SysML - System Modeling Language
Benefits for the Complex Systems of IIoT

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The changing nature of products is disrupting value chains, forcing companies to rethink and retool nearly everything they do internally.”
A holistic, multi-disciplinary and collaborative approach to designing and maintaining complex systems.
• Model-based Systems Engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing through-out development and later lifecycle phases.” (INCOSE, 2007).

• Modeling is at the heart of all aspects of the development effort
  Covers the complete product and project lifecycle
  Has a direct effect on any generated artifacts.
  MBE encompasses architecture, systems and software development.
Changes in Systems Engineering Practice

Change from Document centric to Model centric

Requirement Specifications
Interface Definitions
System Architecture
System Functionality
Trade-off Analysis
Test Specifications
Etc.

Old Approach

New Approach
The Four Pillars of SysML

Structure

Definition

Parametrics

Requirements

Behavior

Interaction

State Machine

Activity/Function

The vehicle shall stop from 60 mph within 150ft on a clean dry surface.
The vehicle shall stop on a clean dry surface within 150 ft. The braking subsystem shall prevent wheel lockup under all braking conditions.
1. General Background

The city of Autoville has just elected a new city council with a mandate to reduce traffic on the highways and thoroughfares. After receiving a grant of $200M from the federal government, they have decided to acquire a traffic management system to help them identify areas and times of high traffic density so they can take measures to alleviate the effects of it. The city of Autoville has 100 miles of highway with 10 interchanges and 300 miles of thoroughfares with 100 major intersections. Systems will include controlled parking facilities, availability monitoring and dissemination, emergency management, traffic control and prediction, and support for electric vehicles.
The system shall identify traffic levels on all highways and thoroughfares.

The system shall provide traffic data for intervals not greater than 1 mile for highways and ¼ mile for thoroughfares.

**UREQ_02**

The system shall identify traffic levels on all highways and thoroughfares.

The system shall provide traffic data for intervals not greater than 1 mile for highways and ¼ mile for thoroughfares.
## Requirements Traceability Table

### [Package] User Requirements [Table]

<table>
<thead>
<tr>
<th>Name</th>
<th>Txt</th>
<th>Rationale</th>
<th>Satisfied By</th>
<th>Traces To</th>
</tr>
</thead>
</table>
| UREQ_01| The system shall identify traffic levels on all highways and thoroughfares. | «Software» Traffic Flow Calculation SW (Autoville Traffic Management Architecture::System Views::Resources::Software)  
«Materiel» Video (Autoville Traffic Management Architecture::System Views::Resources::Materiel)  
«Materiel» Traffic Sensor (Autoville Traffic Management Architecture::System Views::Resources::Materiel)  
«Activity(System)» Calculate Traffic Levels (Autoville Traffic Management Architecture::System Views::System Activities::System Software Activities) | «Capability» Calculate Traffic Levels (Autoville Traffic Management Architecture::Enterprise Views::Capabilities)                                                                                     |
| UREQ_02| The system shall provide traffic data for intervals not greater than 1 mile for highways and ¼ mile for thoroughfares. | «Rule(System)» Sensor Spacing (Autoville Traffic Management Architecture::System Views::Resources::Materiel::Traffic Sensor)                                                                            |                                                                                                                                                                                               |
| UREQ_03| The system shall provide traffic data that is no more than 5 minutes old. | «Rule(System)» Update Rate (Autoville Traffic Management Architecture::System Views::Resources::Materiel::Traffic Sensor)  
«Rule(System)» Traffic Data Update Interval (Autoville Traffic Management Architecture::System Views::System Activities::System Software Activities::Send Traffic Report) |                                                                                                                                                                                               |
| UREQ_04| The system shall record traffic data for 30 days.                     | «Software» Traffic Data Archive SW (Autoville Traffic Management Architecture::System Views::Resources::Software)  
«Rule(System)» Traffic Data Archive Capacity (Autoville Traffic Management Architecture::System Views::Resources::Software::Traffic Data Archive SW) |                                                                                                                                                                                               |
Operational Concept with Boxes

High Level Traffic Control Concept

- Traffic Display Board
- Emergency Services
- Internet
- Traffic Control Organization
- Control Center
- Mass Media
- Video
- Vehicle
- Traffic Sensor

Informs
Reports
Updates
Manages
Traffic Images
Traffic Measurement
Records
Measures
Operational Concept with Graphics
Traffic Management Use Cases and Stakeholders

OV-1d [Whole Life Enterprise] Traffic Whole Life Enterprise [OV-1d]

- Drivers
- EPA
- Highway Commission
- City Government
- Control Room Operator
- Emergency Organizations

- «Mission» Travel To Destination
- «Mission» Minimize Pollution
- «Mission» Provide Funding
- «Mission» Manage Traffic
- «Mission» Provide Traffic Updates
- «Mission» Manage Traffic Events

[Architectural Description] Measurement Definitions
Manage Traffic Activity Sequence

Diagram showing the sequence of traffic management activities:
1. System Test
2. Monitor Traffic Speed
3. Calculate Traffic Flow
4. Analyze Routes
5. Search for Traffic Events
6. Dispatch Emergency Services
7. Monitor Accident
8. Re-Route Traffic
9. Control Traffic Signals
10. Execute Accident Report

[Performer] Autoville Context [OV-2]
Operational Structure


[Architectural Description] Operational Nodes [OV-3]
## Interaction Summary (ICD)

<table>
<thead>
<tr>
<th>Information Exchange</th>
<th>Producer</th>
<th>Needline</th>
<th>Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name</td>
<td>Conveyed</td>
<td>Performer</td>
</tr>
<tr>
<td>CS-&gt;CM:SS</td>
<td>«Information Element» Service Status</td>
<td>«City Services»</td>
<td>«City Management»</td>
</tr>
<tr>
<td>CS-&gt;TC:SS</td>
<td>«Information Element» Service Status</td>
<td>«City Services»</td>
<td>«Traffic Control»</td>
</tr>
<tr>
<td>TC-&gt;CS:SR</td>
<td>«Information Element» Service Request</td>
<td>«Traffic Control»</td>
<td>«City Services»</td>
</tr>
<tr>
<td>TP-&gt;TC:AP</td>
<td>«Information Element» Accident Prediction</td>
<td>«Traffic Control»</td>
<td>«Traffic Control»</td>
</tr>
</tbody>
</table>
Operational Modes

[Diagram showing operational modes with states and actions such as System Startup, System Shutdown, Monitoring, Calculating Flow, Generating Report, Controlling, Active Traffic Event, No Active Events, and Search for Traffic Events.]

[Architectural Description] Typical Organizations [OV-4 Typical]
System Connection Matrix – $N^2$
Parking Lot System With Charging Stations

- Pressure sensor
- System controller & barrier motor
- Traffic lights
- Safety barrier
- IR beam sensor
- Display Boards
  - Lot 1: Spaces
  - Lot 2: Full
  - Lot 3: Spaces
- Serial Links
- Entry
- Exit
Parking Lot System Model

```
ibd [block] Parking Lot System [Physical]

Parking Lot System

exitSnr : PressureSensor
prS : 5Vhigh
high : 5Vhigh
low : 5Vhigh

entrySnr : IR Sensor
irS : 5Vhigh
high : 5Vhigh
low : 5Vhigh

motor : Barrier Motor
mot : 12Vhigh
high : 12Vhigh
low : 12Vhigh

ctrlr : Controller
: IOUcomms
: serialByte
: dispString
: ~IOUcomms

ioUnit : IO Unit

greenLt : Light
gL : 12Vhigh
high : 12Vhigh
low : 12Vhigh

redLt : Light
rL : 12Vhigh
high : 12Vhigh
low : 12Vhigh

fullLt : Light
fL : 12Vhigh
high : 12Vhigh
low : 12Vhigh

serial connection data
Type RS232/V24
inputs : 1 start bit, 2 stop bits, no parity
7 data bits:
0-3 : key value
4 : keypad press (see bits 0-3 for value)
5 : display button press
6 : reset button press
output : 4 bytes, each byte:
1 start bit, 2 stop bits, no parity
7 data bits: ASCII number
```
Example - Parametrics Context

Max Capacity Equation

- **constraintParameters**
  - dl : integer
  - maxC : integer
  - sa : surfaceArea
  - ua : surfaceArea
  - vSA : surfaceArea

\[
\text{maxC} = \frac{\text{sa} - \text{ua}}{\text{vSA} + (\text{dl} \times 4)}
\]

**rationale**
Need to maximise total capacity

Number Vehicles Equation

- **constraintParameters**
  - c : integer
  - d : integer
  - m : integer
  - vSA : surfaceArea

**rationale**
Ratio of vehicle types can be subject to local legislation

Parking Lot System

- **values**
  - PLid

PL Params

- **values**
  - totalSurfaceArea : surfaceArea
  - totalUnusableArea : surfaceArea

Surface area in square metres:
- sa
- vSA
- dl
- ua

Number of vehicle types:
- c (normal car spaces)
- d (disabled car spaces)
- m (motorbike spaces)

Quantity Kind:
- **Area**
- **SquareMeter**
Parking Area with Charging Space

ibd [Block] Parking Area [IBD]

«block»
Parking Area

CHS : Charging Space 1..*

CHG : Charger

EC : Electric Car

CHG-EC:PW : Power

DS : Disabled Space

CS : Car Space

MS : Motorcycle Space
ThingWorx Platform

- **Connectivity**: Connectivity and Device Management
- **Device Cloud**: Private Device Cloud
- **Application Enablement**: Application Enablement Platform
- **Composer**: Rapid Application Development and Graphical User Interface Builder
- **Federated Deployments**: Deploy how you like

- **Marketplace**: Smart Extensions and Applications
- **Cassandra**: Big data for operational data
- **ColdLight**: Machine learning and predictive analytics

- Predictive Analytics
- Augmented Reality* (Beta)
- Digital Twin* (Beta)
• Customer Portals
  – Mashup of Data Sources

• Mobile Applications
  – Smartphone and Tablet Applications to enhance Product Experience

• New Internal Applications
  – Field Service Applications
System Model Simulation

**CAPABILITIES**

- Simulate SysML model visually
- Store simulation information within system model blocks
- Drag and Play Simulation
- Connect to third-party simulators (MATLAB Simulink™, etc.)

**BENEFITS**

- Validate complex behavior early
- Project cost reduction
- Reduce design walkthrough efforts
- Reduce design errors

Reuse blocks containing simulation data within diagrams
Simulate behavior
PTC Integrity Modeler – Automated ThingWorx Code Generation

Prototype driving requirements for Integrity Modeler 8.3
Questions and Answers

Thanks for your attention!

Speaker