An MBD Adoption Story from Bombardier Transportation

Matlab Expo 2018
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Agenda

1. Bombardier Transportation, Propulsion & Controls
2. Challenges
3. Adopting MBD
4. Results
5. Questions
6.
7.

Bombardier Transportation mobility solutions

The broadest portfolio in the rail industry

Rail Vehicles

- Light rail vehicles
- Metros
- Commuter trains
- Regional trains
- Intercity trains
- High speed trains
- Locomotives

Transportation Systems

- Driverless systems: Monorails, Metros, People Movers
- Light rail systems
- Metro Systems
- E-mobility solutions
- Operations and Maintenance

Services

- Fleet Management
- Asset Life Management
- Material Solutions
- Component re-engineering and overhaul

Rail Control Solutions

- Integrated control systems
- Automatic train protection and operation
- Interlocking systems
- Wayside equipment
- Services

Propulsion & Controls

- Traction converters
- Auxiliary converters
- Traction drives
- Control and communication

Bogies

- Portfolio to match entire range of rail vehicles
- Full scope of service over the lifetime of a bogie

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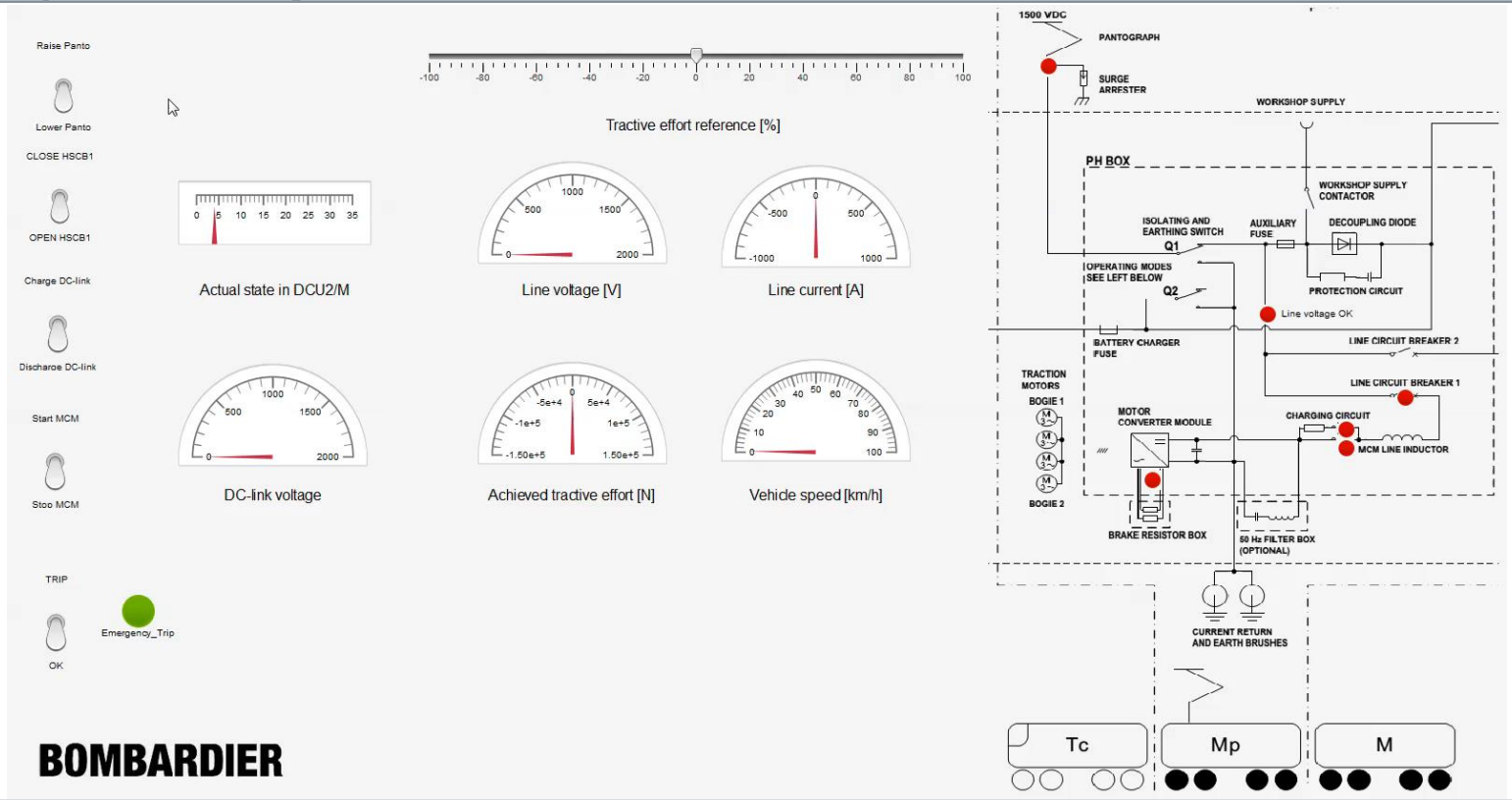
Propulsion & Controls
Scope of Delivery



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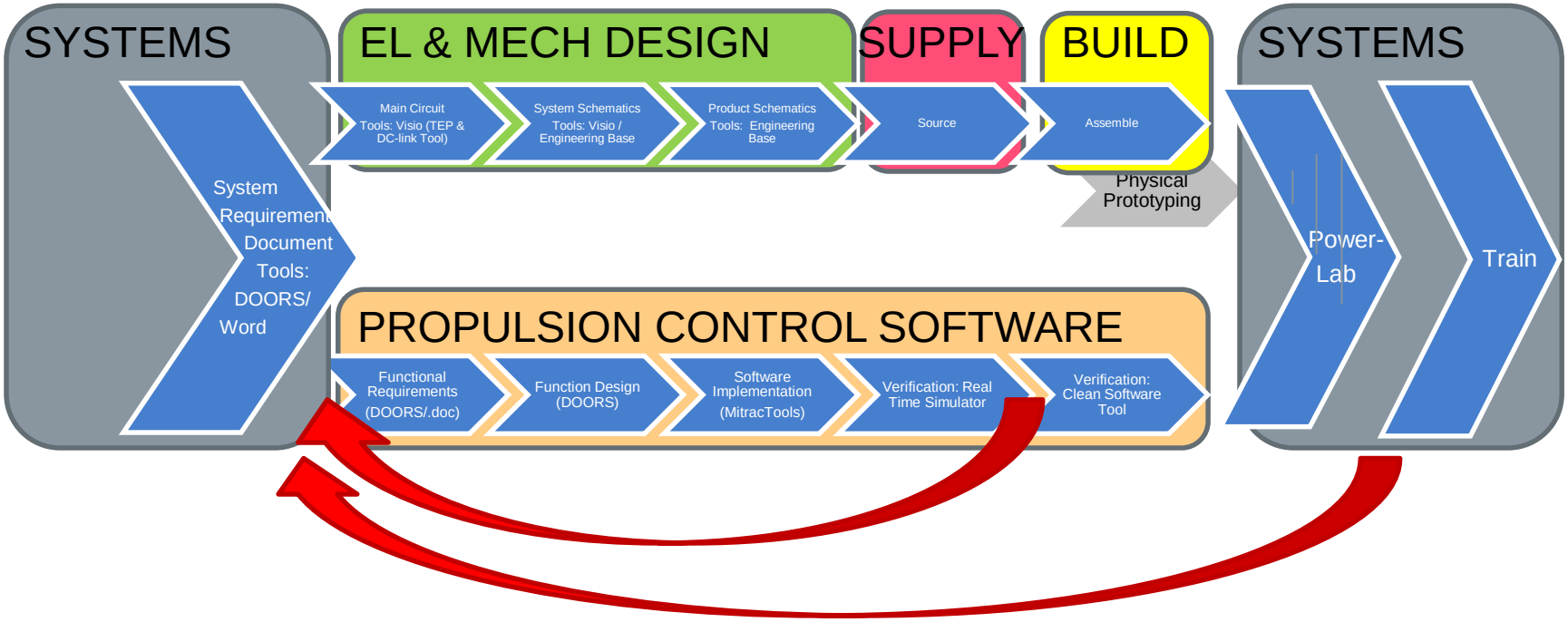
The Challenge
Late Verification



Long & expensive correction loops on design & requirements

~5 months | ~3 months | ~3 months | ~6 months | ~5 months

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The Challenge
Complexity, People, Lead time and Quality

- Complex systems, prone to faults
- Faults detected too late, thus the cost to correct them has been too high
- Roughly 50 people are involved in any project spread over 10 different teams
- The organization has been highly dependent on a few very skilled employees
- Our lead time has been too long

Conclusion

Too many faults detected too late, involving too many people driving lead time too far → The cost has been too high.

The First Steps
Exploring MBD

2013: 120 hours prestudy as part of a process improvement work package

- We learned that we can detect and correct design errors earlier and more quickly
- We learned that Matlab/Simulink is a strong contender
- A seminar arranged by Mathworks introduced MBD to Propulsion Control

2014: 1 MSEK investment

- 60% spent on creating “base” models, 15% on training and 15% on licenses
- 10% spent on mitigating identified risks in a real customer order project
- Results
  - One electrical design issue was located ahead of first train being assembled,
  - Iterated a complete system design early, saving lead time for the project
  - Altogether the savings were larger than the investment (ROI slightly above 100%)

Modelling Purpose
Risk Centric versus Model Based Design

Risk Centric Modelling

- All deliverables in the project are in traditional format (textual design, manual implementation, electrical circuits in visio etc)
- High risk areas of the project are mitigated through modelling, results will be incorporated into the traditional format

Model Based Design

- Key deliverabels in the project are derived from the models (software design, code and electrical circuits)
- With parts of the system being modelled, high-risk areas can be effectively mitigated with low effort

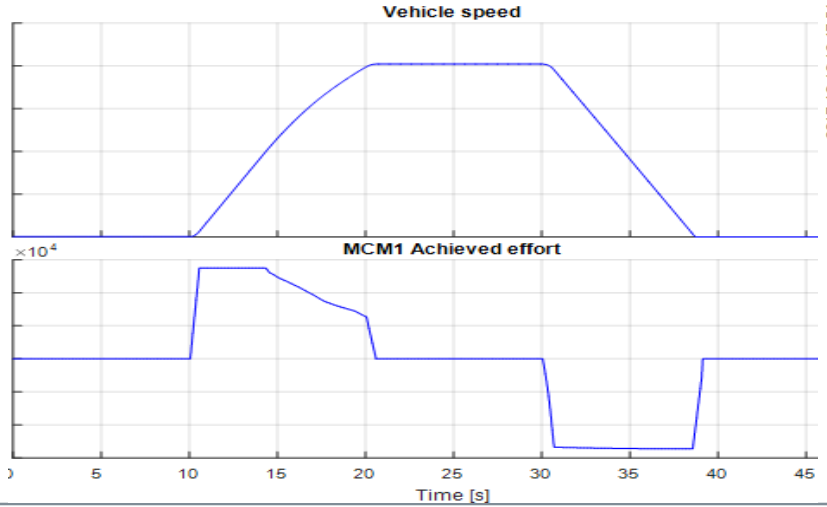
Use Case: Automatic Code Generation in PowerLab (2017)

Software Quality Right from day 1

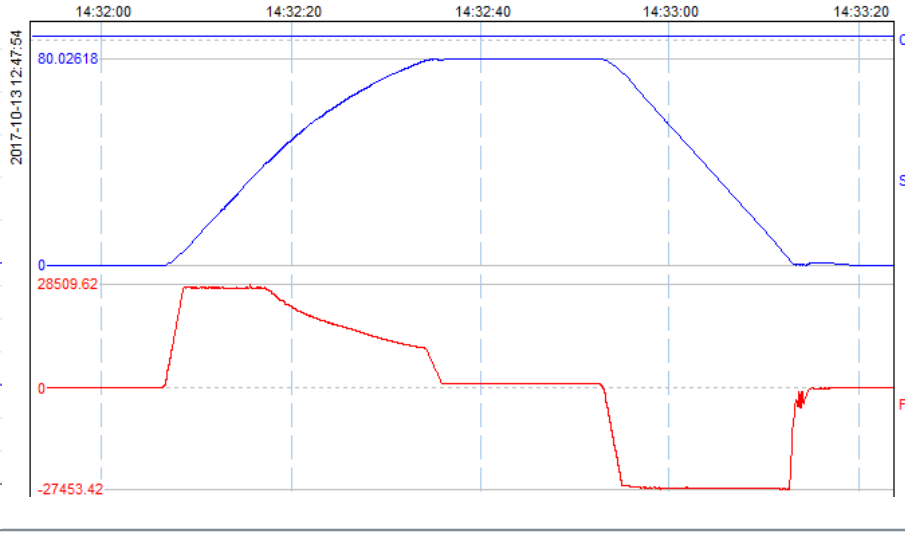
Problems resolved in PowerLab have mostly been related to incorrect wiring.

Lessons Learned: Ensure that you have ability to debug on target!

System data from a PC simulated drive cycle



Actual system data from a drive cycle in PowerLab



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First attempt to truly adopt MBD was a learning
Remember to change project planning

2017-2018: We chose a small project, rationale being to focus on process change

- Software is generated from model
- Electrical main circuit is defined by the model

Lessons learned:

- The project must actually plan for early verification (i.e. update standard deliverables list).
- Underestimated the work going from a quick & dirty model, to a model fullfilling all formal requirements (configuration management, debug on target, test strategies, functional safety etc.)
- Main Circuit Design: The electrical part of the model has to „look & feel“ like a traditional electrical schematics if you want the electrical and system teams to embrace the new method.

A few more words on change….
Keep in mind The Change Curve

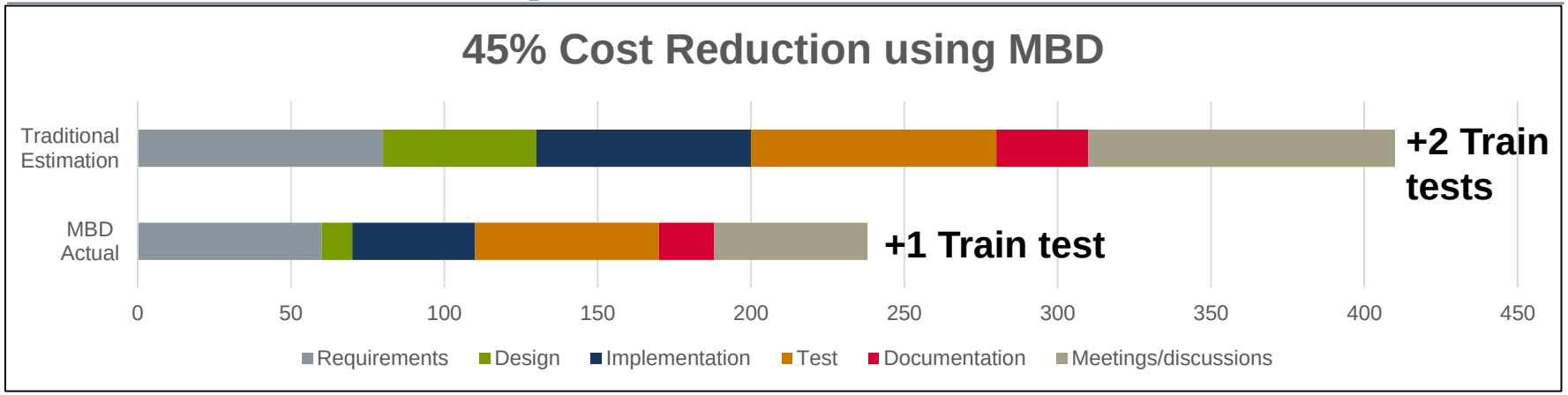
- There is a whitepaper*, I can confirm it is correct & valid also for Bombardier☺
- We have been fortunate in having quite a few different people actively embracing and driving the change
  - Such a team is imperative in a bottom-up MBD adoption
  - Such a team can go through the „change curve“, the risk is to lose remaining organization
  - ….the imperative in enabling the change must be balanced towards also ensuring the entire organization to be onboard

DO NOT UNDERESTIMATE THE CHANGE!!!

*Best Practices for Establishing a Model-Based Design Culture, 2007
Paul F. Smith, Sameer M. Prabhu, Jonathan Friedman, The MathWorks

Result from 2017
Use Case: New Complex Function

35 % Lead Time Reduction



Workflow Step	# MBD Iterations (Actual)	# Traditional Iterations (Estimated)
Requirements	4	4
Design	1	3
Implementation	1	3
Test	1	3
Documentation	1	3
Train Test	1	2

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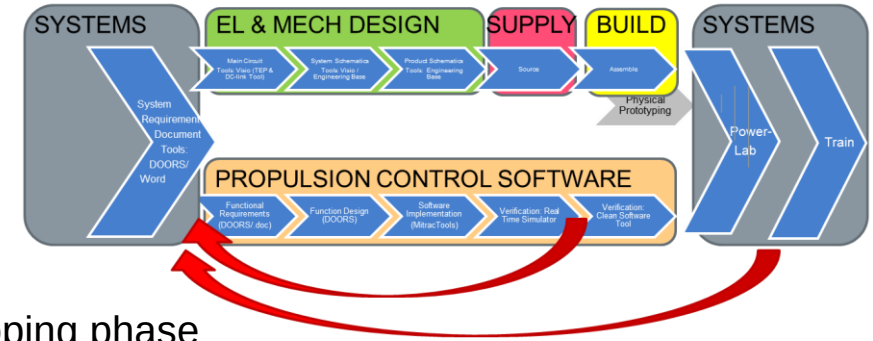
Status 2018
Work in Progress & Outlook

Update of the software process is in the works

First alpha-baseline of model

- Tested in February in PowerLab
- Launch in real order project planned second half of 2018
  - Complient with Safety Integrity Level 2 according to safety norms



System Modelling & Verification

- We expect the largest gains here
- Including all three departments is in a developing phase
- 10 Different teams must coordinate their efforts and define a joint process

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Communicate Results
Monitor, Learn & Report

- First investment in 2014 was monitored from a business perspective (ROI) & and a report was compiled.
- Publish articles, reports & results on Company Intranet
- …..and of course share your learning on Matlab Expo! ☺

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NewsFlash

March 2017

Rolling Stock Equipment

Did you know…?
Advantages of Using Virtual Rapid Prototyping to Develop Propulsion Systems

During the execution of a project, the main circuit hardware (HW) and control software (SW) design of a propulsion system are usually combined earliest one year after project start. By using virtual rapid prototyping, this HW and SW integration can be done to a high extent already during the initial design phase, which reduces costly mitigation and unwanted lead time delays at later project stages.

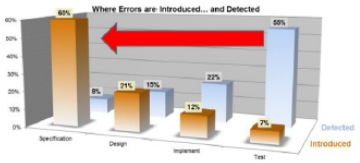
Traditionally, the first interaction of HW and SW design of a propulsion system happens during the combined system test, which is undertaken one year after the official start of a project.
The system test can be set up to represent a relevant part of the full train system, but it will never be a full train.

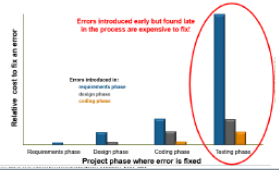
By using compatible SW tools for HW design and models of SW functionality, a virtual system representation can be created more or less from day one in the project, or even in the bid phase.

The system design is based on customer requirements. The virtual rapid prototyping, using Model Based Design, means a shift in design principle from requirement management to design management. The latter enables early validation of concept designs, which results in a parallelization of refining and validating the design.

The virtual rapid prototyping will not lead to a disappearance of the combined propulsion HW and control SW system test in the future. E.g. there will always be a need to validate systems from a thermal perspective. However, the functionality of the system will be validated already through Model Based Design, which reduces the need for long and costly system tests.

The two recent examples below, of issues experienced in projects, have been captured to illustrate the potential benefit of Virtual Rapid Prototyping using Model Based Design.





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Q&A