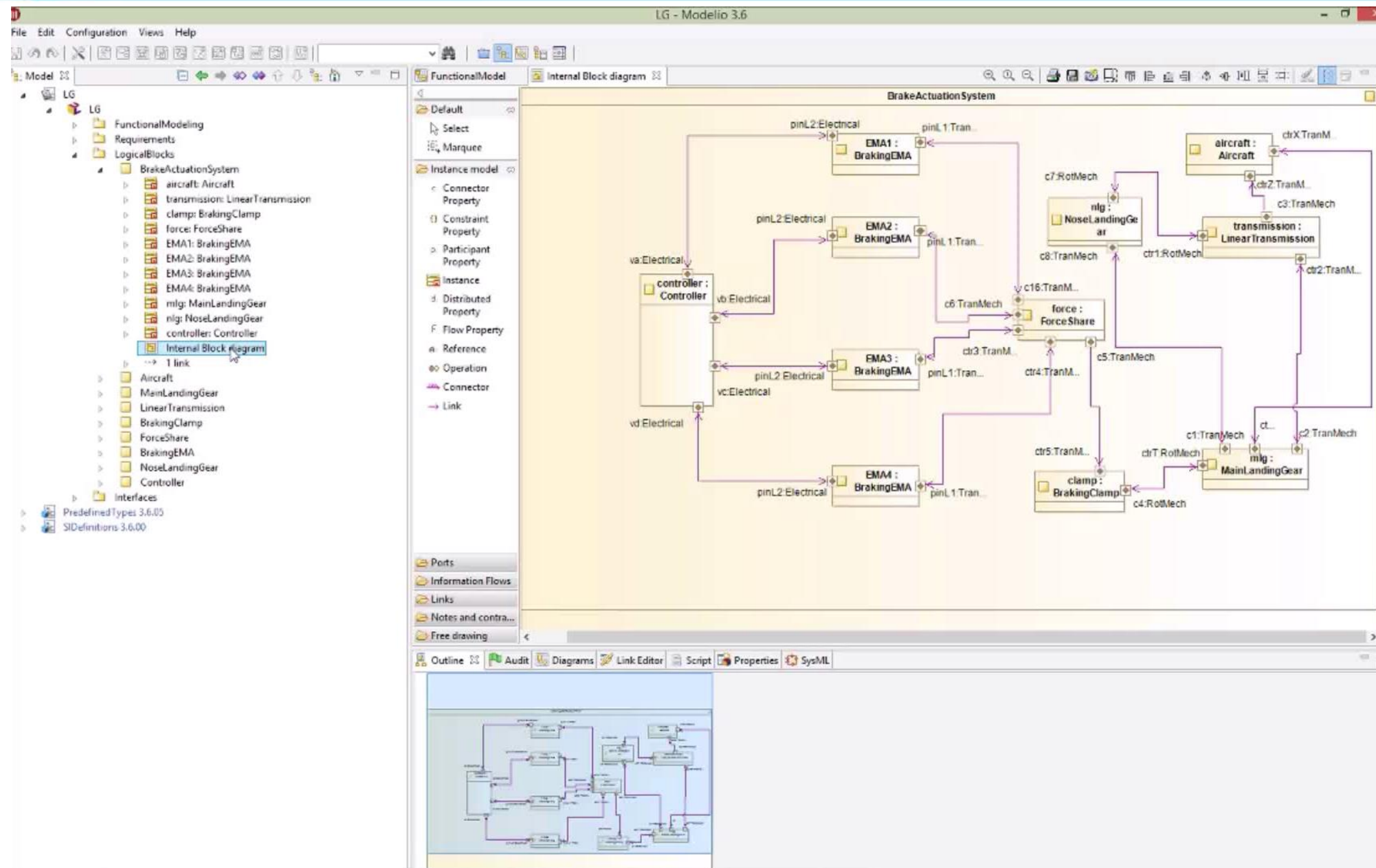
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Start Page Requirements Documents - La... System Requirements - Landin...

	Name and Description	Variant Depend...	Links	Source Project
1	1 Aircraft-level requirements			Landing Gear Syst..
	The aircraft has left and right landing gear		180119_LG_phy_2...	Landing Gear Syst..
	Left and right landing gear have two wheels each		180119_LG_phy_2...	Landing Gear Syst..
	Four EMA actuators per wheel		180119_LG_phy_2...	Landing Gear Syst..
	The aircraft shall be able to brake in 1.5 km [20] in wet conditions at sea level (normal TO)		180119_LG_phy_2...	Landing Gear Syst..
	The aircraft shall be able to brake in 600 m (40% of runway [21]) in dry [25] conditions (RTO). Thermal requirements and tyre integrity do not apply in this situation		180119_LG_phy_2...	Landing Gear Syst..
2	2 Functional requirements			Landing Gear Syst..
	Max braking force per wheel shall be 50 kN		180119_LG_phy_2...	Landing Gear Syst..
	Anti-skid is deactivated when ground speed is less than 20 knots (10.3 m/s)		BSCU_LGContrPto...	Landing Gear Syst..
	The anti-skid can be turned off and on from the cockpit		BSCU_LGContrPto...	Landing Gear Syst..
	When active, the anti-skid system shall order brake release when the speed of a wheel drops below 0.87 times the aircraft speed		BSCU_LGContrPto...	Landing Gear Syst..
3	3 Performance requirements			Landing Gear Syst..
	The drive maximum current shall be 15 A		180119_LG_phy_2...	Landing Gear Syst..
	All control loops shall have a 6 dB gain margin and a 45° phase margin		BSCU_LGContrPto...	Landing Gear Syst..
	Current loop bandwidth 200 Hz		180119_LG_phy_2...	Landing Gear Syst..
	Anti-skid loop bandwidth 2 Hz		BSCU_LGContrPto...	Landing Gear Syst..
	Actuator maximum stroke shall be 60mm in the most extended position		180119_LG_phy_2...	Landing Gear Syst..
	Actuator shall be designed for maximum rate of 12mm/s at max load of 5000daN		180119_LG_phy_2...	Landing Gear Syst..
	The BSCU controller shall run at 1ms rate		BSCU_LGContrPto...	Landing Gear Syst..
	The EBAC controllers shall run at 1ms rate		EBAC_EMAContrP...	Landing Gear Syst..

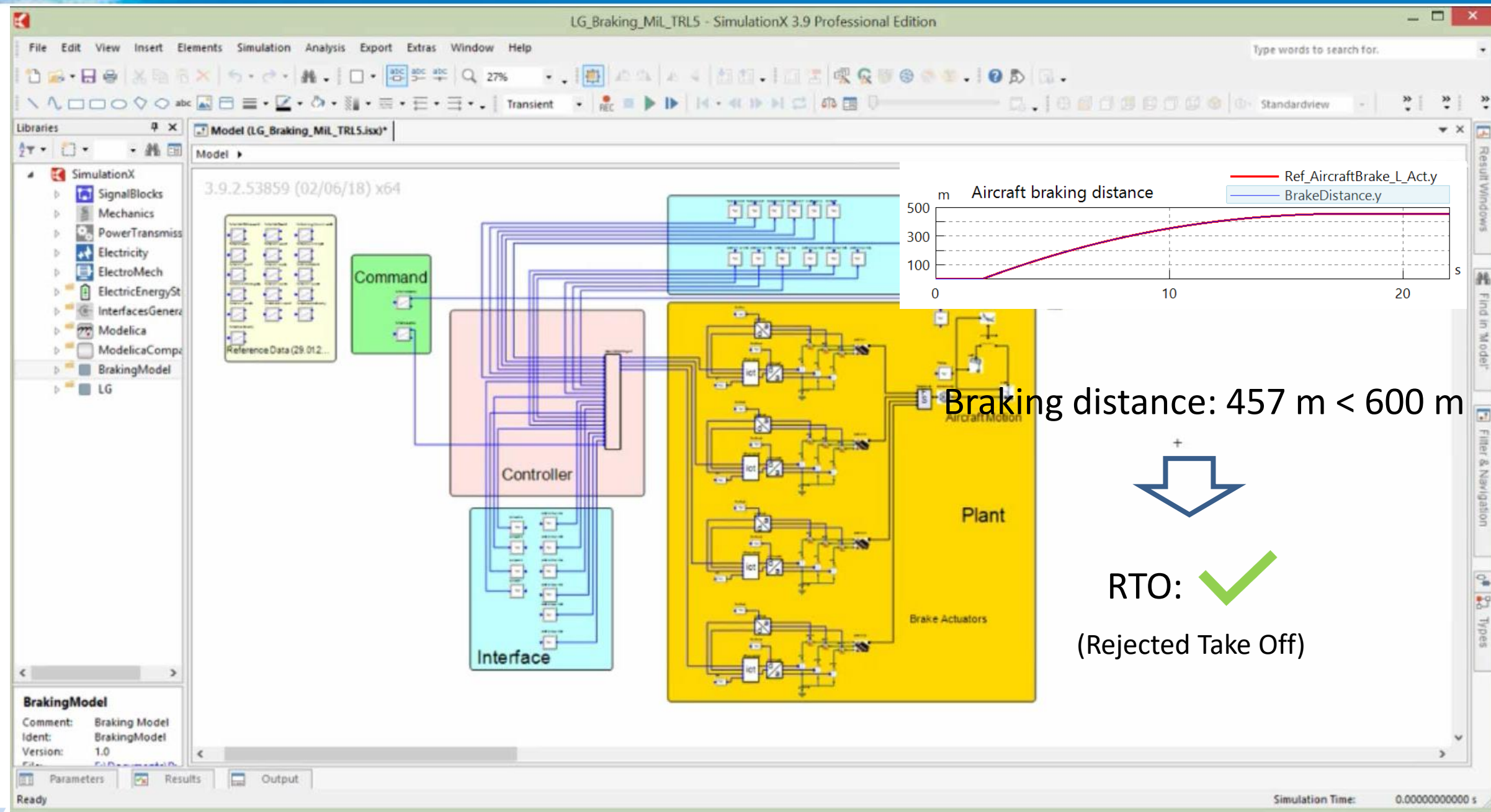
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Architectural design

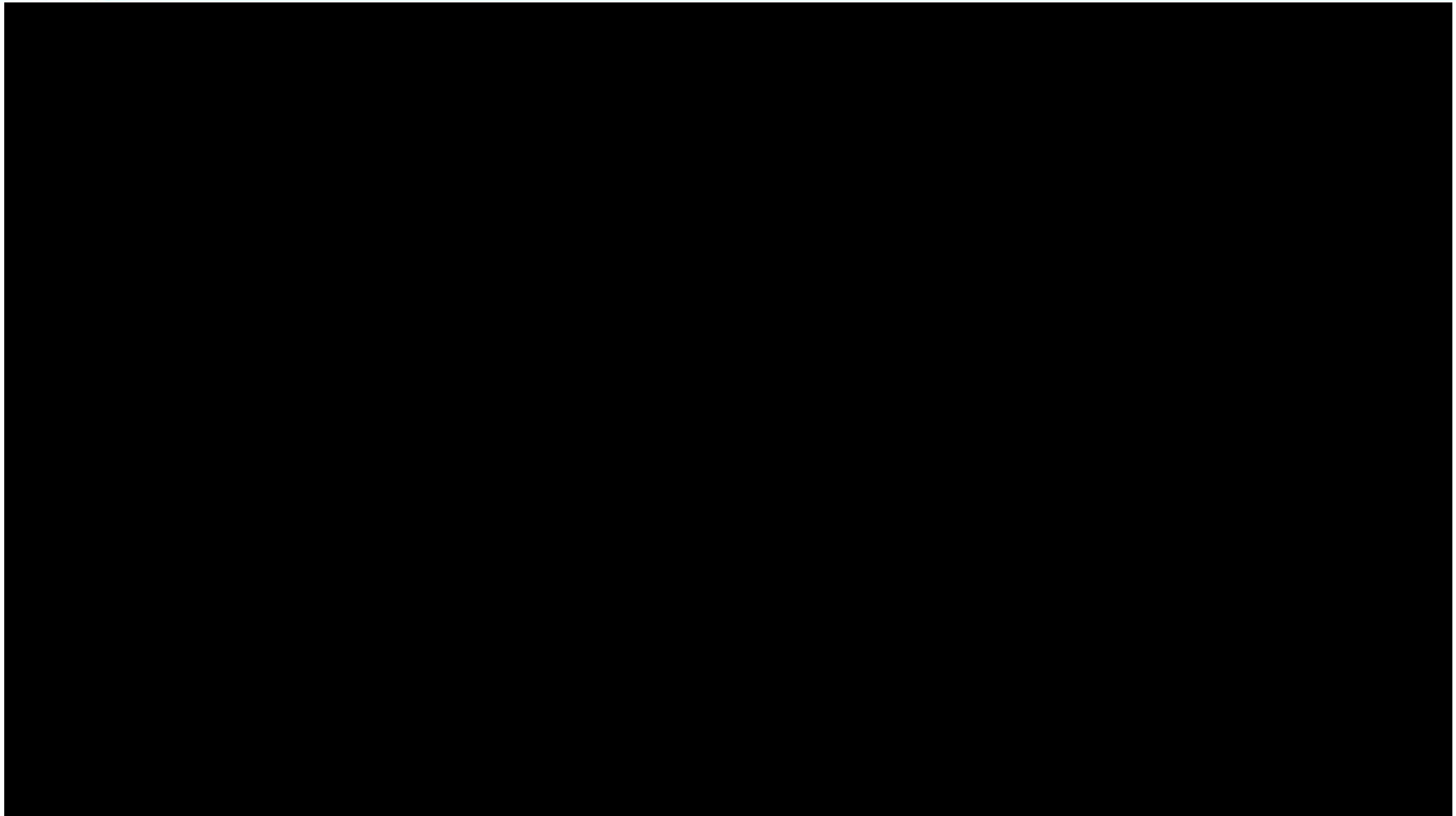


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MIL – Simulation and Requirements Verification



System Verification with DESYRE





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Summary of Demonstration

- Achievements demonstrated
 - Open framework: modular, customizable and adaptable
 - Linkage and traceability from requirement to performance model
 - Process safety and reliability by introduction of automatisms into workflow
 - Benefits of incremental virtual testing procedures
 - Continuous integration by virtual testing at early stages
- Ongoing: introducing test authoring and execution towards more automation in test driven development: test definition → model augmentation → test model → test execution → test validation → requirements verification

The project Modelling and Simulation Tools for Systems Integration on Aircraft (MISSION) receives funding from the Clean Sky 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No CS2-SYS-GAM-2014-2015-01.



United
Technologies



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Demonstration of the MISSION framework Technology Readiness Level 5 – Towards workflow integration