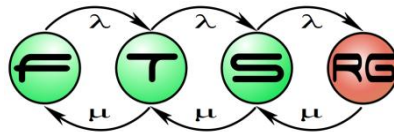


Introduction to Model-Driven System Development

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Dept. of Measurement and Information Systems



Song writing methods of Simon and Garfunkel

Paul Simon's technique #1

Bridge Over Troubled Water

Words & Music by Paul Simon

Moderately, like a spiritual

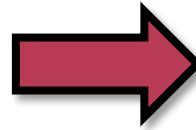
The image shows a musical score for the song 'Bridge Over Troubled Water'. It consists of four systems of music. The first system is a piano introduction in 4/4 time, marked 'Moderately, like a spiritual' and 'mf'. The second system continues the piano introduction, marked 'mp' and 'p', and includes the instruction 'rubato'. The third system begins the vocal melody with the lyrics 'When you're' and is marked 'p'. The fourth system continues the vocal melody with the lyrics 'wea - ry, feel - ing small,'. The score includes various musical notations such as notes, rests, and dynamic markings.

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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*



1. Create music first

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



The Boxer

Words & Music by Paul Simon

Moderate tempo

I am just a poor boy. Though my
sto - ry's sel - dom told. I have squan - dered my re - sis - tance for a
pock - et - ful of mum - bles, such are prom - is - es.

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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.



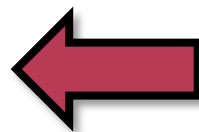
Scarborough Fair/Canticle

Traditional
Arrangement & Original Countermelody by Paul Simon & Art Garfunkel

Moderately slow

Musical notation for the Scarborough Fair/Canticle arrangement. It includes a piano introduction with a treble and bass clef, a vocal line with lyrics, and a piano accompaniment. The tempo is marked 'Moderately slow'. The key signature is one sharp (F#) and the time signature is 3/4. The lyrics are: 'Are you go-ing to Scar-bo-rough Fair...'.

Are you go - ing to Scar - bo - rough Fair...



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...

Music Driven Song Development (MDSD)

Bridge Over Troubled Water

Words & Music by Paul Simon

Moderately, like a spiritual

rubato

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

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

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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

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



The Boxer

Words & Music by Paul Simon

Moderate tempo

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

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2. Compose music accordingly

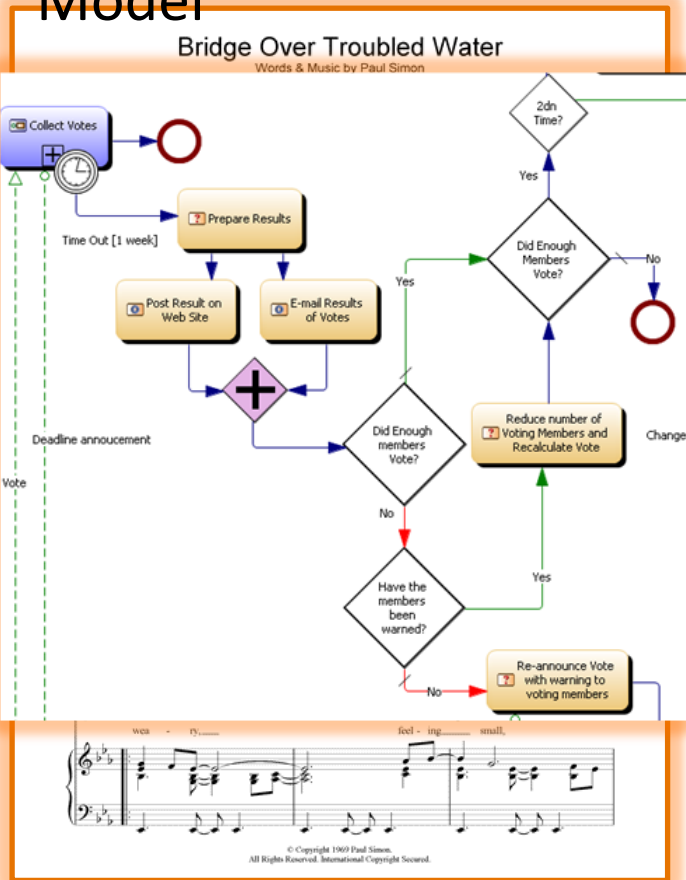
Lyrics Driven Song Development

1. Create music first

Applying the Principle to Software Systems

MDSD = Model Driven Software Development / Engineering

Model



Music

Code

```
Bridge Over Troubled Water  
import com.lauchenauer.istockhelper.  
import com.lauchenauer.lib.ui.Vertic  
import com.lauchenauer.lib.util.Brow  
  
public class AboutDialog extends JDia  
protected CardLayout mLayout;  
protected JButtonLayout mLayout;  
protected JPanel mCredits;  
protected JPanel mMainPanel;  
  
public AboutDialog(JFrame owner) {  
    super(owner);  
    setModal(true);  
    setUndecorated(true);  
    initUI();  
}  
  
protected void initUI() {  
    setSize(440, 600);  
    Container cont = getContentPane  
    JPanel p =
```

*Like a bridge over troubled water
I will lay me down*

Lyrics

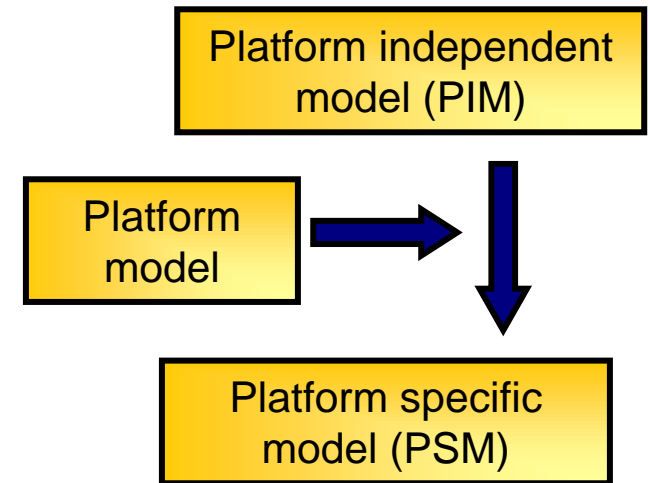
Model Driven System Engineering

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

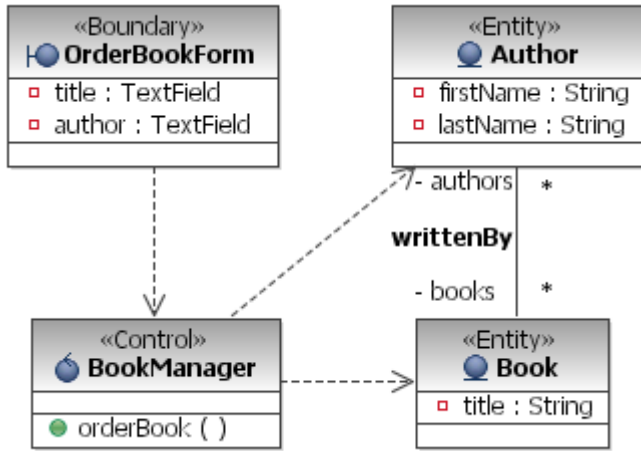
$MDSE \approx MDE > MDSD \approx MDD \approx > MBSE$

- **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) \approx **MBT** (Model Based Testing)

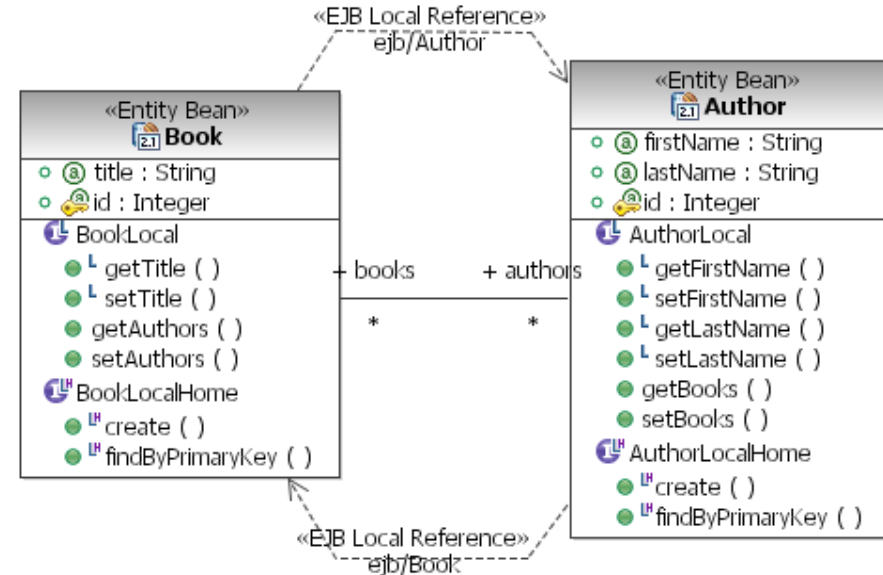


Model Driven Architecture – Example

Platform Independent Model



Platform Specific Model



```
BookLocal.java x *Analysis Model.emx Analysis Model::On-Line Book Store:...
package hu.bme.mit.entity;
/**
 * Local interface for Enterprise Bean: Book
 */
public interface BookLocal extends javax.ejb.EJBLocalObject {
    /**
     * Get accessor for persistent attribute: title
     */
    public java.lang.String getTitle();
    /**
     * Set accessor for persistent attribute: title
     */
    public void setTitle(java.lang.String newTitle);
```

Code

Please enter author information

First Name:

Last Name:

Submit Cancel

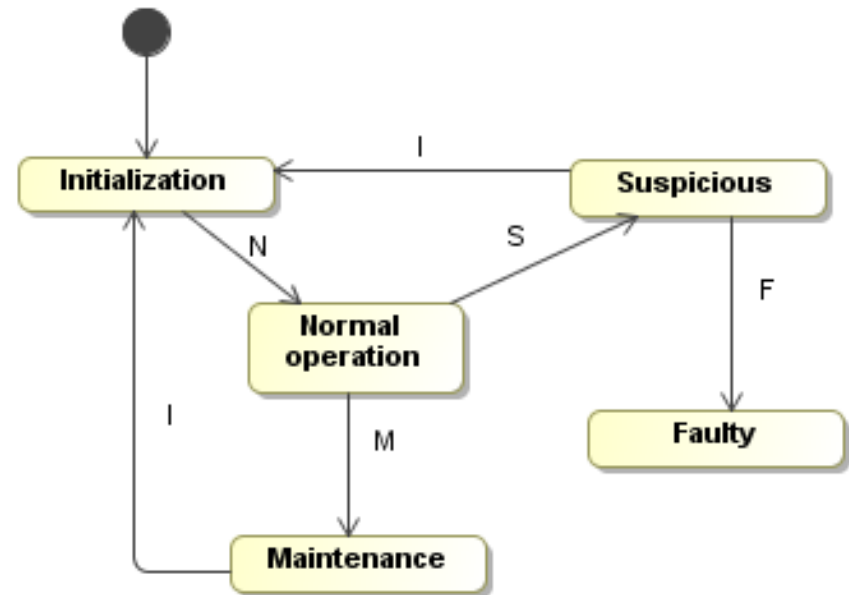
Application

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?

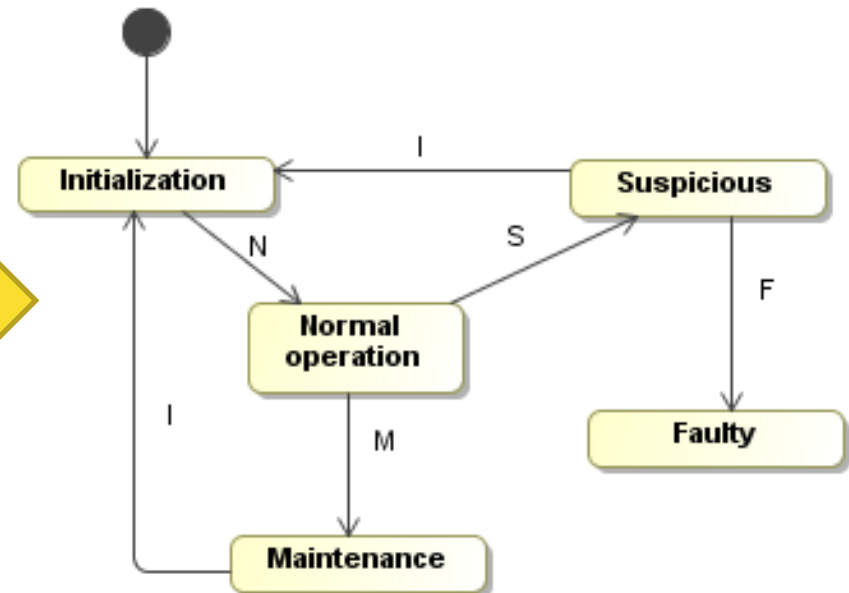
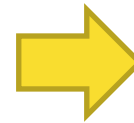
```
public class Something2 {  
  
    private static final int INITIALIZATION = 0;  
    private static final int NORMAL = 1;  
    private static final int SUSPICIOUS = 2;  
    private static final int MAINTENANCE = 3;  
    private static final int FAULTY = 4;  
    int state = 0;  
  
    public 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

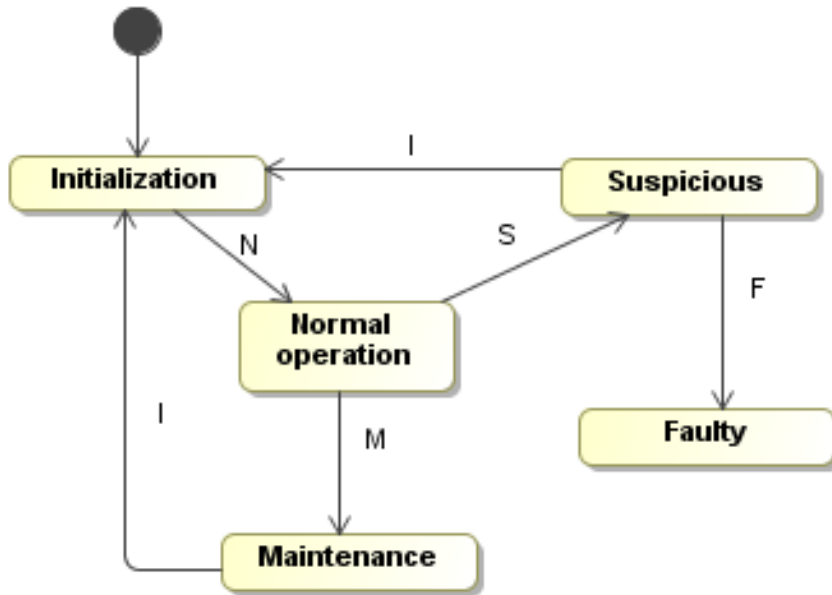
Why to model?

```
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;  
        }  
    }  
}
```



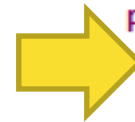
Generate code

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;
    }
}
```

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*:

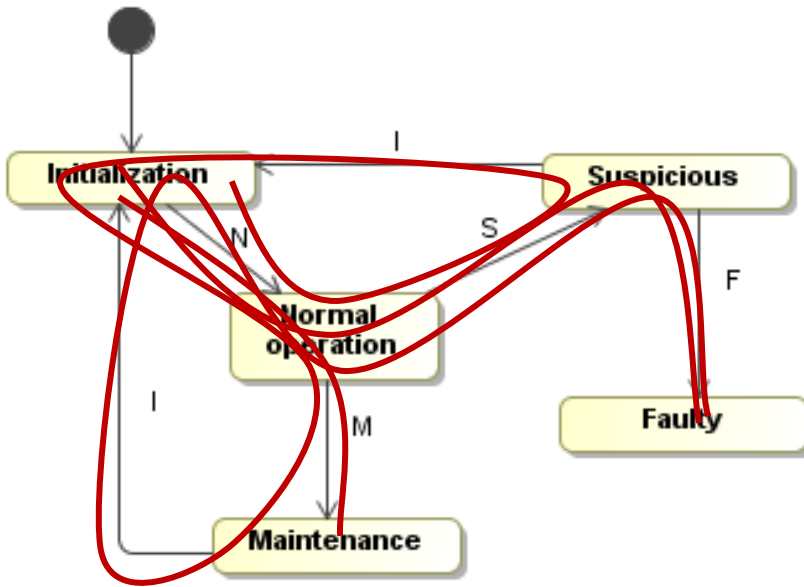
NSF,

NSI NSF,

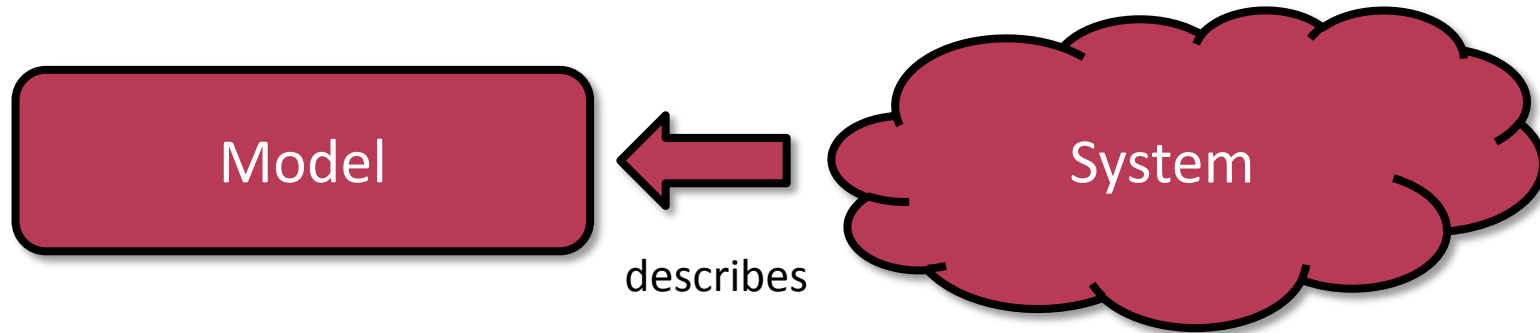
NMI NSF,

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

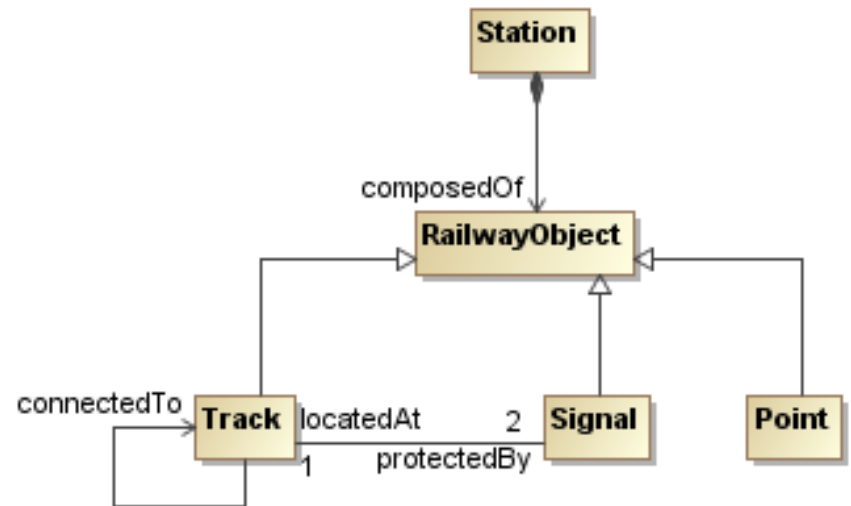
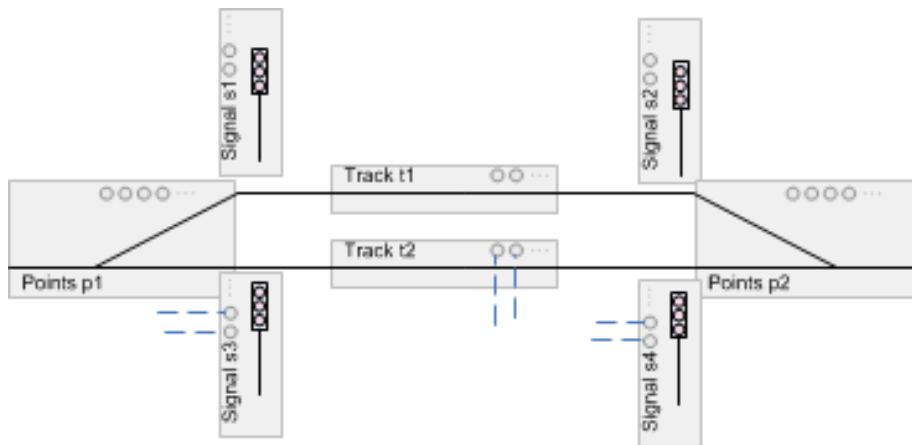
What is a model?

- Structured representation of the information

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

Tracks can be connected to each other.

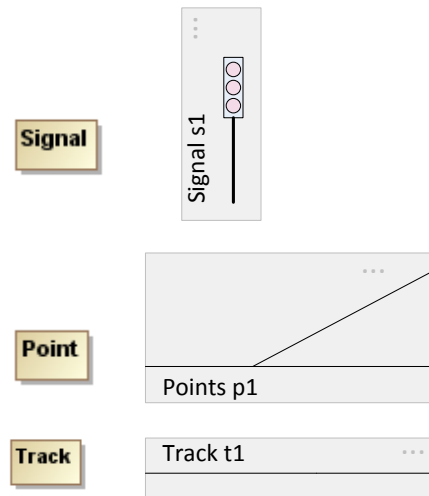
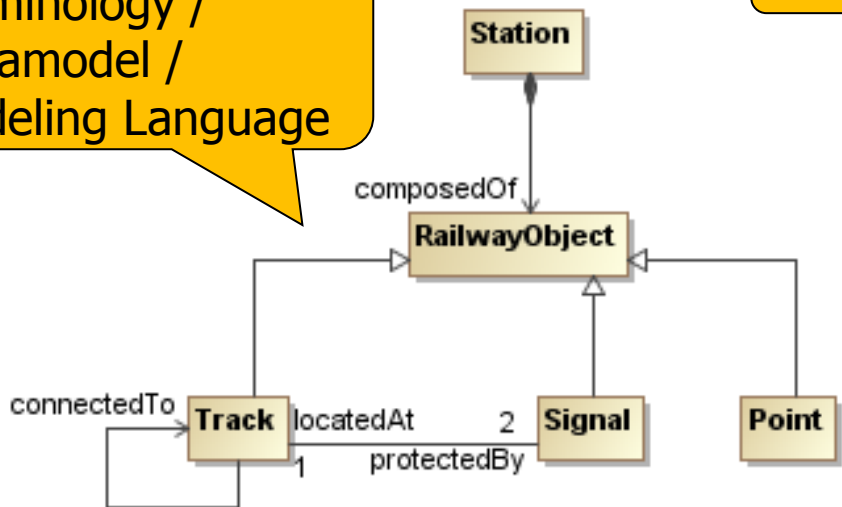
Signals are located at both ends of the track.



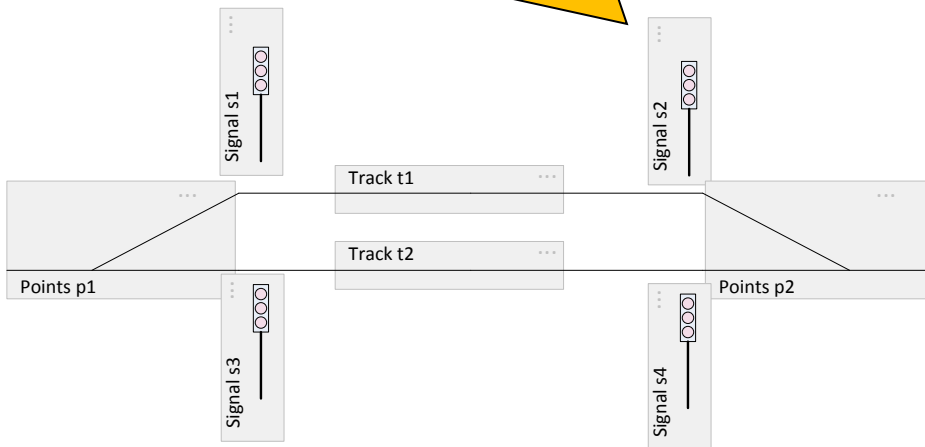
What is a model?

Terminology /
Metamodel /
Modeling Language

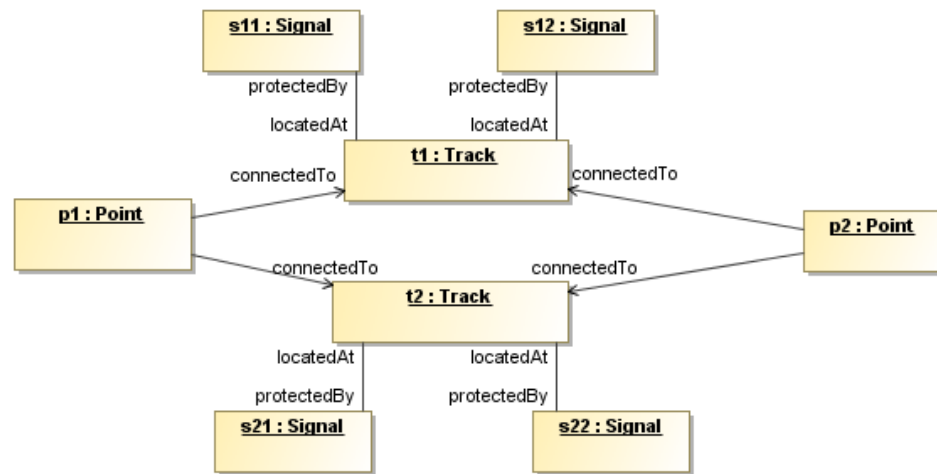
Graphical syntax



Instance model – diagram



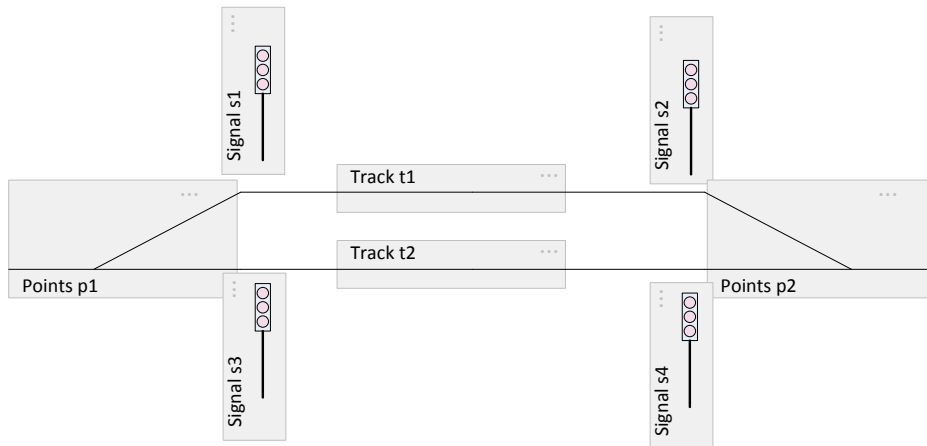
Instance model – abstract syntax



Model vs. Diagram

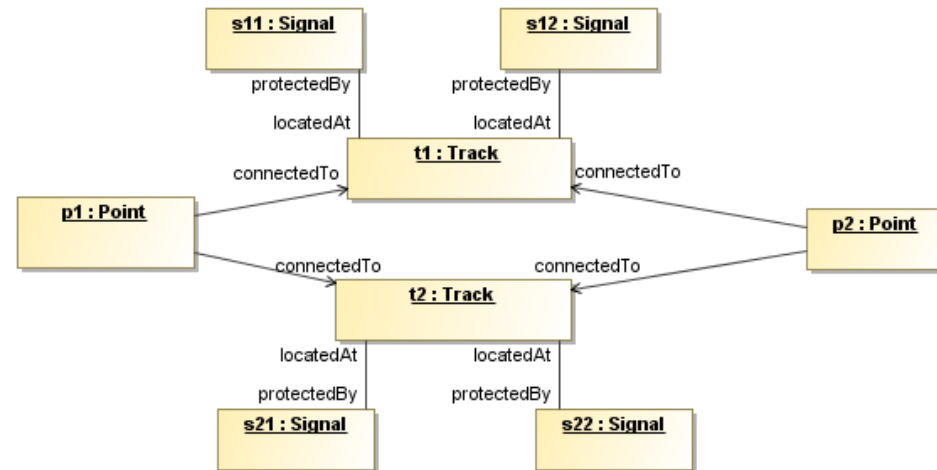
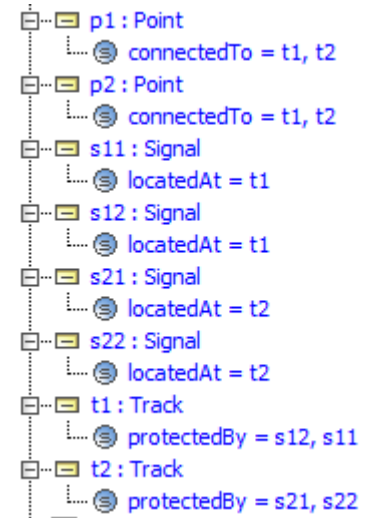
■ Diagram

- A view of the model
- Important aspects from a given viewpoint are shown



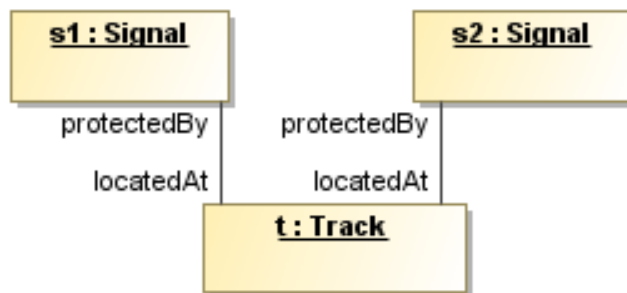
■ Model

- 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(s2,t);  
  protectedBy(t,s1);  
  protectedBy(t,s2);  
}
```

- Find in the model (pattern matching)

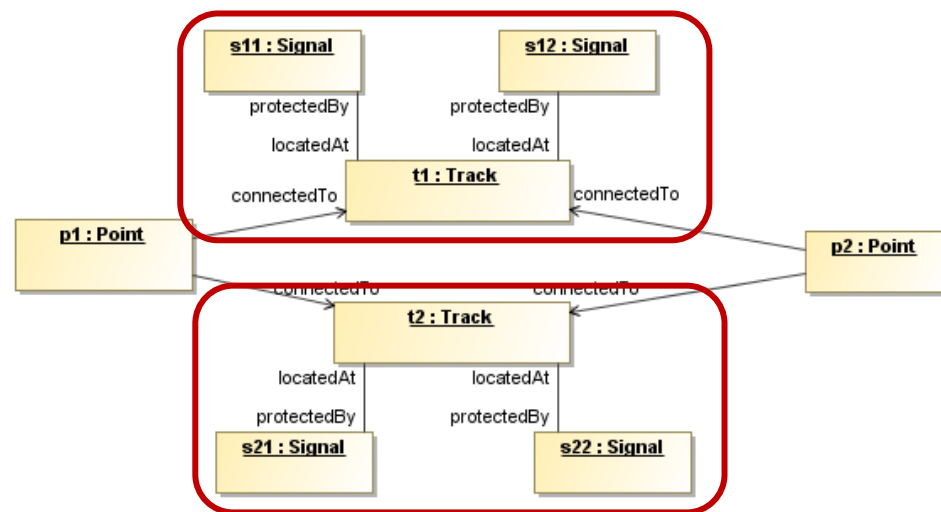
- Result: match sets

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?

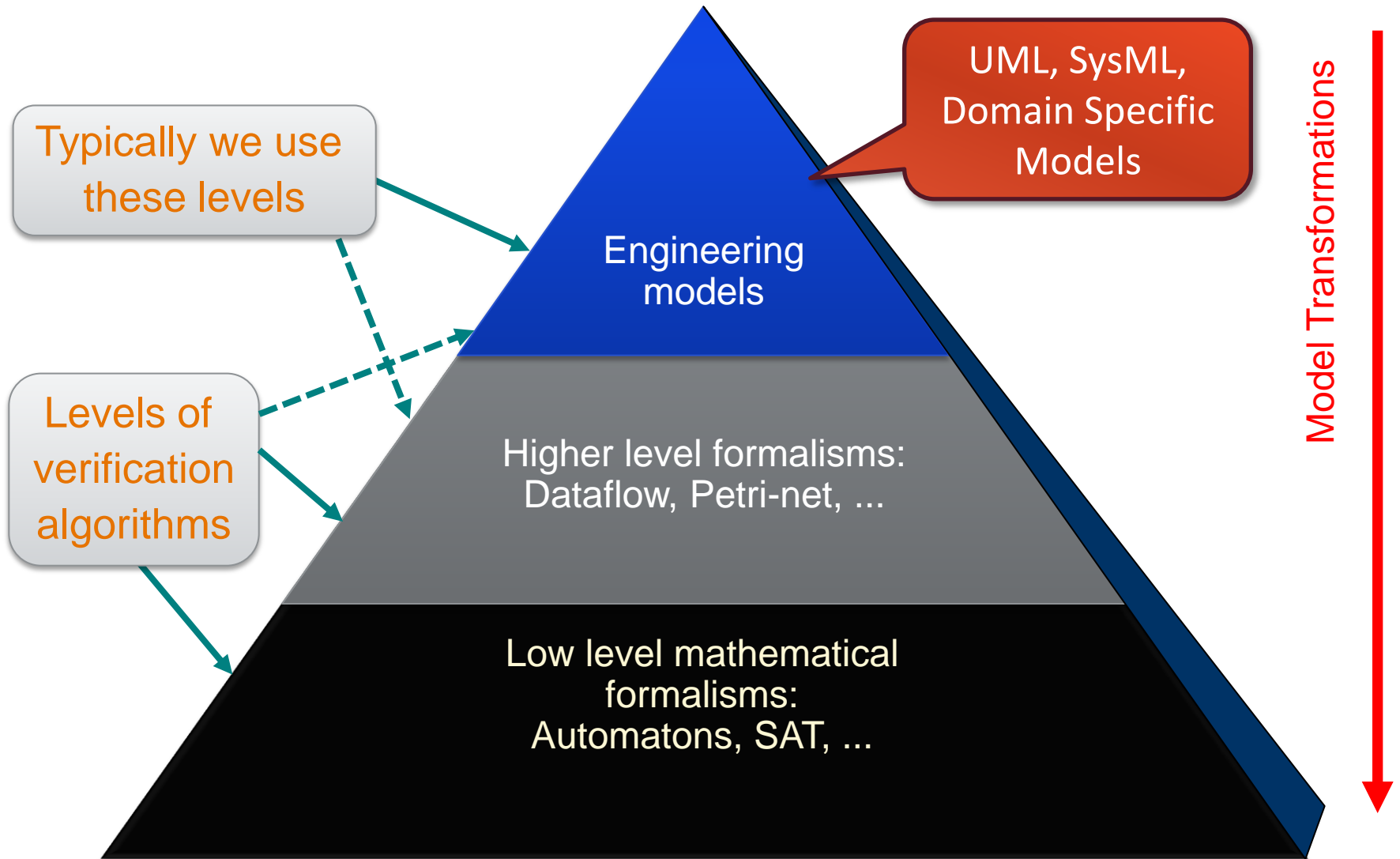
■ **Static models**

- 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

- Synthesize some parts of the system
 - design, application or other artefacts

Analysis in Model Driven System Engineering

System Design

Formal verification

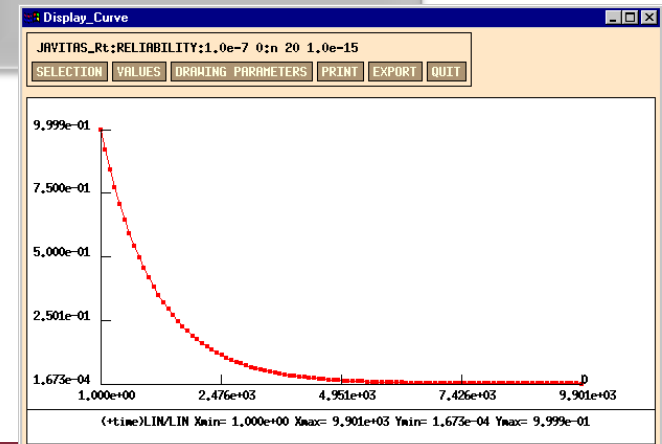
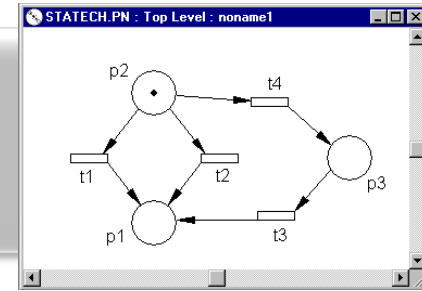
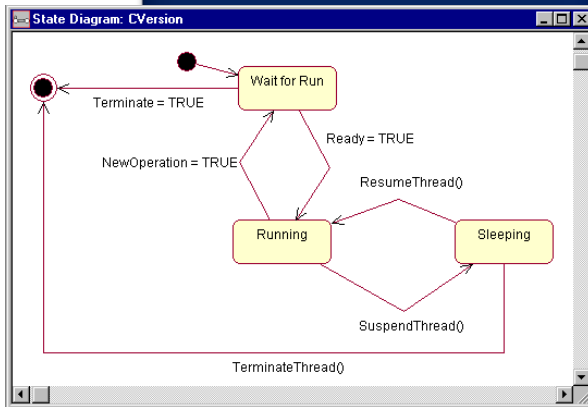
Engineering model
(e.g. SysML)

Automated
Model Generation

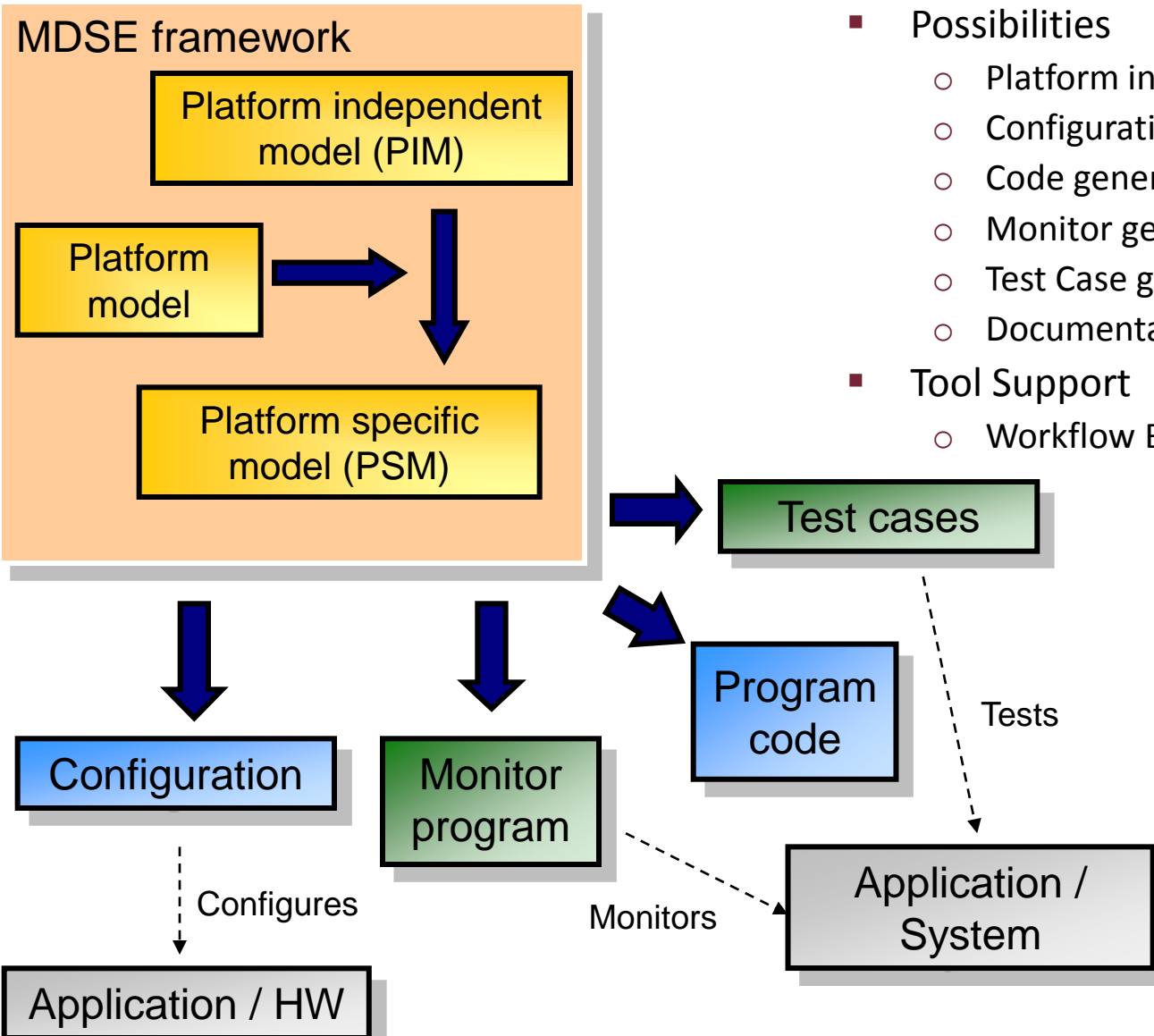
Formal model

Backtracing
results

Analysis



Synthesis in Model Driven System Engineering



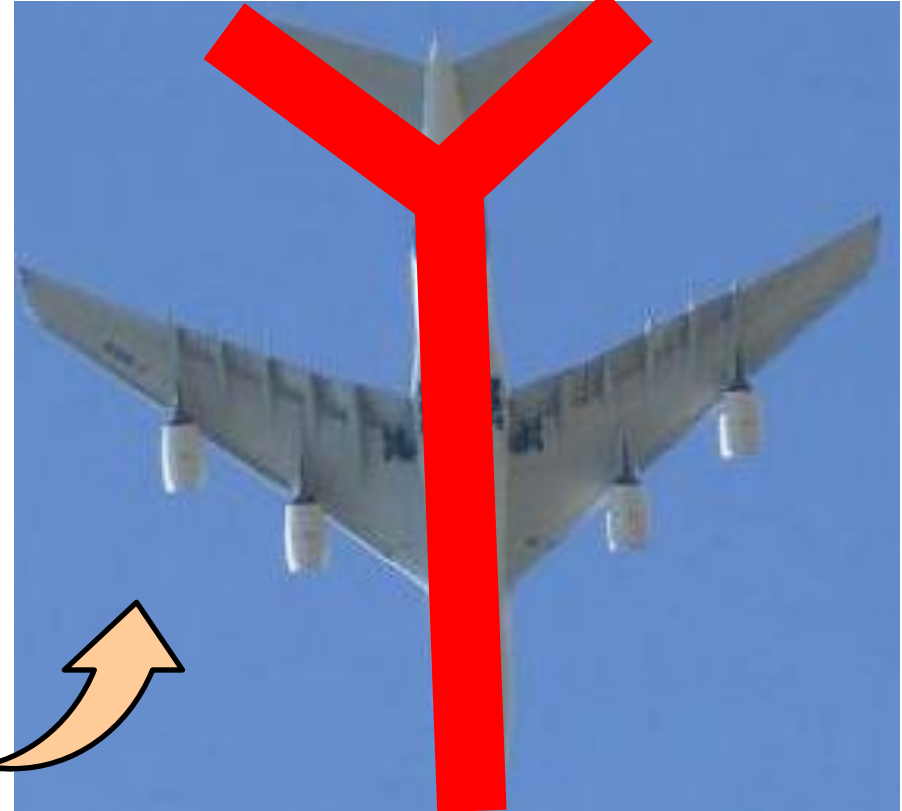
- Possibilities
 - Platform independent → platform specific
 - Configuration generation
 - Code generation
 - Monitor generation
 - Test Case generation
 - Documentation generation
- Tool Support
 - Workflow Based Execution

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--

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