How to boost the extended enterprise approach in engineering using MBSE – a case study from the railway business

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Railway sector - business chain for rolling stocks systems
Role of system and subsystem integrators

CUSTOMERS: Railway operators

External need (Input requirements)

SYSTEM INTEGRATOR (vehicle level)

Subsystem specifications
Subsystems INTEGRATOR (Subsystem level)

Rolling stock Sub-systems

Sub-systems Components

Final Product: train set (consist)
Product evolution – complexity growth

- **Technological complexity growth** by increased electronic and software driven system functionalities
  - Historically, railway vehicle were fully mechanical and once electronic appeared all the « non mechanical » functions to monitor and control the system were realized with wiring (relays logic)
  - Today the trend is to implement (when possible) more and more functionalities (also “safety relevant”) in software

- **Increase of required services** for improve passengers travel experience
  - public announcement, infotainment and multimedia, video surveillance, internet access

- **Increase of integration** with the system environment
  - The IoT revolution has huge impact on the train ‘as a connected thing”, more and more interactions with external systems require to implement new functionalities (e.g. drive from remote control center) with very high level of safety and security (cyber-security)

- **Increased performances**
  - lead to a more sophisticated and precise control of the subsystem.

<table>
<thead>
<tr>
<th>Key values</th>
<th>Classic Trains</th>
<th>Todays Metros</th>
<th>Modern Trains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boats with project-specific</td>
<td>~30</td>
<td>2 – 12</td>
<td>50 – 100</td>
</tr>
<tr>
<td>Application SW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal signals between</td>
<td>~30</td>
<td>50 – 300</td>
<td>~15000</td>
</tr>
<tr>
<td>Brake Control units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External signals from TCMS</td>
<td>~50</td>
<td>200 – 1000</td>
<td>~3500</td>
</tr>
</tbody>
</table>
Functional architecture and MBSE @ Bombardier

Requirements
Operational analysis
Functional analysis
Technical analysis

Operational Spec
Functional Spec
(Functional mock-up
(Derived reqs

(including functional derived requirements with properties))
# Functional architecture and MBSE @ Knorr Bremse

<table>
<thead>
<tr>
<th>What is required?</th>
<th>What is it used for?</th>
<th>Which functionality is offered?</th>
<th>Which components is the system composed of?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>Operational Analysis</td>
<td>Functional Analysis</td>
<td>Technical Synthesis</td>
</tr>
</tbody>
</table>

## Train Level

- **Train Subsystem Brakes**
  - Level S1 Req's: Context, Use Cases
  - Level S2 Req's: **Architectures of Train Subsystems**
  - Level S3 Req's: Context, Use Cases
  - Level D Req's: **Main Functions**

## Subsystem Domains

- **Function Carriers**
  - **Architectures of Subsystem Domains**
  - **Pneumatics**
  - **Electronics**
  - **Software**

## Asset Portfolio

- Reference Architectures
- Function Carriers Library
- Standard System Functions

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**KNORR-BREMSSE**

**Bombardier**

*the evolution of mobility*
Rolling stock integrator vs. Subsystem supplier a key and complex relationship

Traditional interface follow the classical V-cycle stages with many data exchanges between the two parties. Re-use of existing off-the-shelf existing solutions is difficult while this approach is mainly top-down oriented.
The extended enterprise approach

- What is Extended Enterprise? is when a company goes beyond its traditional perimeter and may include its business partners, its suppliers, and its customers in it. For instance, when focusing suppliers, this might be translated into virtual integration, outsourcing, joint global R&D programs, partnership agreements and preferred supplier approach.

- To tackle the railway market evolution challenges:
  - product development life cycle duration dramatically reducing
  - the competition intensifying
  - the level of risk of not delivering on time increasing

→ smart organizations are considering to implement the extended enterprise approach.

- According to Jan Duffy and Mary Tod, the authors of the article "The Extended Enterprise: Eliminating the Barriers", the extended enterprise can only be successful if all the component groups and individuals have the information they need to do business effectively.

- In the specific case of rolling stock integrator and subsystem supplier for what concern the functional architecture development, MBSE can be a great booster to implement the extended enterprise approach efficiently.
The Goals of the BT-KB MBSE Cycle are:

- Simplifying the definition of interfaces
- Generating interface control documents based on consistent models
- Traceability of functional requirements and design decisions across company borders
- Facilitating iterative refinement and change management
- Effect analysis across company borders
- For subsystems (e.g. Brakes, Doors, etc.): Using standardized products taken from a portfolio of standard system functions, function carriers and reference architectures
- For vehicle level: Integration of standardized subsystem products into standardized functional building blocks
Conclusions

- Railway market evolution is requiring **improved collaboration and communication between vehicle integrators and subsystems providers** to share the end goal, the related risks and to remain competitive.

- The extended enterprise approach answers to that need, but it requires some enablers, while MBSE can definitively be the one for the functional content of the product.

- Unfortunately, the only available and widely adopted standards in the MBSE domain are the generic system modelling language SysML and generic modelling methodologies, for what concerns the railways sector, **no common industrial standards has been developed yet**.

- The lack of such standards requires companies that want to implement an MBSE approach (like Bombardier and Knorr-Bremse) to **develop by their own specific profiles of the SysML language and related modelling methodologies**. As major consequences it’s very difficult to interlink models across companies,

- The case study presented here is an **exceptional lucky case** where the lack of those standards hasn’t been impeding Bombardier and Knorr-Bremse to explore the feasibility of implementing a real MBSE based extended enterprise approach and to appreciate all the possible benefits of it.

- **Both companies strongly believe in MBSE** and in the potentialities to enable an efficient extended enterprise approach, and wish that a **modelling methodology open standard for the railway industry** will be developed providing a **common MBSE framework** across it.
Thank you for your attention!