Physical Modelling Integration and Co-simulation in a Real-Time Environment

A. Ramsay & C. Hoyle
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Contents and Context

- Flight Systems
  - What are Flight Systems
- The Challenge
  - To industry as a whole and us as a consequence
- The Solution
  - How we’re addressing this challenge and how MathWorks are helping us
What are Flight Systems?

• Systems required to enable the aircraft to operate

• Multi-domain physical systems covering, electrical, mechanical, thermal and fluidic elements.

• Systems typically requiring safety critical software control.

• Systems requiring a high degree of complex integration across the aircraft
  • Physical and software elements
The Challenge

Develop and use the latest technology to deliver a more capable product and meet more challenging performance requirements

Deliver the product in shorter timescales than previous products and be capable of rapidly adapting to changes if required

Meet cost challenges to deliver a more affordable product
The Solution

- Better: Optimise system and platform design through integrated physical modelling and a model based engineering approach
- Quicker: Rapidly assess change in a virtual environment and embed automation into the design process
- Cheaper: Streamline and reduce physical rework by identifying emergent behaviour earlier through virtual integration and assessment
Context
Progression of Flight Systems Integrated Modelling Capability

Traditional Modelling:
Desktop Simulations

Real Time Modelling:
Target Based Simulations

Virtual Integration:
Collaborative System Modelling

Virtual Product:
Integrated Platform Modelling
Traditional Modelling

Desktop Environment

Independent System Development

• Traditional use for modelling
• Foundational to all other modelling
• Models used for trade studies & concept development
• Isolated system design with models used to resolve/explore specific design problems
• Simulation time can be long as it is dependent on model complexity coupled with processing power, but it is unconstrained by model fidelity
### Traditional Desktop Modelling

Challenges with Modelling Physical Systems for Flexibility and Re-use

<table>
<thead>
<tr>
<th>Physical System Models</th>
<th></th>
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<tbody>
<tr>
<td><strong>Simulink</strong></td>
<td><strong>Simscape</strong></td>
</tr>
<tr>
<td>Built from first principle equations</td>
<td>Drag and drop component architecture</td>
</tr>
<tr>
<td>Difficult to read and use except by creator</td>
<td>Schematic representation makes models more universally readable</td>
</tr>
<tr>
<td>Architecture changes require re-working of underlying equations</td>
<td>Architecture changes easily made and managed by Simscape solvers</td>
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</tbody>
</table>
Simulink DC Motor Model
Causal Model
Simscape DC Motor Model
Non-causal Model
Real Time Model Simulation

Real Time Environment

Independent System Development

- Rapid Prototyping
  - Early development and testing of software requirements
- Hardware-in-loop Testing
- Enables model based testing
  - Re-use of model tests on hardware
- Simulations run in real time (limited by model fidelity)
Real Time Challenge
Solver Selection

![Normalized Cost of Fixed Step Solvers](image-url)
Real Time Challenge
Discretization of Models

“Model Discretizer” within the Control Analysis Toolbox identifies elements within the model needing to be changed
Virtual System Integration
Collaborative Real Time Environment
Integrated System Development

- System-of-Systems Virtual Integration
- Simulation Time and/or Real Time
- Assessment of emergent properties and impact of cross-system failures/degraded performance
- Modular architecture design approach
- Potential to support system design through to qualification and in-service support
Virtual System Integration
Model Architecture and Management

Model architecture supported by use of:

- Reference models
- Simscape libraries
- Concurrent execution
- Custom Simscape components
- Simulink Projects
Flight Systems Capability Hub
An Integrated Modelled Systems Vision

- Primary & Secondary Actuation
- Ice Detection & Protection
- Landing Gear & Brakes
- Thermal Management
- Utilities Management
- Fuel
- Lighting
- Electrical Power
- Propulsion
- Fire Detection & Protection
- Air Data
- Ice Detection & Protection

MathWorks
DESIGN VERIFIER
EMBEDDED CODER
STATEFLOW
SIMULINK
MATLAB
Addressing the Challenge

- Adopting a model based design approach
- Utilising multi-domain physical modelling tools
- Transitioning desktop models into real time capable models
- Assessing complex system interaction in a virtual environment
- Optimisation and fault finding earlier in the lifecycle resulting in better, quicker and cheaper products