Introduction to Model-Driven System Development

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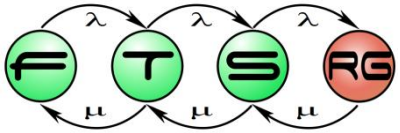
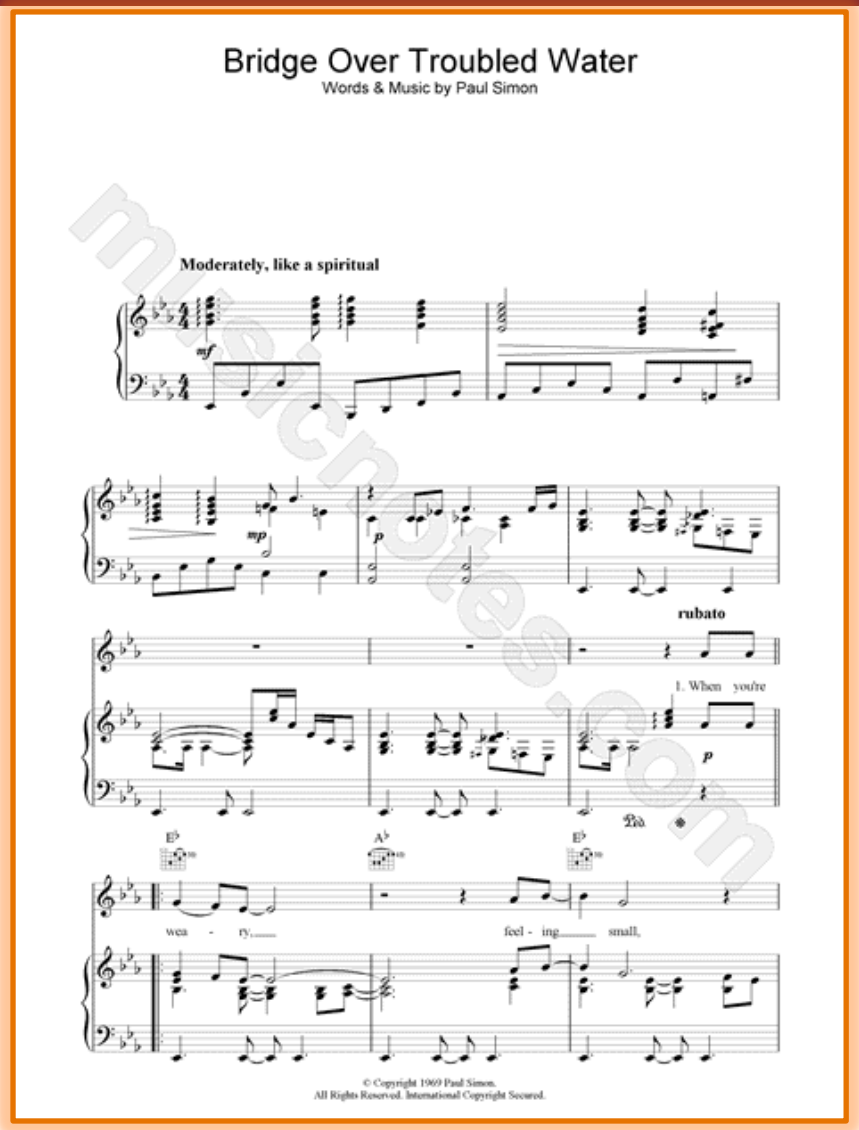


Song writing methods of Simon and Garfunkel

Paul Simon's technique #1



1. Create music first

Bridge Over Troubled Water

When you're weary
Feeling small
When tears are in your eyes
I will dry them all

I'm on your side
When times get rough
And friends just can't be found
Like a bridge over troubled water
I will lay me down
Like a bridge over troubled water
I will lay me down

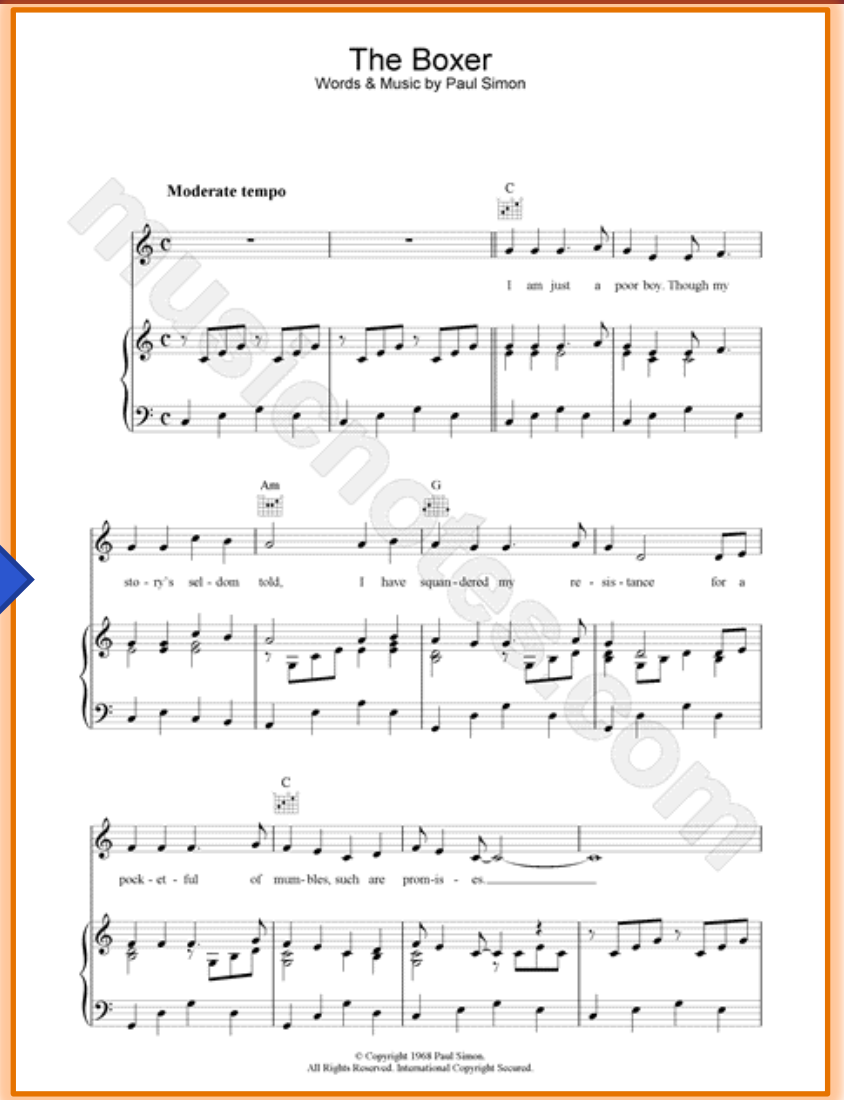
2. Write lyrics accordingly

Paul Simon's technique #2

The Boxer

I am just a poor boy
Though my story's seldom told
I have squandered my resistance
For a pocket full of mumbles such are promises
All lies and jests
Still a man hears what he wants to hear
And disregards the rest
When I left my home and my family
I was no more than a boy
In the company of strangers
In the quiet of the railway station running scared
Laying low, seeking out the poorer quarters
Where the ragged people go
Looking for the places only they would know

1. Write lyrics first

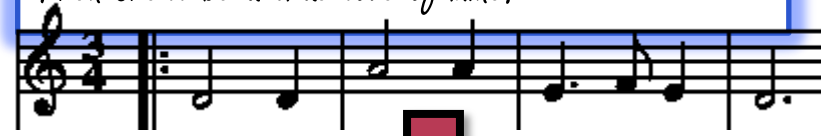


2. Compose music accordingly

A Combined Technique…

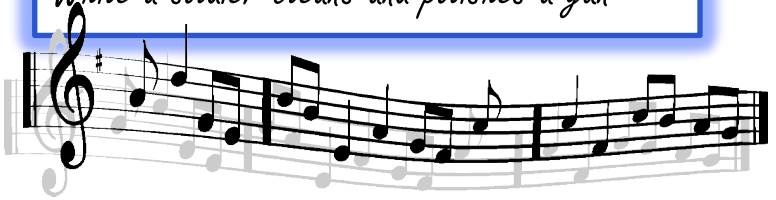
Scarborough Fair (Folk Song)

Tell her to find me an acre of land,
Parsley, sage, rosemary and thyme;
Between the salt water and the sea strand,
Then she'll be a true love of mine.



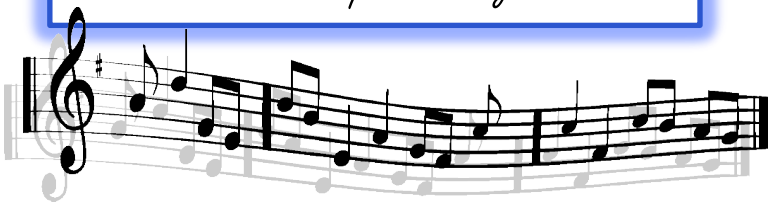
The Side of a Hill (P. Simon)

On the side of a hill, a little cloud weeps
And waters the grave with its silent tears
While a soldier cleans and polishes a gun

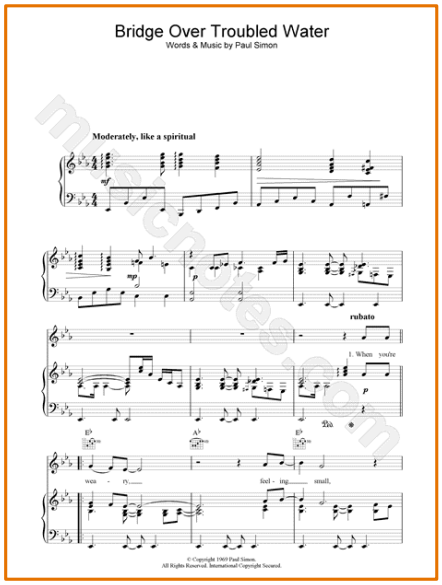


Canticle (rearranged by A. Garfunkel)

On the side of a hill a sprinkling of leaves
Washes the grave with silvery tears
A soldier cleans and polishes a gun



Naming These Techniques…



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Music Driven Song Development (MDSD)

Lyrics Driven Song Development

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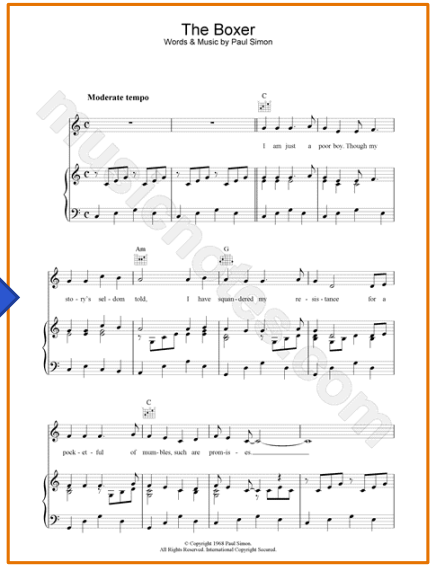
1. Write lyrics first

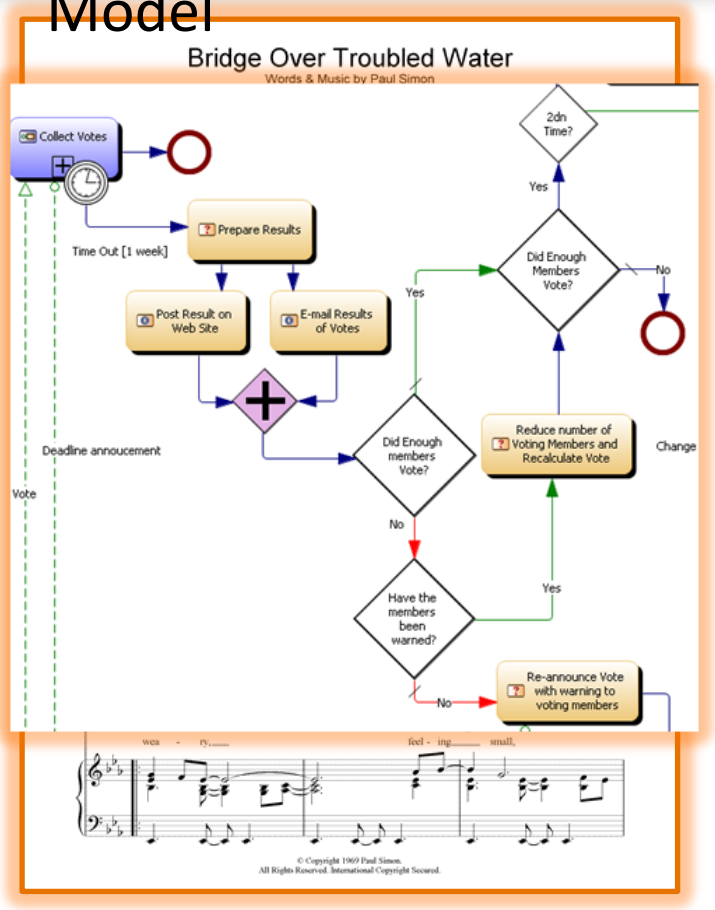


2. Compose music accordingly

Applying the Principle to Software Systems

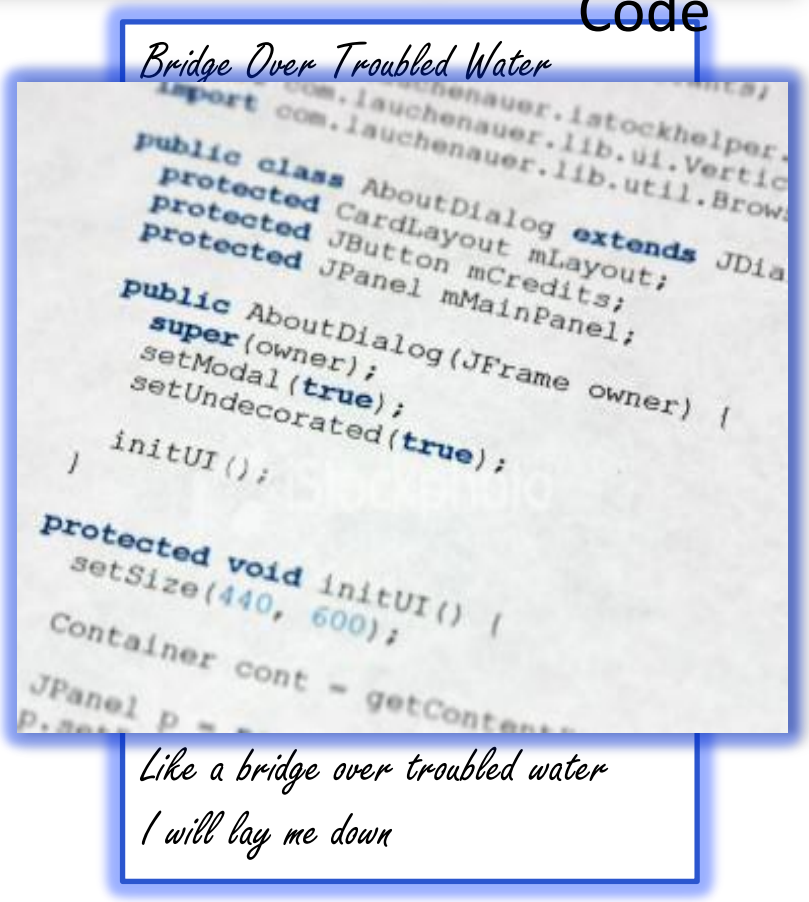
MDSD = Model Driven Software Development / Engineering

Model



Music

Code



Lyrics

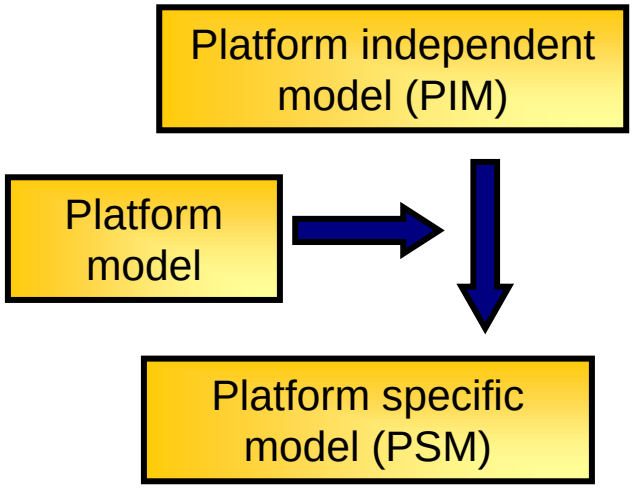
Model Driven System Engineering

Terminology

- MDSE = Model Driven System Engineering
- MDSD = Model Driven System Development
- MDD = Model Driven Development
- MDE = Model Driven Engineering
- MBSE = Model Based Systems (Software) Engineering

MDSE ≈ MDE > MDSD ≈ MDD ≈ > MBSE

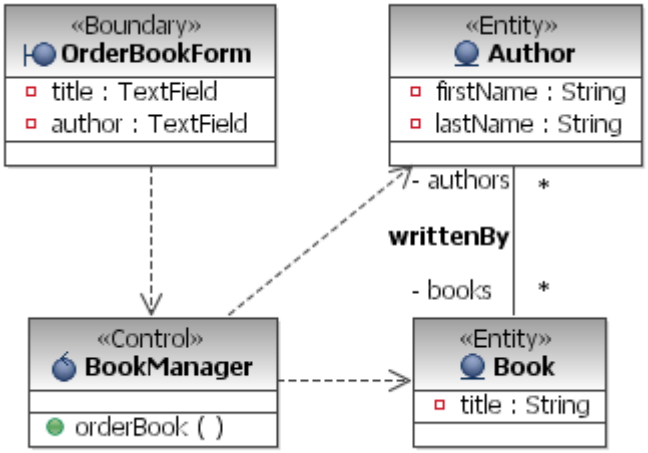
- MDA = Model Driven Architecture
  - Design methodology proposed by OMG (Object Management Group)
  - A specific realization of Model Driven Software Engineering



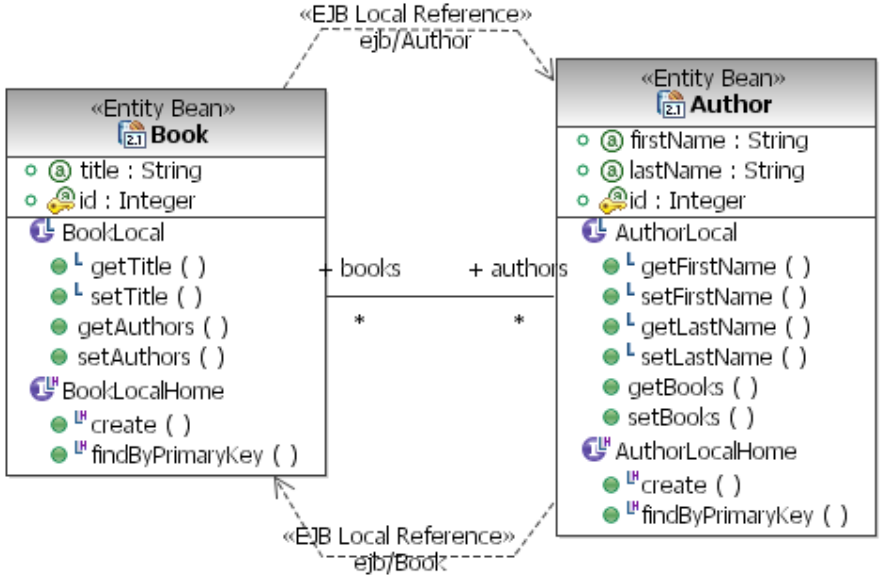
- Related concepts
  - MDT (Model Driven Testing) ≈ MBT (Model Based Testing)

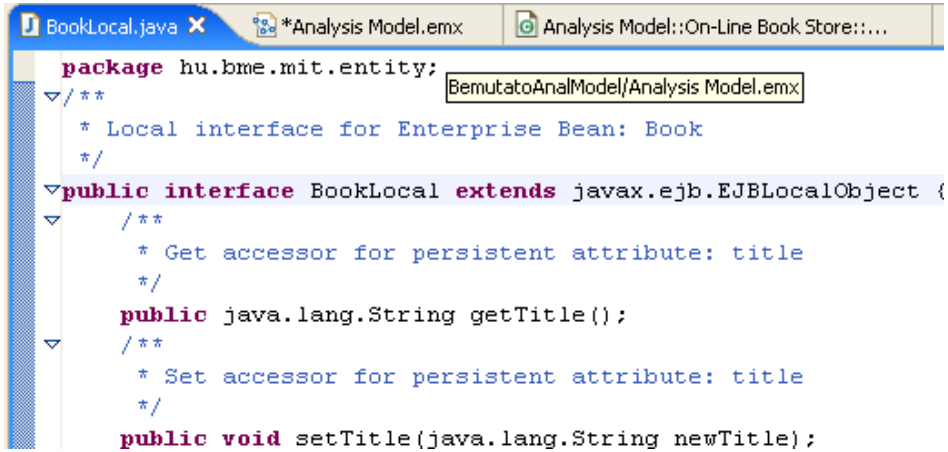
Model Driven Architecture – Example

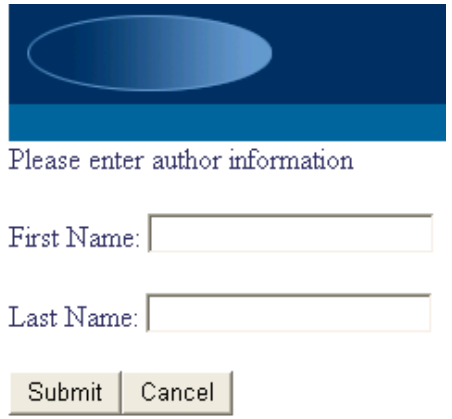
Platform Independent Model



Platform Specific Model







Code

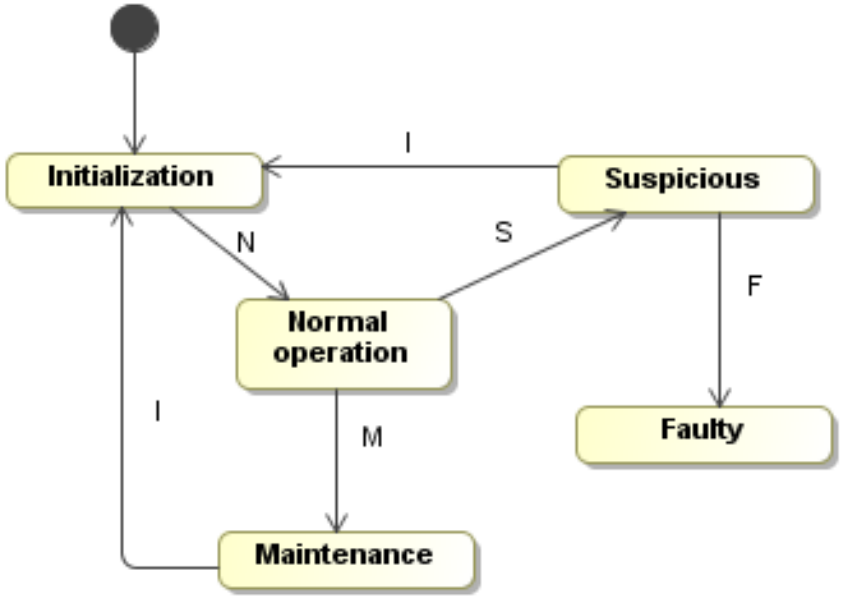
Application

Why to model?

```
public class SomeThing {

    int s = 0;

    public void process(E e) {
        if (s==0) {
            if (e == E.N) s = 1;
        } else if (s==1) {
            if (e == E.S) s = 2;
            else if (e == E.M) s = 3;
        } else if (s==2) {
            if (e == E.I) s = 0;
            else if (e == E.F) s = 4;
        } else if (s==3) {
            if (e == E.I) s = 0;
        }
    }
}
```

Why to model?

```
public class SomeThing2 {

    private static final int INITIALIZATION = 0;
    private static final int NORMAL = 1;
    private static final int SUSPICIOUS = 2;
    private static final int MAINTENANCE = 3;
    private static final int FAULTY = 4;
    int state = 0;

    public void process(E event) {
        if (state == INITIALIZATION) {
            if (event == E.N) state = NORMAL;
        } else if (state == NORMAL) {
            if (event == E.S) state = SUSPICIOUS;
            else if (event == E.M) state = MAINTENANCE;
        } else if (state == SUSPICIOUS) {
            if (event == E.I) state = INITIALIZATION;
            else if (event == E.F) state = FAULTY;
        } else if (state == MAINTENANCE) {
            if (event == E.I) state = INITIALIZATION;
        }
    }
}
```



Better documentation

Better understanding

Why to model?

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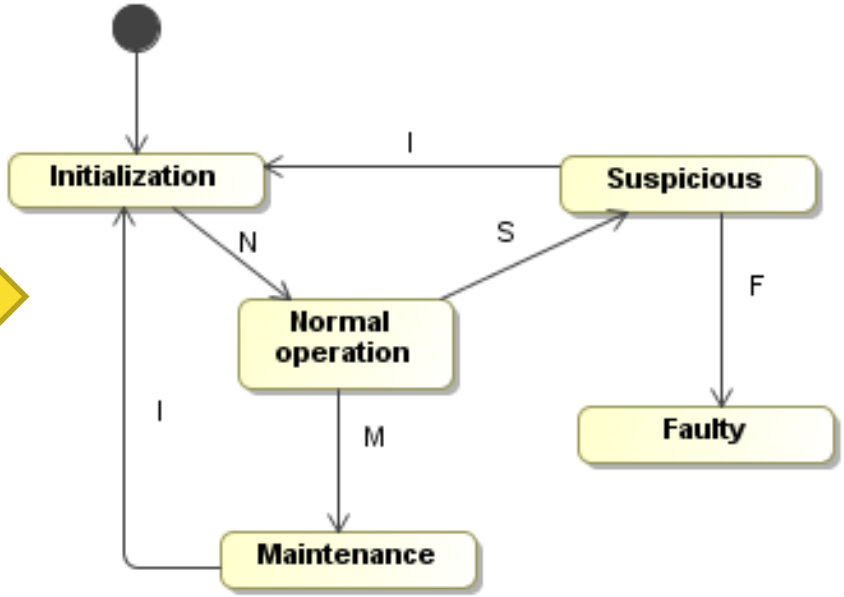
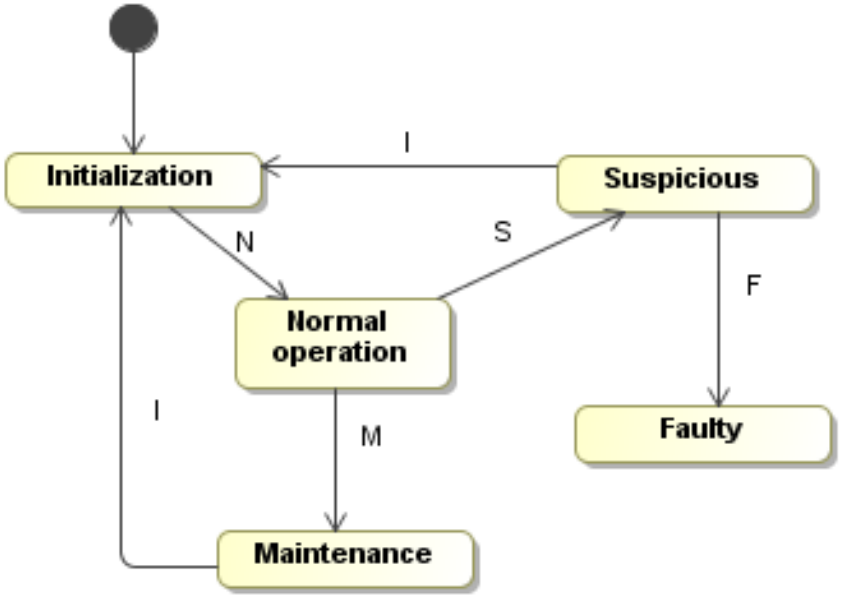
        }
    }
}
```



Generate code

Why to model?

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    int state = 0;

    public void process(E event) {
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        } else if (state == MAINTENANCE) {
            if (event == E.I) state = INITIALIZATION;
        }
    }
}
```
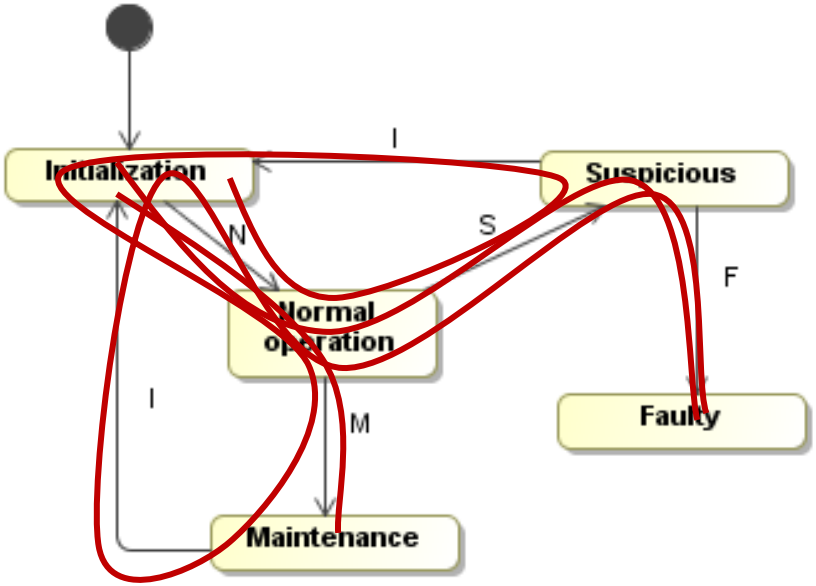

Can I return to *Normal operation* from *Faulty* state?

Better analyzability

Why to model?



- Generate tests
  - state coverage

    test1: N, S, F

    test2: N, M
  - transition coverage

    N,S,I,N,M,I,N,S,F
  - path coverage

    from all states to all other states

    e.g. from *Initialization* to *Faulty:*

    NSF,

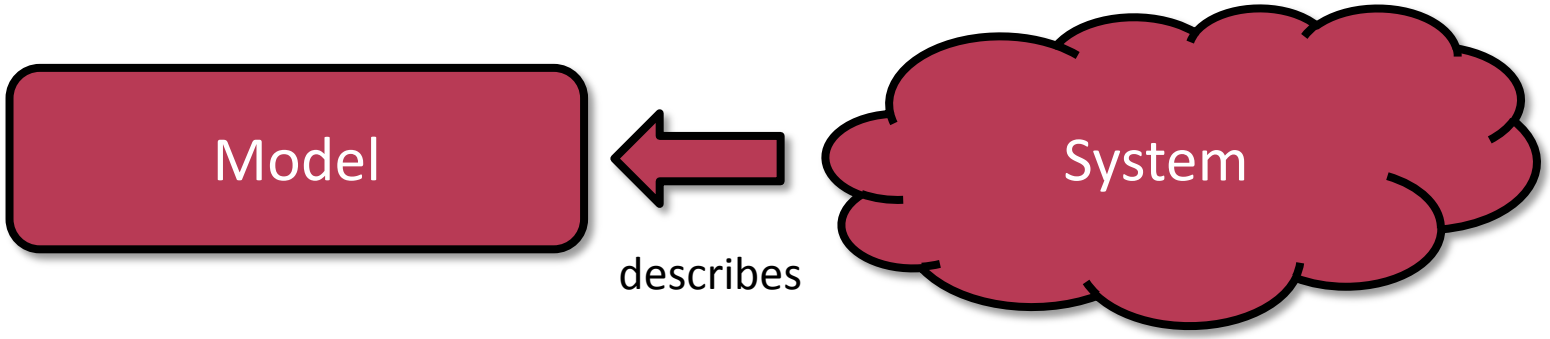
    NSI NSF,

    NMI NSF,

    NSI NMI NSF,

    NMI NSI NSF

What is a model?



- *Mapping* → the model is based on the original system
- *Reduction* → it reflects only an important/relevant segment
- *Replaceable* → can be used in place of the original system for a limited feature

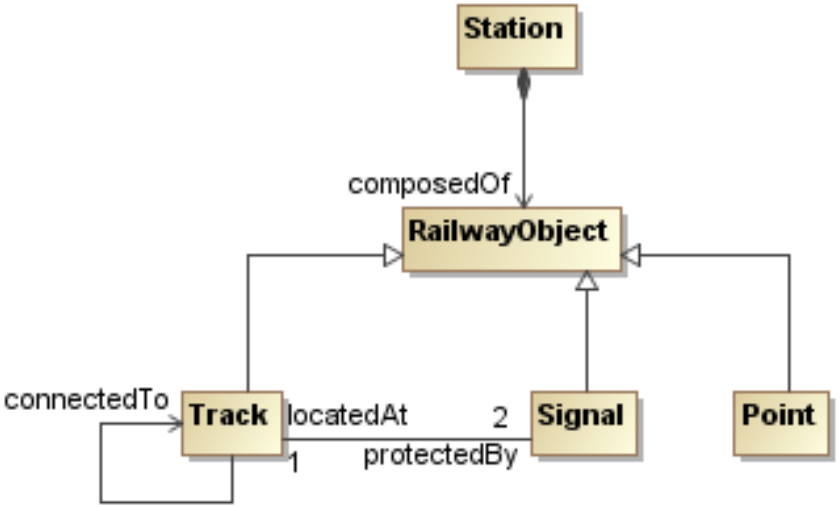
What is a model?

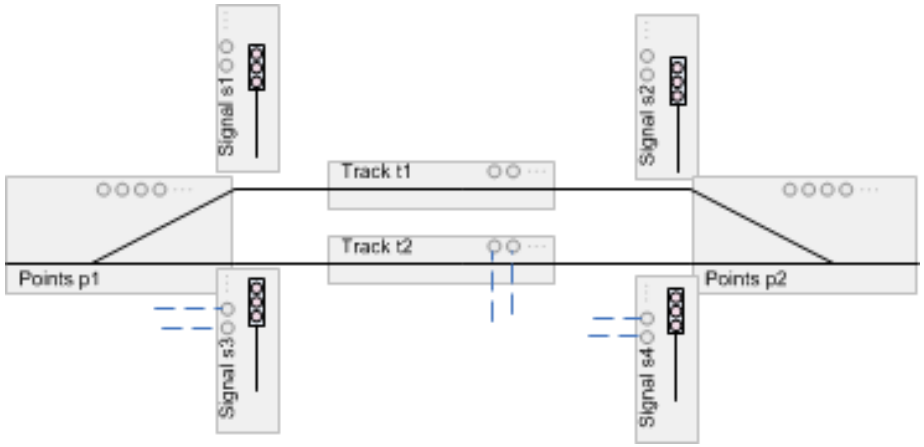
- Structured representation of the information

A railway station is composed of signals, tracks and points.

Tracks can be connected to each other.

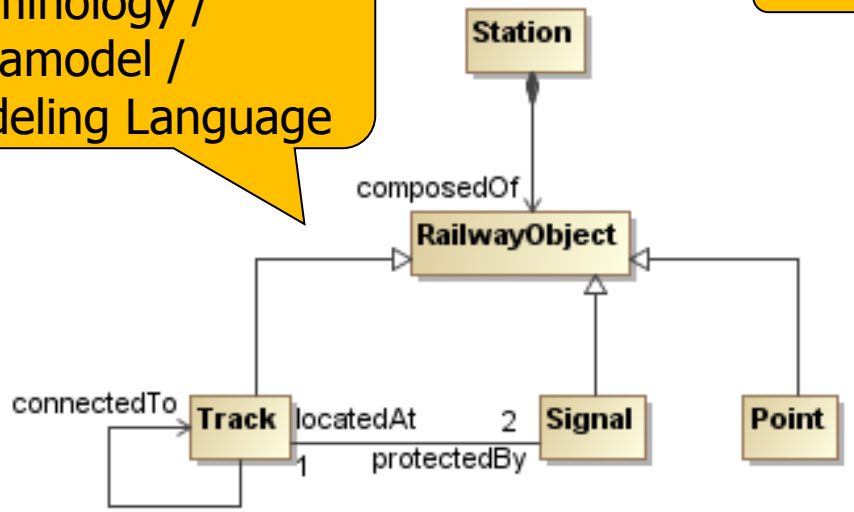
Signals are located at both ends of the track.



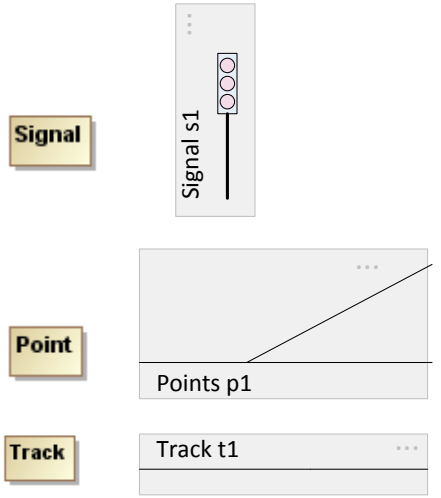


What is a model?

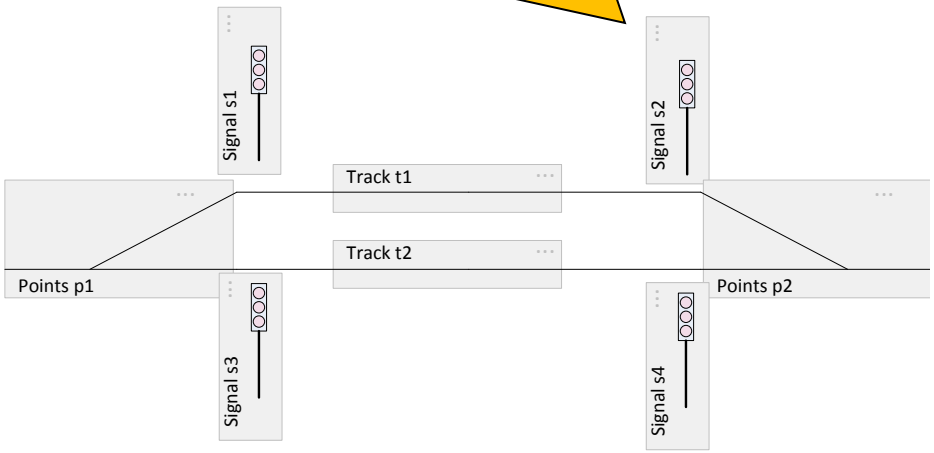
Terminology / Metamodel / Modeling Language



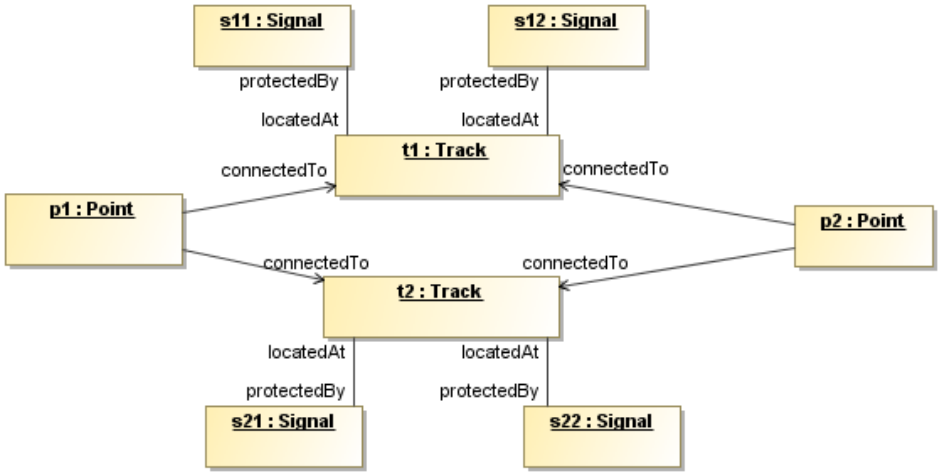
Graphical syntax



Instance model – diagram

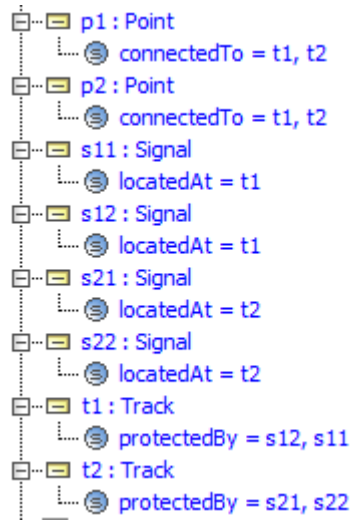


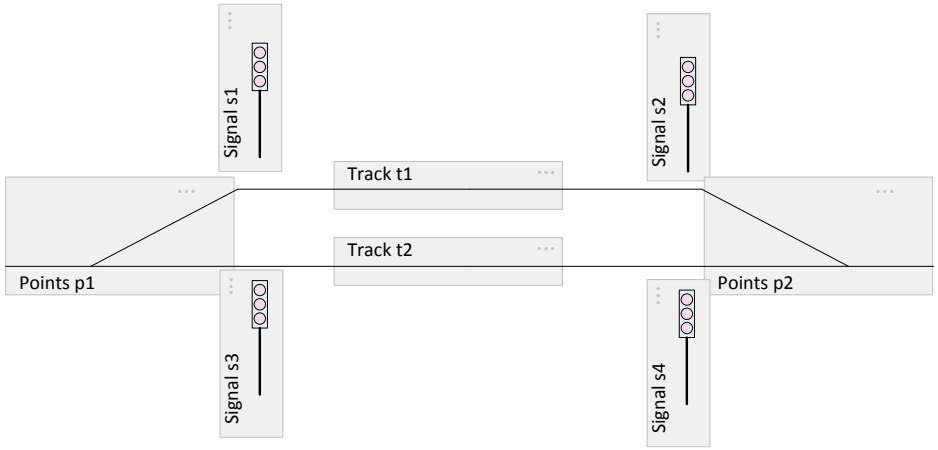
Instance model – abstract syntax

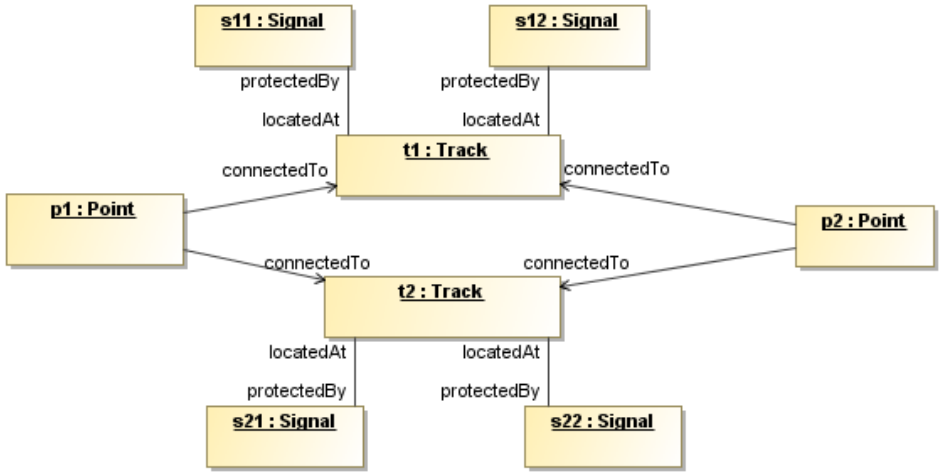


Model vs. Diagram

- Diagram
  - A view of the model
  - Important aspects from a given viewpoint are shown
- Model
  - All the elements and their relations

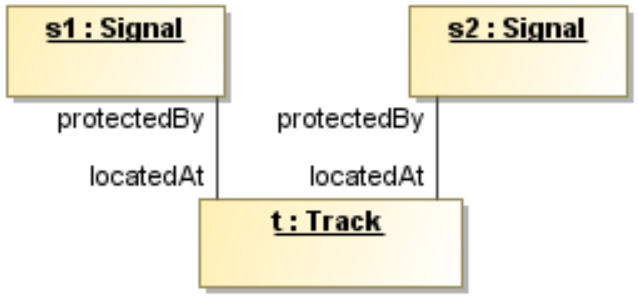






How to process a model?

- Define interesting model parts (patterns)

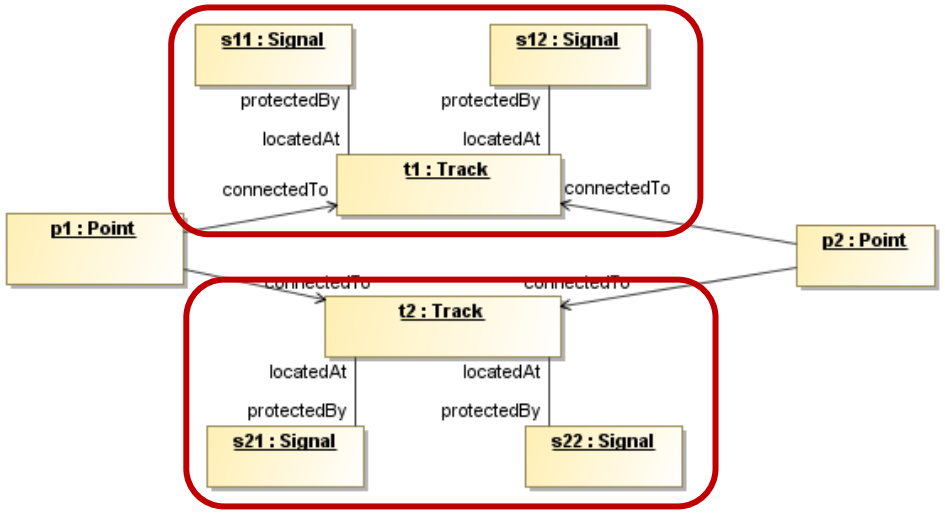



```
pattern p1 (s1,s2,t) {
        Signal(s1);
        Signal(s2);
        Track(t);
        locatedAt(s1,t);
        locatedAt(s1,t);
        protectedBy(t,s1);
        protectedBy(t,s2);
}
```

- Find in the model (pattern matching)
  - Result: match sets

    s11,s12,t1

    s21,s22,t2



- Apply some operation
  - modify model
  - create other model
  - generate artefact

What is needed for MDSE? The Three Pillars

- Modeling Language
  - Defines elements and their relationship
  - Defines syntax and semantics
  - *What type of elements can be used during modeling?*
  - E.g. SysML

- Development Methodology
  - Defines the steps of analyzing and designing the system
  - Defines the usage of the model elements and diagrams
  - *How shall the model be built?*
  - E.g. SYSMOD (SYStem MODeling) by Tim Weilkiens, OOSEM, Rational Harmony

- Proper! Tool
  - E.g. MagicDraw, Enterprise Architect, IBM Rational Rhapsody

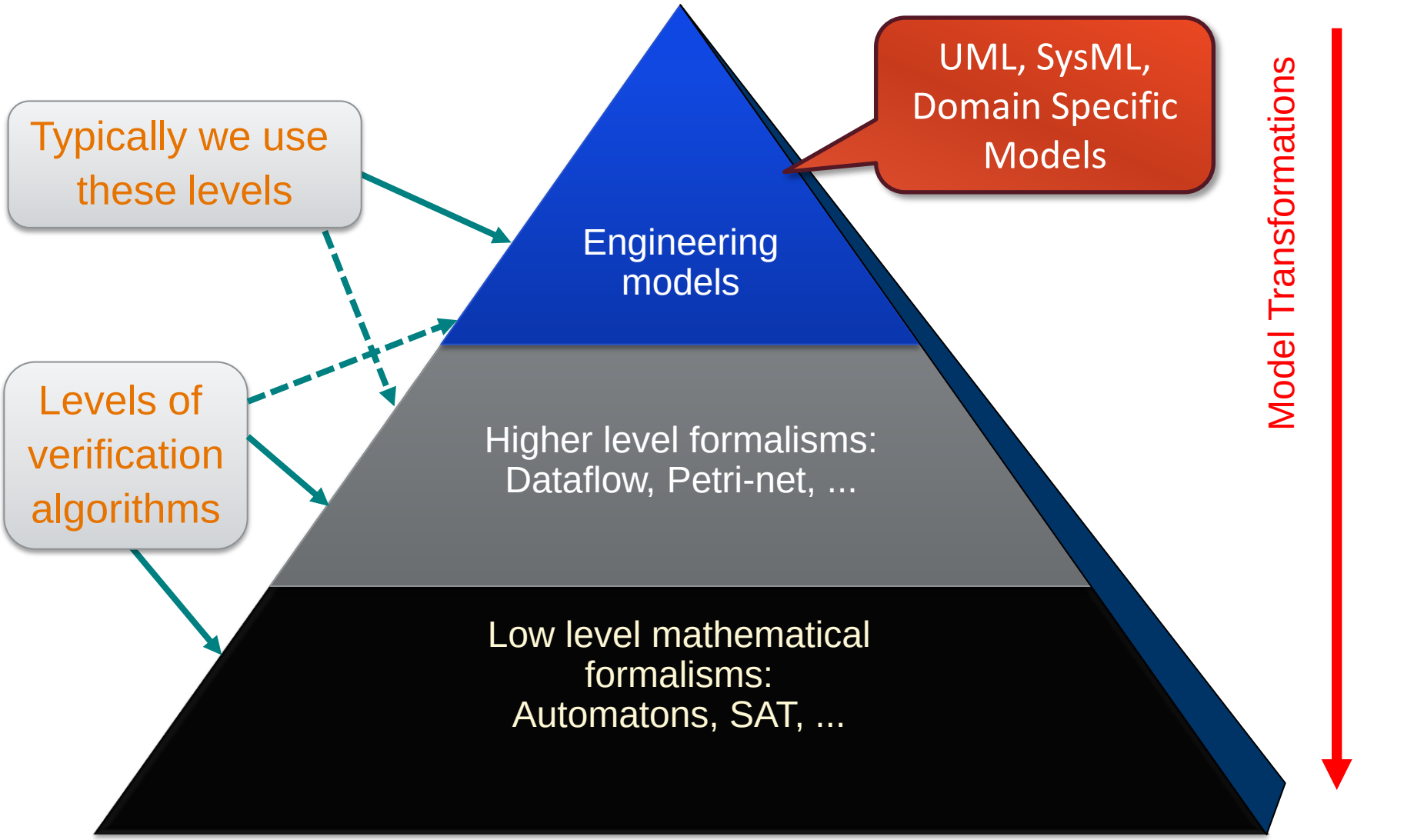
What is needed for MDSE?
+ Two extra things

- **Domain knowledge**
  - Should know what to model
- **Distinguished team**
  - Should have people who have the ability and experience to create good models

What types of models can be used?

- **Static models**
  - Defines the static aspects of the system including data, design and architecture.
  - e.g., E-R model
- **Dynamic models**
  - Defines or describes the dynamic behavior of the system.
    - Usually demonstrates execution.
  - e.g., State machine

What types of models can be used?



What types of modeling languages can be used?

- **General Purpose Modeling** languages
  - Languages that can be applied to any domain for modeling purpose
  - e.g., State machines, Petri-nets, SAL, UML, SysML

- **Domains Specific Modeling** languages
  - Languages that are specifically designed for a certain domain
  - e.g., AutoSAR, Mathematica, Logo, AADL, etc

What can be done with MDSE?

- DOCUMENTATION
  - Support requirements specification
    - Textual based → extended with models (diagrams)
  - Support system design
    - Mind based → documented
- VERIFICATION
  - Check consistency, completeness, well-formedness
- ANALYSIS
  - Analyze / simulate parts of the system to determine or derive properties
    - Applied separately for a selected component
      - E.g. for a communication protocol: consensus is always reached
    - Integrated into the model based development process
- SYNTHESIS
  - Synthetize some parts of the system
    - design, application or other artefacts

Analysis in Model Driven System Engineering

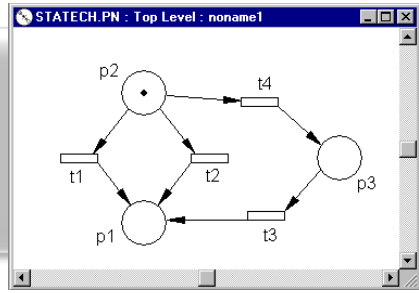
System Design

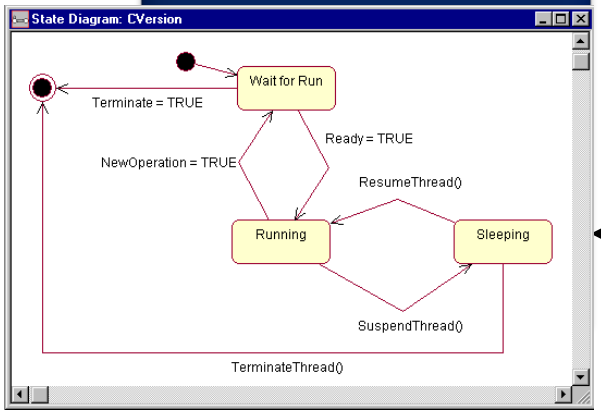
Formal verification

Engineering model (e.g. SysML)

Automated Model Generation

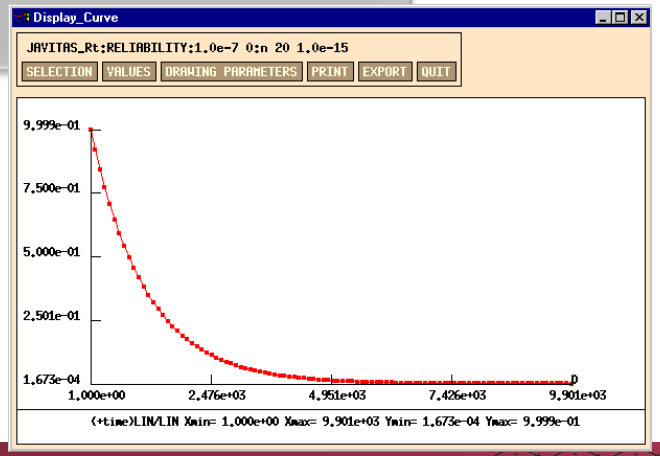
Formal model



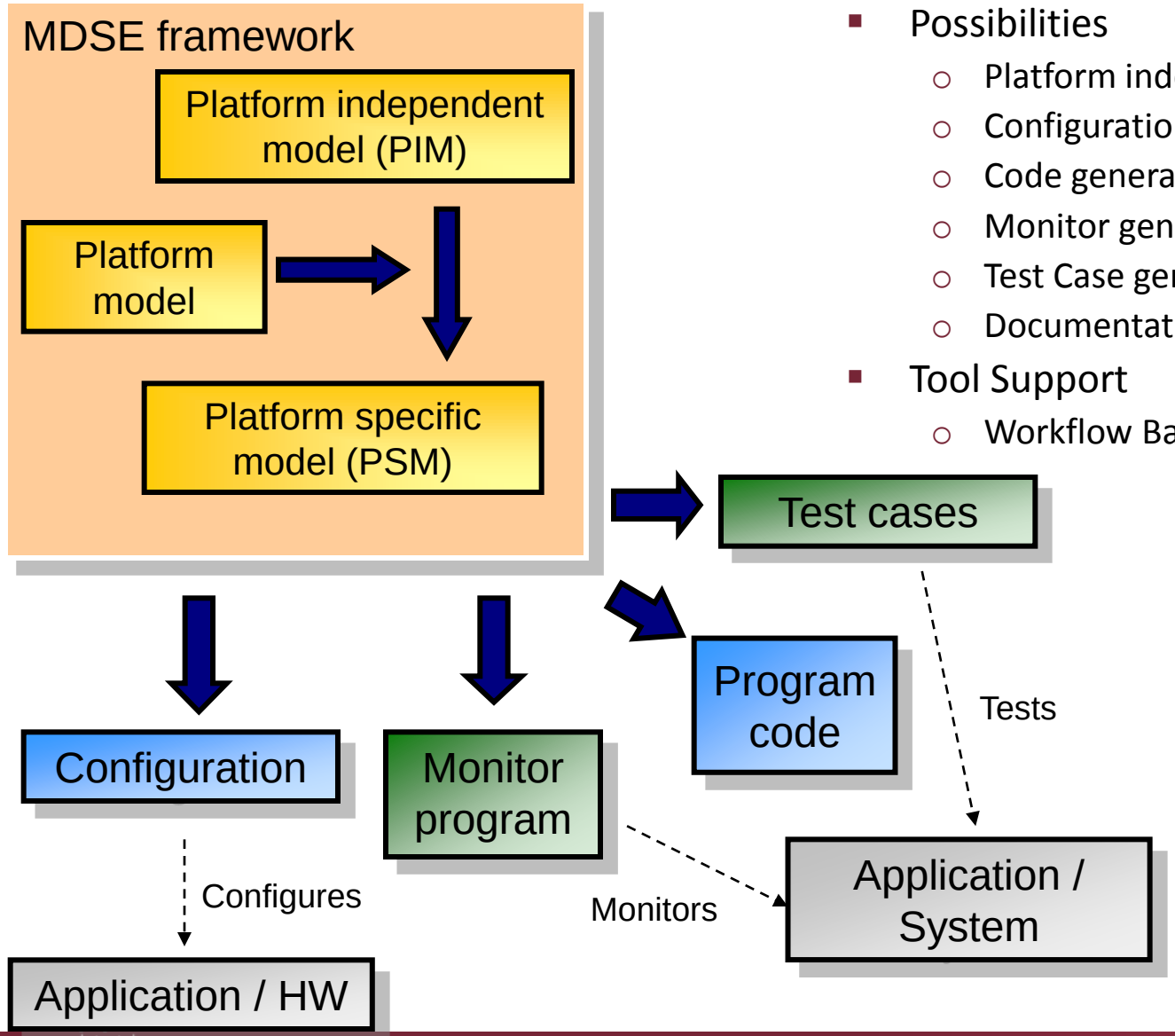


Backtracing results

Analysis



Synthesis in Model Driven System Engineering

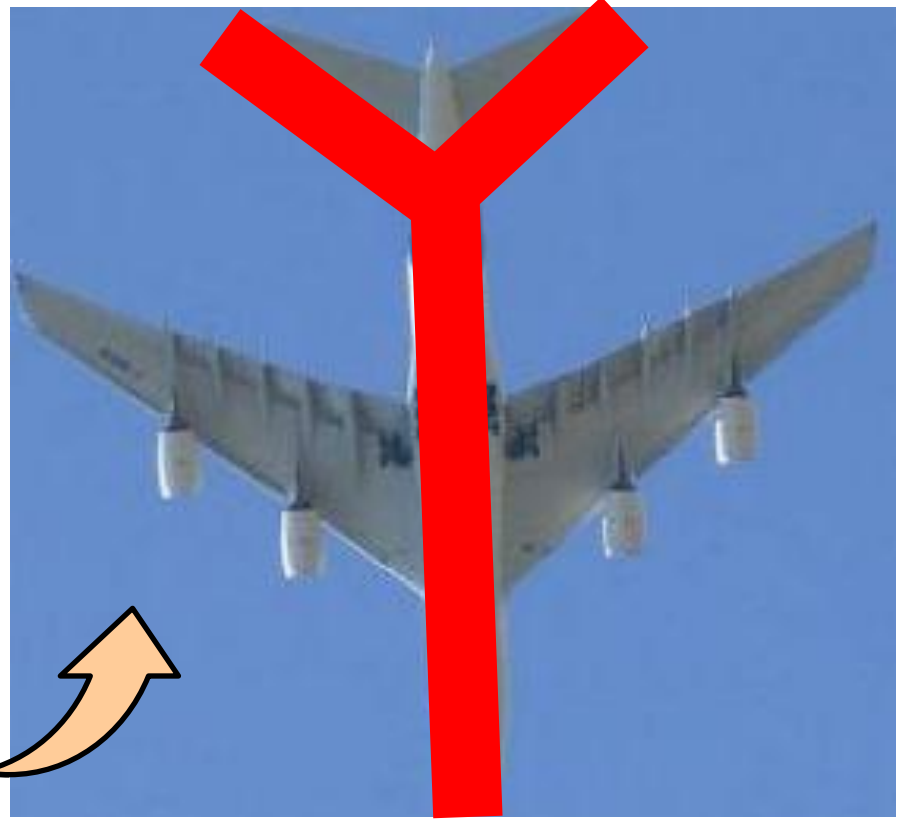


- Possibilities
  - Platform independent → platform specific
  - Configuration generation
  - Code generation
  - Monitor generation
  - Test Case generation
  - Documentation generation
- Tool Support
  - Workflow Based Execution

Model-Driven Engineering of Critical Systems

Traditional V-Model

Model-Driven Engineering



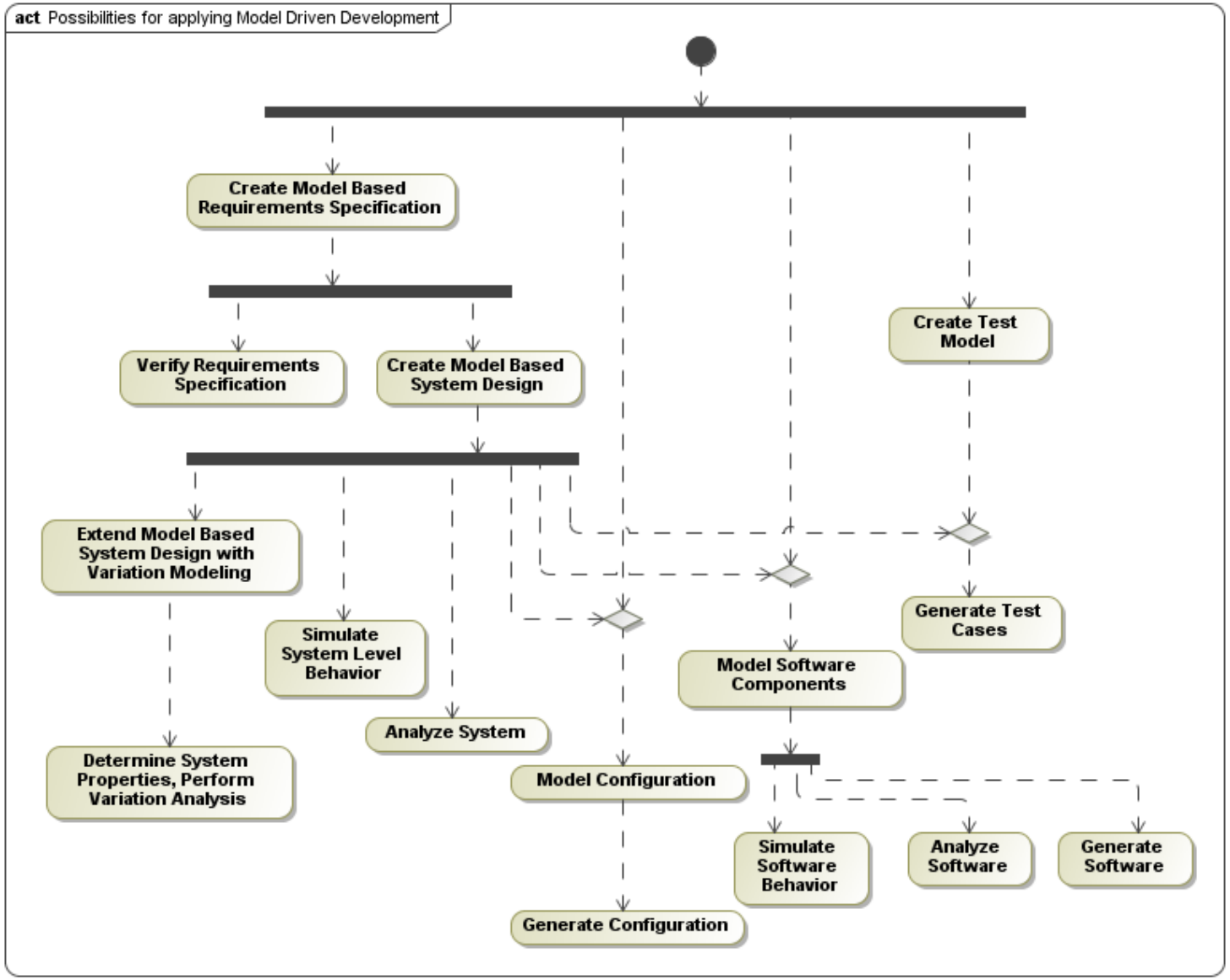
- DO-178B/C: Software Considerations in Airborne Systems and Equipment Certification (RTCA, EUROCAE)
- Steven P. Miller: Certification Issues in Model Based Development (Rockwell Collins)

Main ideas of MDE

- early validation of system models
- automatic source code generation

➔ quality++ tools ++ development cost--

How to apply Model Driven Engineering?



Summary

- *What is a model?*
  - Abstraction of the real world
  - Built from elements defined by the modeling language (metamodel)
- *Why to model?*
  - Document, verify, analyze, synthesize
- *What are needed for modeling?*
  - *Language + methodology + tool + domain knowledge + expertise*
- *What types of models to use?*
  - General purpose vs. domain specific
  - Engineering vs. mathematical (~ semi-formal vs. formal)
  - For modeling behavior and structure
- *How to process models?*
  - By means of model queries and transformations