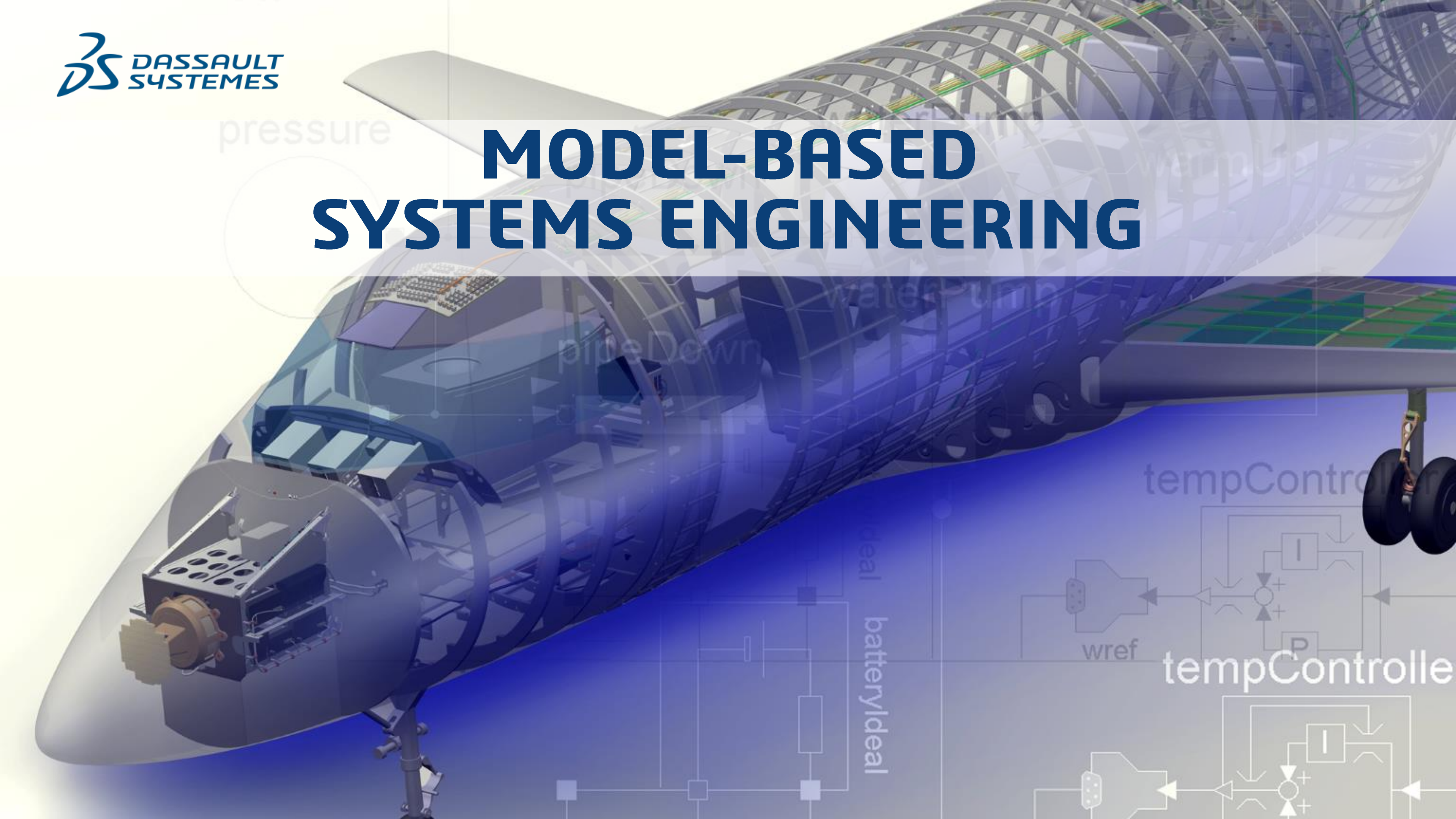
DASSAULT SYSTEMES

MODEL-BASED SYSTEMS ENGINEERING



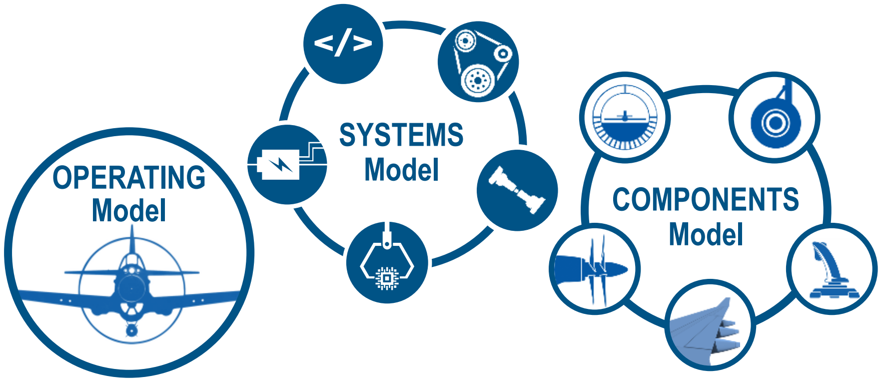
INTRODUCTION

In the 20th century, systems engineering methodology was developed so that a system could be decomposed into multiple sub-systems and each sub-system could be independently engineered, manufactured and serviced. The emphasis was laid on defining requirement specifications such that the sub-systems and its interactions with other sub-systems were clearly defined. This method emphasized upfront planning, analysis and specification. Hence, the term Requirements Driven Systems Engineering. In practice, it was always very difficult to specify upfront with a high level of accuracy and to resist changes to specifications during development. By and large this methodology has been inadequate and has led to delayed programs and last minute surprises; commonly referred to as the requirements-surprise-delay factor!

In the 21st century, iterative modeling and simulation play a crucial role in systems engineering. An operational model is first developed to understand all usage conditions, including the surrounding environment; then systems models are built and simulated; finally, component models are developed.

Change is integral to this methodology and requirements, structure, and behavior are derived and finalized with the help of the models. In short, the model as the master!

The fidelity of the models is continuously improved during the development and it is possible to combine models and physical systems, also called, Hardware in the Loop (HiL). When the physical systems are assembled, they are just a twin of the model. Tests conducted on this physical prototype can be continuously correlated against predicted behavior and be used to improve the fidelity of models.

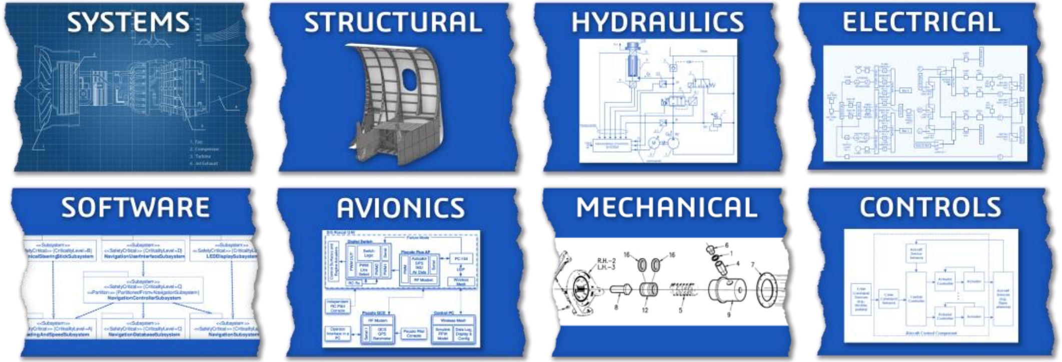


MODELS ARE EVERYWHERE

Aerospace & defense companies are cautious about incorporating new technologies – often the cause for delays in systems integration and validation. With a document-centric process, it is difficult to identify potential issues before the final system is assembled and program teams discover problems only during the physical testing of prototypes. This reliance on prototypes has proven to be time consuming and expensive. Moreover, it is difficult to test all possible scenarios with physical prototypes, thereby limiting the scope of validation. The need to develop systems behavior models and perform simulations starting early in product development process, has never been greater.

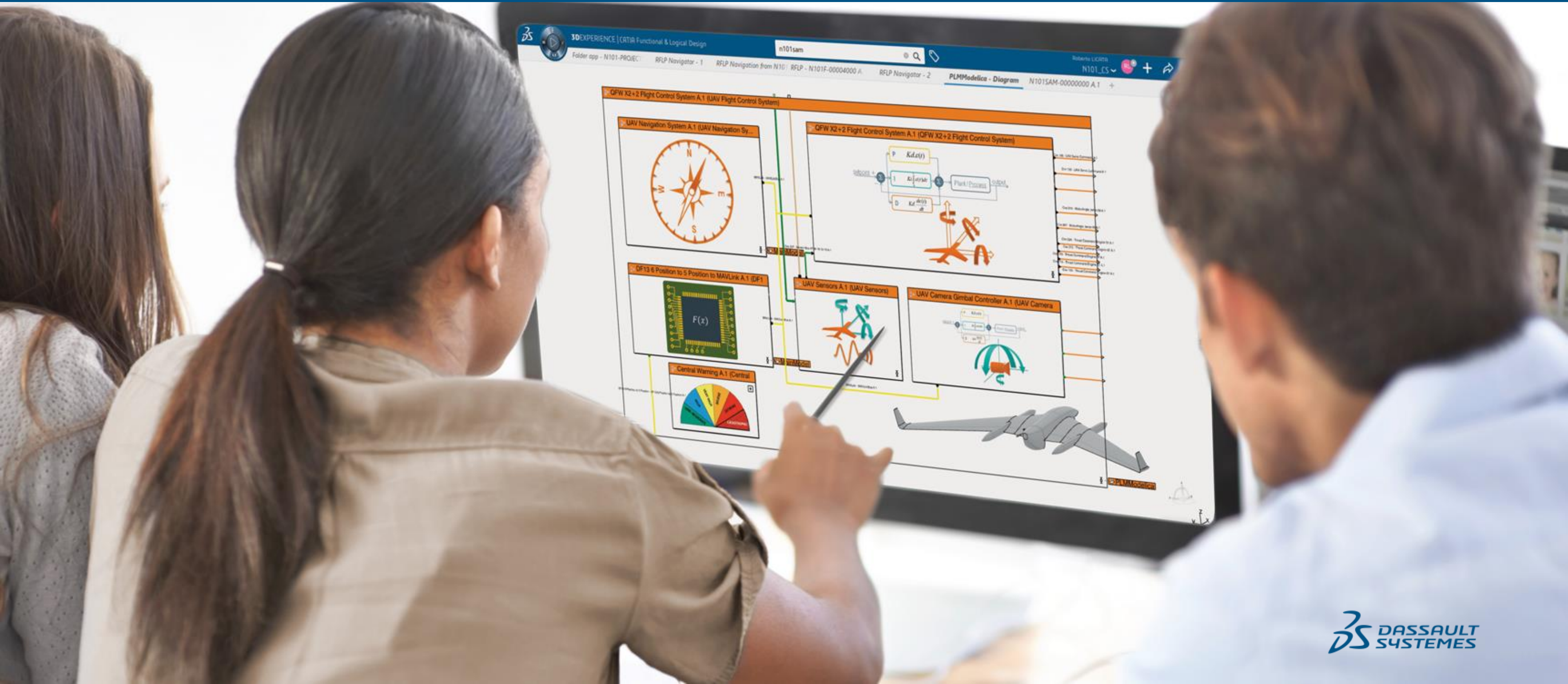
It's fairly common today for structural engineers to develop CAD models and subject them to structural and aerodynamic simulation. Similarly, a number of models are built by engineers from other disciplines: software engineers use models to specify the operating conditions and interactions between systems; control systems developers build block-based models and generate software code for controllers; electrical engineers develop schematics and layouts of their design; electronics engineers develop high-level logic that is synthesized into physical design; hydraulic engineers define hydraulic circuits. When interdisciplinary work is critical, multiple domains are combined. For example, the structural and aero-dynamics models are simulated together to understand the behavior of the overall fuselage.

Systems integration nightmare. Since each discipline is working on their own models, most often the first time the engineers witness how the systems function together is when they finally assemble a physical prototype. It's not uncommon that the physical prototypes require numerous build, test, fix iterations, before they work as intended. The net effect: programs are delayed and quality suffers.



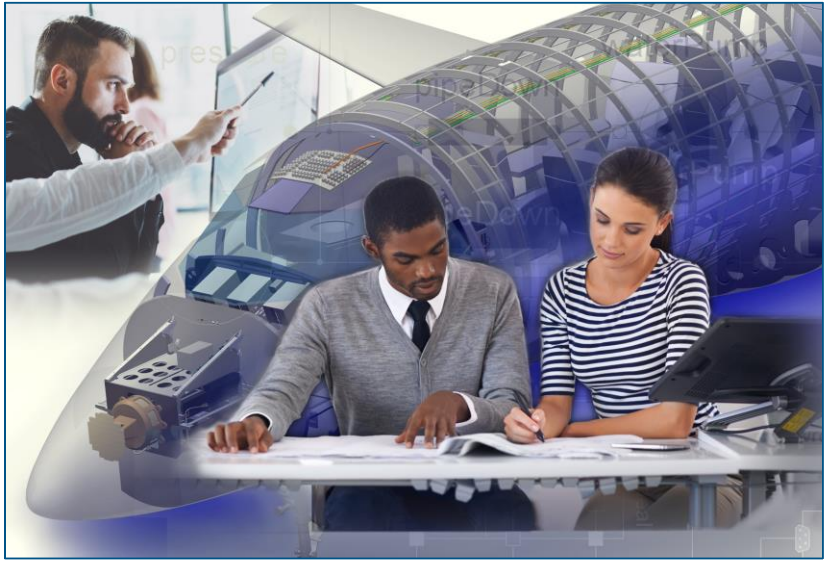
Even though models are used by every engineer, they are siloed by discipline, requiring physical prototypes for integration and validation.

WHAT IF… Engineers from all the disciplines could work together on a multi-disciplinary functional mockup and simulate how the systems work before building a physical prototype?



CO-DESIGNED TO TARGET

Deliver aerospace programs on-time, on-target and to specification



Dymola® is a physical modeling and simulation environment, for model-based design of dynamic systems. Dymola adopts the Modelica® language and is accompanied by a portfolio of multi-disciplinary libraries covering the mechanical, electrical, control, thermal, pneumatic, hydraulic, powertrain, thermodynamics, air-conditioning and flight dynamics domains. Library component models are coupled together to form a single complete model of the system. You can extend existing models or create custom models, improving reuse across programs.

Dynamic modeling of flight systems. The analysis of flight dynamics and structural loads is a key aspect in the design optimization of environmentally friendly and highly efficient aircraft configurations and in the design of their flight control systems. Dymola models are typically used for development of flight control laws, flight loads analysis, specification and testing of on-board systems, aircraft handling qualities and system assessment in real-time manned flight simulators.

Co-designed to target, a purpose-built industry solution based on the 3DEXPERIENCE® platform, connects multi-disciplinary engineering teams on an end-to-end digital platform and enables them to build a functional mockup right from the early stages of concept design. Engineers can rapidly model and test their ideas in various operating conditions before proceeding with detailed design. They can simulate the way multi-disciplinary features interact and detect potential conflicts, early in the design process. This improves stakeholders' agility and ability to rapidly choose concepts that improve safety and performance.

DLR FLIGHT DYNAMICS LIBRARY

DLR at a glance. DLR is the national aeronautics and space research center of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

Institute of System Dynamics and Controls (SR) is part of DLR with primary objectives to build innovative solutions for space flight systems, space robots aircraft, road and rail vehicles. The institute leads the development and establishment of international modeling standards such as Modelica and the Functional Mock-up Interface (FMI®) and develops model libraries for various fields of applications including Flight Dynamics.

DLR Flight Dynamics Library. The Modelica-based Flight Dynamics library enables the rapid modeling, simulation and analysis of the flight dynamic characteristics of a wide range of flight vehicles. The library is ideal for the multi-disciplinary development of accurate flight control laws as well as for use in real-time flight simulators for commercial and military aircraft, unmanned aerial vehicles (UAVs), airships and rotorcraft.

DLR Flight Dynamics Library

Flight Vehicle Components
- Aerodynamics and Propulsion-base Classes
- Airframes and Kinematic Components
- Weight and Balance Components
- Sensor and Control Systems

Environment Models
- Earth and Terrain Models
- Atmosphere and Wind Models
- Ground Objects

Interfaces
- Flight Gear Visualization
- External Devices Input

Capabilities

Full Compatibility with Standard Libraries	Scalable Complexity	Detailed Environment Models	Accurate Trimming
Develop and interconnect airframe and systems models using standard mechanical connectors.	Quickly switch between point mass or full six-degrees-of-freedom equations of motion, local geodetic or WGS'84 position states, velocity states in body or flight path coordinates via a single parameter.	Simulate one or more aircraft in a single model using a common detailed gravity, magnetic field, terrain, wind and atmospheric models.	Accurately initialize flight dynamic models to their desired initial state.

The DLR flight dynamics library has been used to model several aircraft:

"Weather and Flying"

- Integrated flight dynamics model of DLR's VFW-614 ATTAS fly-by-wire testbed
- Automatically generated control laws based on "Nonlinear Dynamic Inversion" from the flight dynamics model
- Design of advanced control functions with improved handling of atmospheric disturbances

Project "ELHASPA"

ELHASPA: Electric High Altitude Solar Powered Aircraft – A cooperation between DLR and various German partners (Airbus, SFL, Rödel Aircraft Systems)

- Integrated model of flight dynamics, aero-elasticity, flight loads, energy systems
- Use of model for aircraft design analyses
- Use of model for design of autopilot control functions

FLIGHT DYNAMICS MODELING & SIMULATION

Flight dynamics is critical in the design of aircraft physical and control systems. Simulation plays an important role in the design and certification process. Dymola and DLR flight dynamics libraries capitalize on decades of experience with modeling and simulation of various aircraft systems. It has been validated in the following use cases.

Aircraft Design: Assess the impact of aircraft design configuration changes on flight characteristics early in the design process.

Mission Simulation and Optimization: Rapidly execute mission simulations to assess flight performance or to optimize flight trajectories to minimize fuel burn, emissions and flight time.

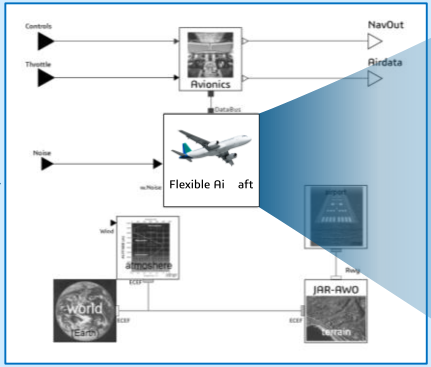
Flight Control Law Design: Design and analyze multi-disciplinary flight dynamic control laws for flight and system dynamics. Generate inverse models for control surface sizing and automatically generate control laws which are based on inverse model equations, like Nonlinear Dynamic Inversion(NDI).

Hardware in the loop. Generate real-time code for simulation on popular HiL platforms from dSPACE® and National Instruments™. Dymola-generated code has been tested and verified for compatibility with multiple combinations of dSPACE and MATLAB® releases.

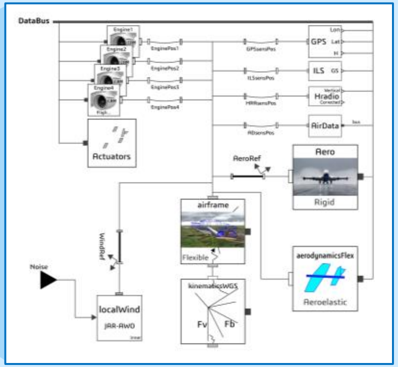
Real-time Simulation: Leverage accurate flight dynamic models and realistic visualization to create real-time simulators for training pilots and product marketing. Pilot training on a robotic arm.

Model Import and Export. Import models directly from Simulink® into Dymola. Export from Dymola via the FMI® Standard 1.0 and 2.0 for both model exchange and co-simulation.

DLR Flight Dynamics Libraries



Aircraft and Environment Model



Flexible Aircraft Model


Hardware in the loop simulation

DYNAMIC FLIGHT SYSTEMS MODELING – A Checklist

If you are want to incorporate dynamic behavior into your aerospace models, the following are some of the key capabilities of the modeling environment that you may want to consider.

Breadth of Library Models: Are there pre-built libraries for the sub-systems that are included in your system? If your systems are multi-disciplinary in nature, look for libraries across multiple domains containing models for flight dynamics, mechanical, electrical, control, thermal, pneumatic, hydraulic, power train, thermodynamics, air conditioning, etc.

Object Oriented: Can you directly instantiate the library models and build your systems with ease? Typically, look for a drag and drop interface. Also, look for the ability to abstract sub-systems into a single model. If necessary can you modify the library models and create your own derivatives of the models? Model management capabilities are a key requirement if you are working in a team.

Equation Based. Can the dynamic behavior of systems be described by differential and algebraic equations? Does it support the concept of *flow* and *across* variables?

Acausal. Does the environment support the definition of equations in a declarative form, without considering the sequence? This reduces the effort to describe behavior in comparison with procedural languages like C and other block-based tools, where signal flow direction needs to be considered.

For a review of Dymola capabilities, please click here.

DASSAULT SYSTEMES

The 3DEXPERIENCE® Company

Articles to follow...

Flight Dynamics Simulation – A Deep Dive

Systems Architecture with SysML