REAL WORLD APPLICATION OF

MBSE AT BOMBARDIER
TRANSPORTATION

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Bombardier is the world’s largest manufacturer of both planes and trains, with a worldwide workforce of 74,000* people.

Bombardier is headquartered in Montréal, Canada. Our shares are traded on the Toronto Stock Exchange (BBD) and we are listed on the Dow Jones Sustainability World and North America indexes. In the fiscal year ended December 31, 2014, we posted revenues of $20.1 billion USD.

* As at December 31, 2014, including contractual and inactive employees
BOMBARDIER
Our evolution

1942-1973
- Company start-up
- Development of passenger and personal snowmobiles
- Vertical integration
- Energy crisis provoked market collapse

1974-1985
- Diversification into mass transit market
- Learning of new industry
- 1982 New York metro contract secured strong position in American market

1986-1993
- Entry into aerospace through Canadair acquisition
- Consolidation of North American mass transit position and reinforcement of presence in Europe

1993-2003
- Aerospace: Short Brothers (UK), Learjet (US), de Havilland (CA)
- Transportation: BN (BE), ANF (FR), Deutsche Waggonbau (DE), Concarril (MX), Talbot (DE), Adtranz (DE)
- CRJ Series, Global Express, Challenger 300
- Tilting train, AGC (Autorail Grande Capacité)
- Sale of Recreational products business unit

2003-
- CRJ NextGen family, Learjet 85, Q400 NextGen, CSeries, Global 7000, Global 8000
- Hybrid AGC, ZEFIRO, ECO4
- Transportation’s expansion into emerging markets
System Engineering Challenges & Goals
## System Engineering Challenges & Goals

With respect to technology

Reduce development costs while increasing quality of the design artefacts.

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Goal</th>
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<tbody>
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<td>Complex products</td>
<td>Manage complexity</td>
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<tr>
<td>Distributed information sources</td>
<td>Share centralized information</td>
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<tr>
<td>Opportunistic, isolated reuse (copy past)</td>
<td>Managed, integrated reuse of development artifacts</td>
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System Engineering Challenges & Goals
With respect to people

Reduce development costs while increasing quality of the design artefacts.

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<tr>
<td>Distributed development</td>
<td>Enable collaboration</td>
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<tr>
<td>Multicultural teams</td>
<td>Improve correct understanding</td>
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Engineering Domains

- Verification & Validation
- Testing
- Safety Engineering
- Functional Engineering
- Mechanical Engineering
- Software Engineering
- Electrical Engineering
- Requirements Engineering
- Project Management
- Systems Engineering (MBSE)
The BT System Modeling Method describes how BT engineers shall analyze, define and represent their system of interest using a Model-Based Systems Engineering approach. The purpose of the method is to manage complexity and increase quality of the design artefacts to reduce development costs.

The BT System Modeling Method consists of three main tasks. Each of them to analyze the system of interest on a different abstraction level.

**Operational Analysis**
- OA - main deliverables
  1. Context & scope
  2. Interactions between SOI and actors
  3. SOI use cases including their detailed behavior

**Functional Analysis**
- FA - main deliverables
  1. Functional architecture
  2. System of interest decomposition
  3. Allocation of Functional Blocks to the SOI’s parts

**Technical Analysis**
- TA - main deliverables
  1. Technical breakdown structure
  2. Technical architecture
  3. Allocation of functional blocks to technical blocks

1 SOI is the system of interest
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BT System Modeling Method – Operational Analysis Example

**Definition of:**
- Use cases
- Associated actors
- Use cases detailed behavior with their activities

**Operational Analysis**

**Functional Analysis**

**Technical Analysis**

**Operational Analysis Example: Set Travel Direction Of Train**

**Act** [Activity] Set Travel Direction Of Train

**Requested train travel direction:** Train Travel Direction

**Select Train Travel Direction,**
- Train Travel Direction
- Train Travel Direction

**Selection allowed?**
- [train travel direction selection not allowed]
- [train travel direction selection allowed]

**Apply Train Travel Direction on Consist**
- Train Travel Direction

**Driver**
- **Train Travel Direction Request**

**Trigger:** «signal» Train Travel Direction Request

**Result:** The train travel direction which has been selected by the driver is applied in all consists of the train
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BT System Modeling Method– Functional Analysis Example

Definition of:
• Functional Blocks
• Functional Block behavior
• Interfaces between Functional Blocks
• Allocation of Functional Blocks to the subsystems
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BT System Modeling Method – Technical Analysis Example

Definition of:
- Technical Blocks
- Technical Blocks breakdown
- Technical Blocks interfaces
Integrated Engineering Approach

Safety Engineering

Requirements Engineering

Functional Engineering

Malfunctions, Hazards

Requirements

Concepts, behavior, architecture

How to manage traceability and enable synchronization?
How to generate a consistent document base on given information?
Linking hazard trees to requirements in DOORS and synchronizing safety information with Datalink Manager.

Linking and synchronizing requirements from DOORS into MagicDraw in Cameo DataHub.

Hazard Analysis in Reliability Workbench.

System Modeling in MagicDraw.

Automatic document generation in MagicDraw.
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MBSE is an integrated approach – Example

Definition of requirement in DOORS (visualized safety attributes)

Definition of safety attributes in Reliability Workbench based on requirement

Synchronized requirement in MagicDraw linked to use case

Reliability Workbench

Vehicle requests opposite train travel direction than demanded and sends information to train

VR801_MF01
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Change Analysis on Different System Hierarchy Levels

Subsystems Level
- 4S_06.03.05: TRX:AC3.1147
- 4S_06.03.05: TRX:AC3.290
- 4S_06.03.05: TRX:AC3.1087
- 4S_06.03.05: TRX:AC3.1000
- 4S_06.03.05: TRX:AC3.228
- 4S_06.03.05: TRX:AC3.227
- 4S_06.03.05: TRX:AC3.229
- 4S_06.03.05: TRX:AC3.230
- 4S_06.03.05: TRX:AC3.231
- 4S_06.03.05: TRX:AC3.232
- 4S_06.03.05: TRX:AC3.233
- 4S_06.03.05: TRX:AC3.234
- 4S_06.03.05: TRX:AC3.1007
- 4S_06.03.05: TRX:AC3.201
- 4S_06.03.05: TRX:AC3.1115
- 4S_06.03.05: TRX:AC3.1162
- 4S_06.03.05: TRX:AC3.1163
- 4S_06.03.05: TRX:AC3.1164
- 4S_06.03.02: TRS:TRAC:AC3.27

Train Level
- 2F TRS:TRAX:AC3.804
- 2F TRS:TRAX:AC3.887
- 2F TRS:TRAX:AC3.824
- 2F TRS:TRAX:AC3.741
- 2F TRS:TRAX:AC3.801

Vehicle Level
- Show the described behavior (activities)
- Show the allocated elements
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System Modeling Tool Criteria

- Excellent tool support and customization
- Fully supported language standard (SysML)
- World wide data accessibility
- Supports concurrent modeling
- Integration of requirements
- Supported change impact analysis
- User friendly
MBSE Lessons Learned
MBSE Lessons Learned

Provide practice oriented methods

Think big but start small

Provide suitable tools to do the job

Provide trainings, coaching and guidelines
Q&A
BOMBARDIER
the evolution of mobility