Model-Driven Development

in the context of embedded automation systems

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0
The Challenge

Software increasingly **complex**

Software increasingly **complex**

Faster innovation cycles

Software increasingly **complex**

Faster innovation cycles

Product Lines - **Variability**

Software increasingly **complex**

Faster innovation cycles

Product Lines - **Variability**

No formal spec – **correctness**?

Solution Approach:

Model-Driven Software Devlopment

Domain-Specific Languages

Code Generation

1

A little History

programming

started

close to the hardware

abstractions

~

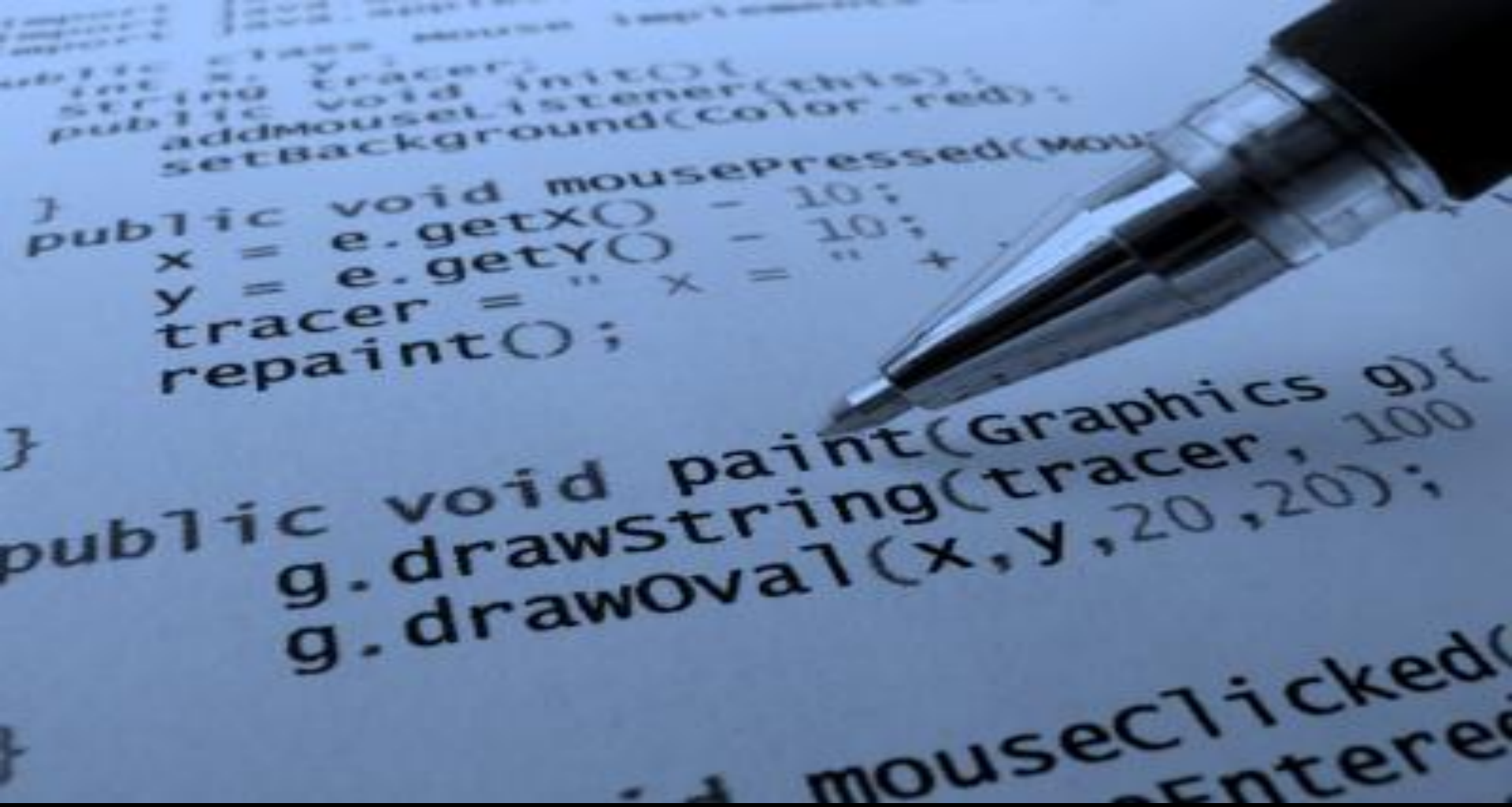
computing

chips

abstractions
~
computing
bits

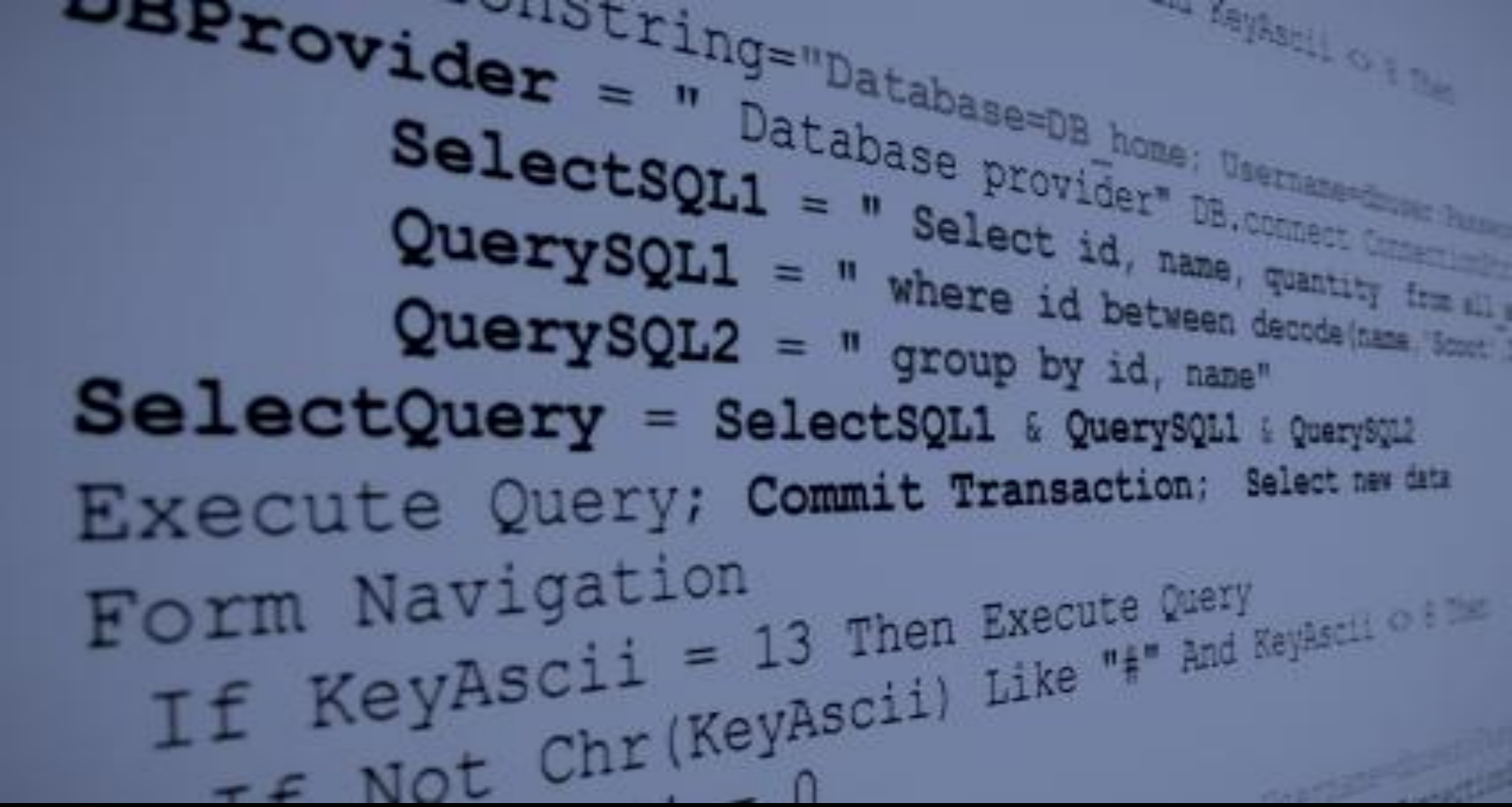
abstractions ~ computing

c



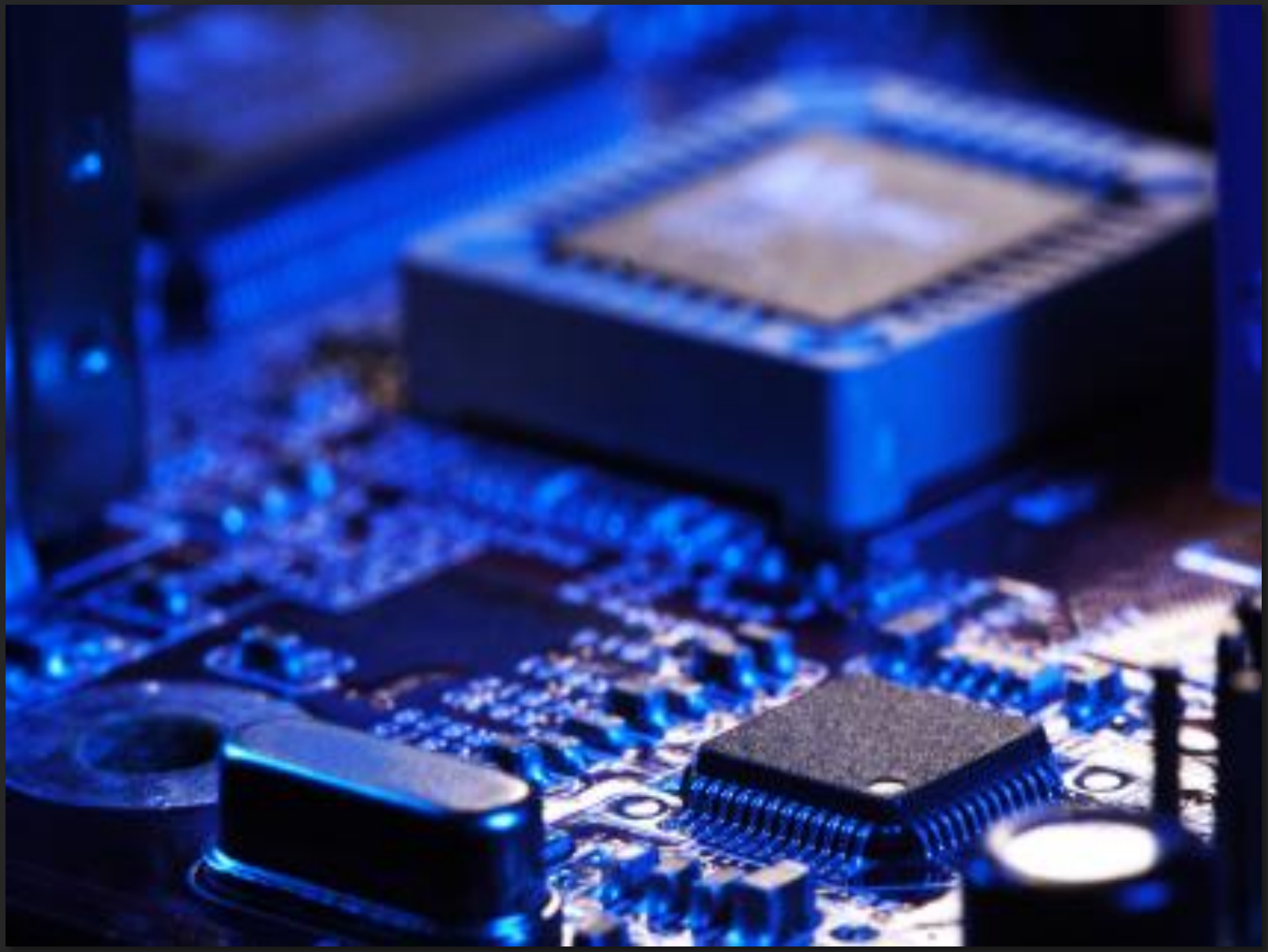
abstractions ~ computing?

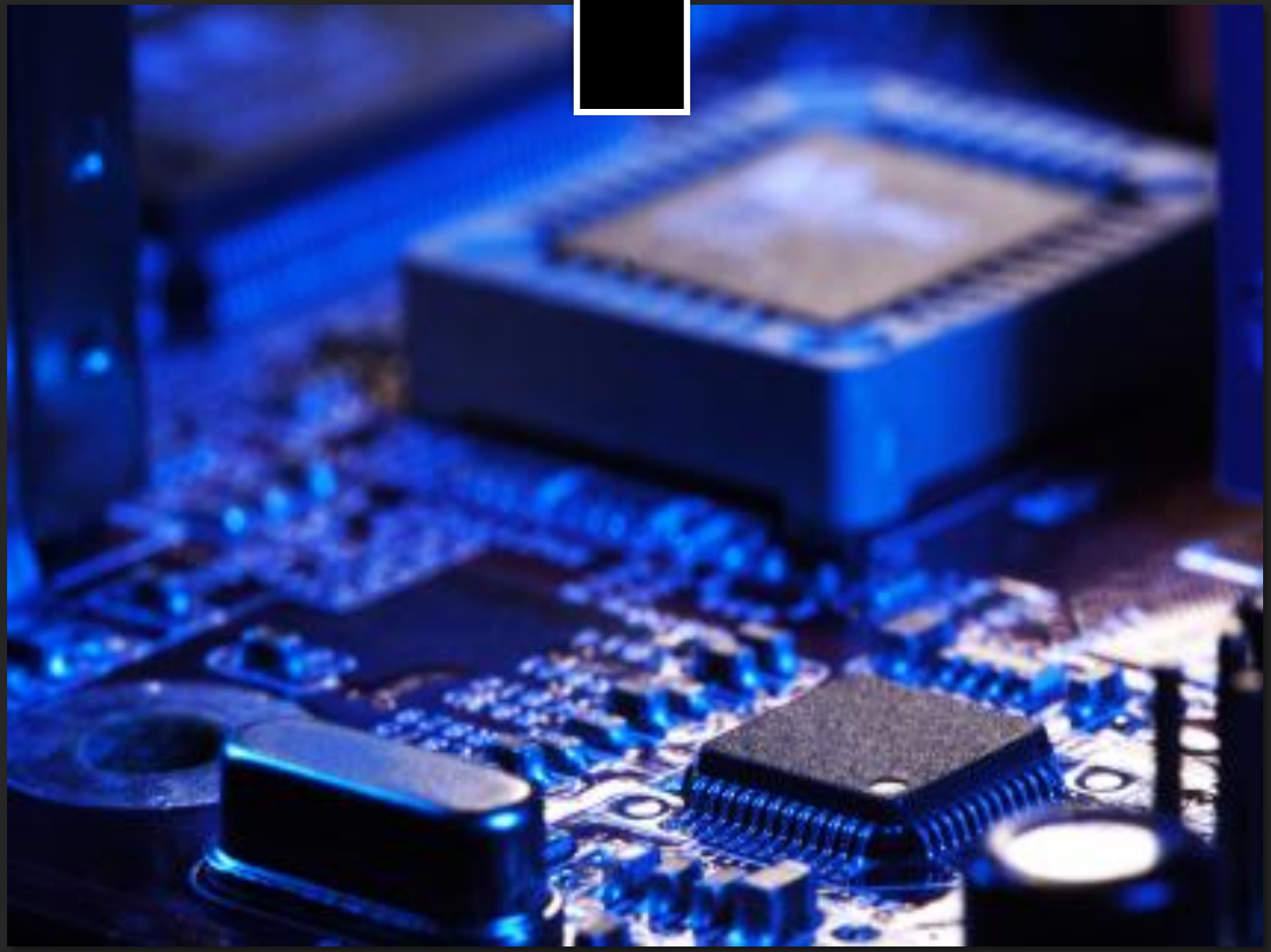
Java



abstractions ~ computing?

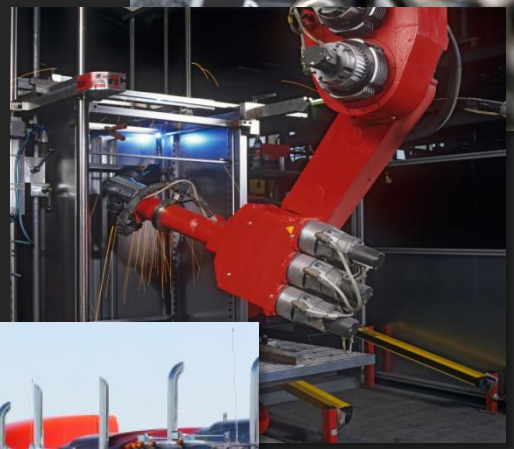
SQL





?

PB



general purpose

domain specific

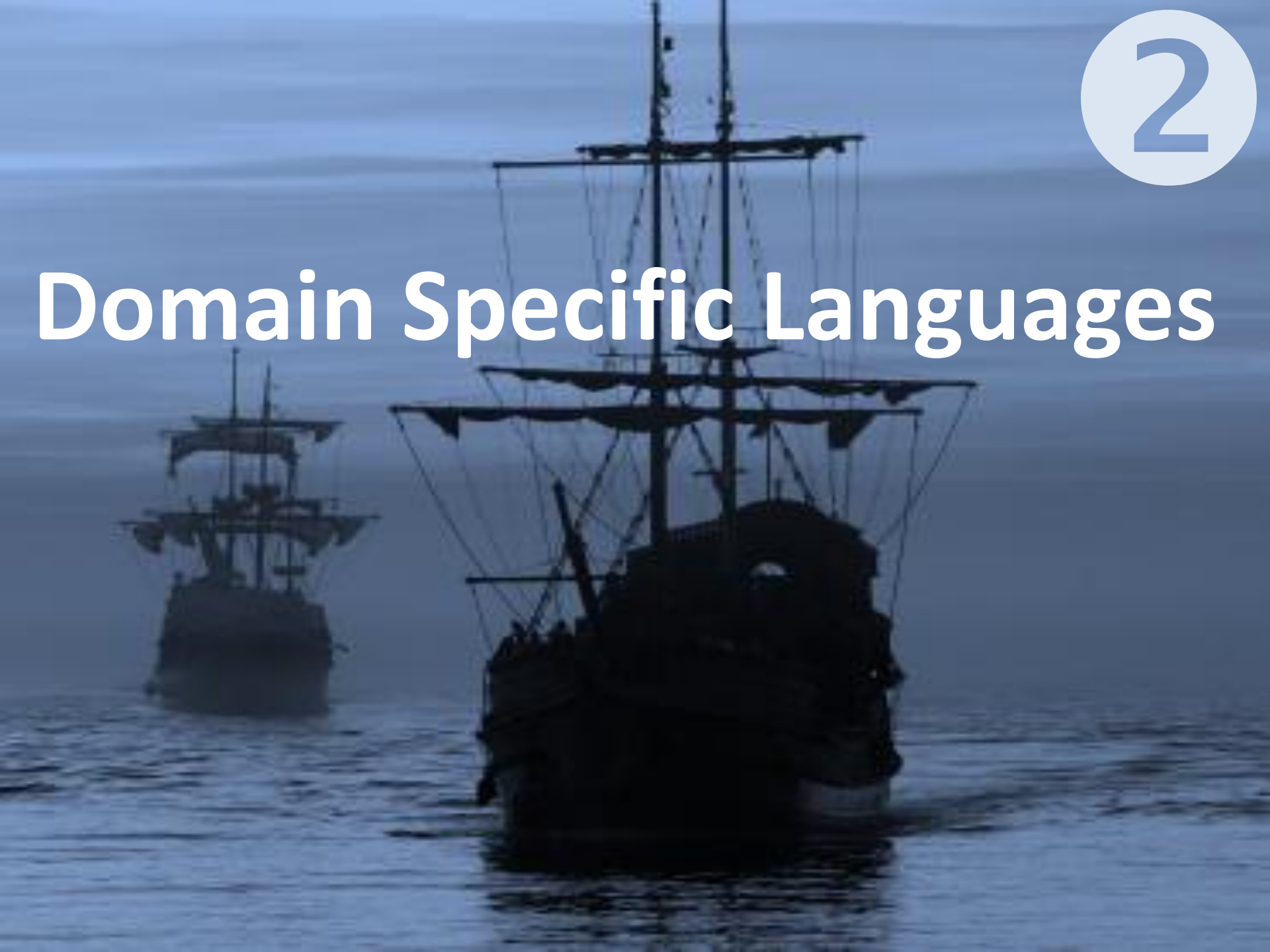
tailor made

effective++

specialized, limited

used by experts

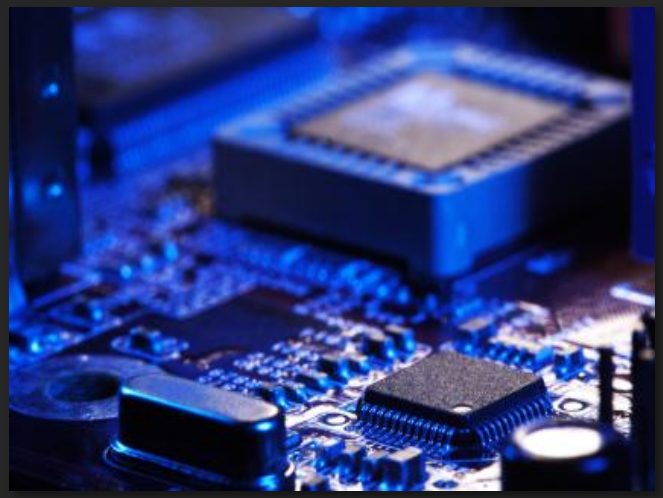
together with other specialized tools


2
Domain Specific Languages

A DSL is a **focussed**, **processable language** for describing a specific **concern** when building a system in a specific **domain**. The **abstractions** and **notations** used are natural/suitable for the **stakeholders** who specify that particular concern.

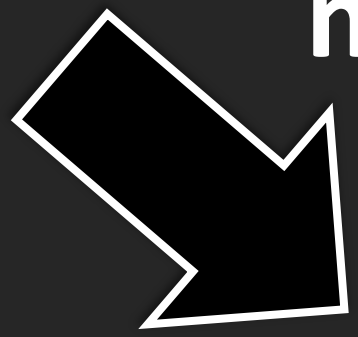
execute?

map



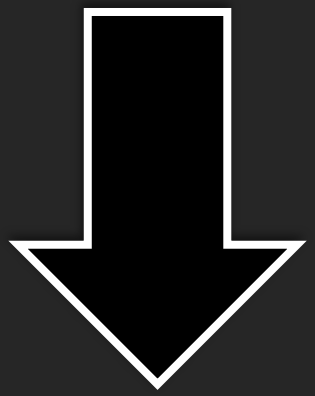
DSL Program
(aka Model)

map



automated!

GPL Program



map

Generation

Transformation

Compilation

Interpretation

LanguageOrientedProgramming
DomainSpecificModeling
GenerativeProgramming
ModelDrivenDevelopment
ModelIntegratedComputing
ModelBasedDevelopment
ModelDrivenEngineering
ModelDrivenArchitecture
ModelBasedEngineering
ModelDrivenSoftwareDevelopment

Activities

Analysing Domains

Defining Languages

Adapting/Selecting

Building Editors

Transforming Models

Building Generators

Building Frameworks

Activities

Analysing Domains

Defining Languages

Adapting/Selecting

Building Editors

Transforming Models

Building Generators

Building Frameworks

… and using all of that to build apps

Architecture

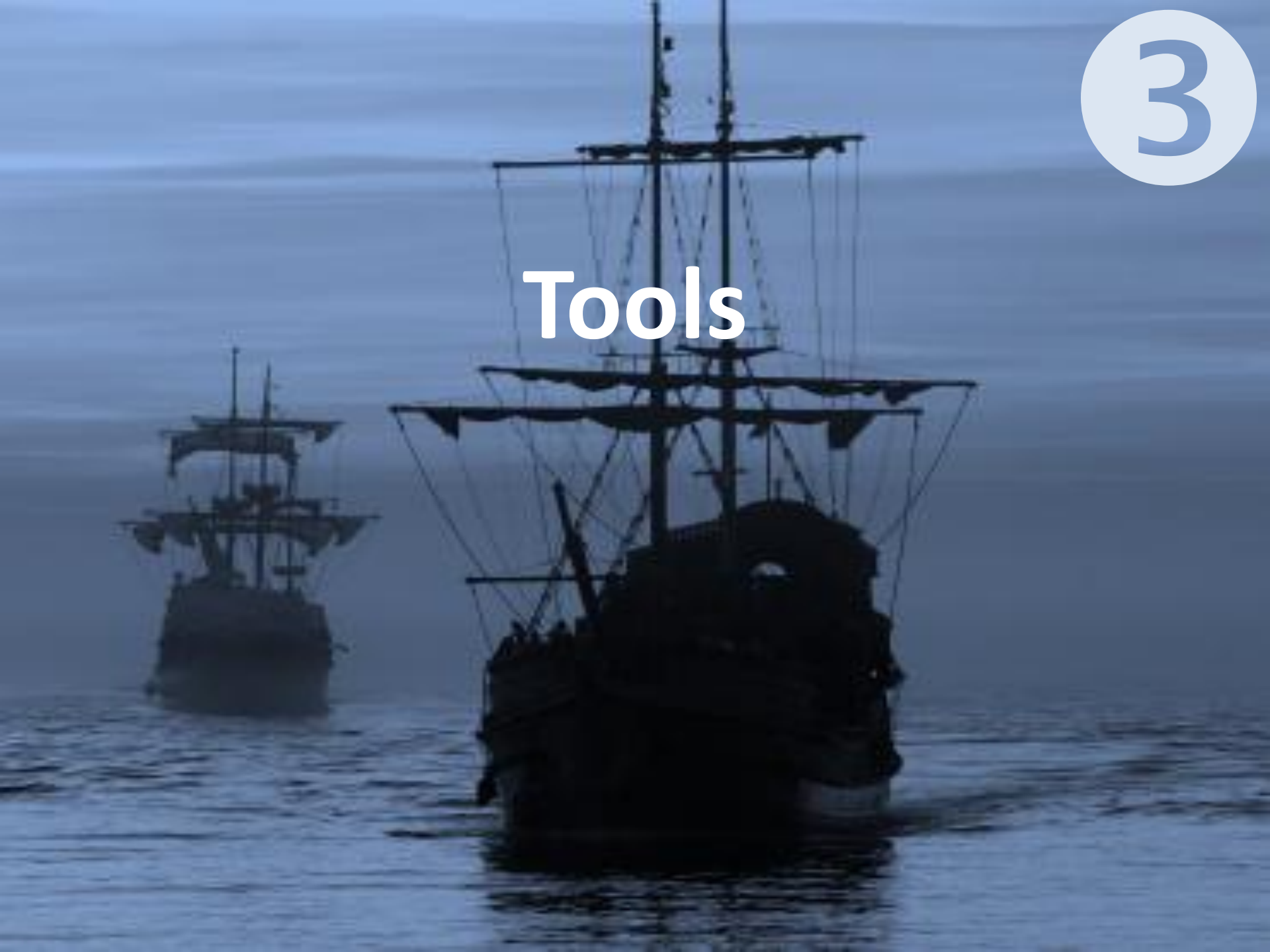
DSL

As you understand and develop your Architecture…

Develop a language to express it!

Language resembles architectural concepts

We express the application(s) with the language.


3
Tools

Tooling!

Tooling!
Editor

Tooling!

Editor, Debugger

Tooling!

Editor, Debugger, Testing

Tooling!

Editor, Debugger, Testing, Groupware

Tooling!

Editor, Debugger, Testing, Groupware, Scalable

Tooling!

Editor, Debugger, Testing, Groupware, Scalable, „All in Eclipse“

Tools Tooling

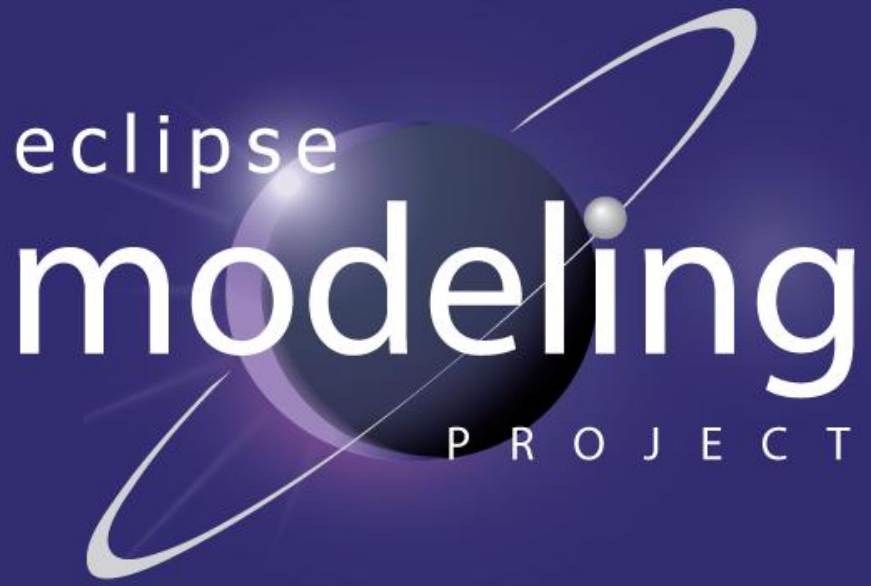
Language Definition Tools

abstract syntax, concrete syntax, constraints

Editor Frameworks

Transformation Languages

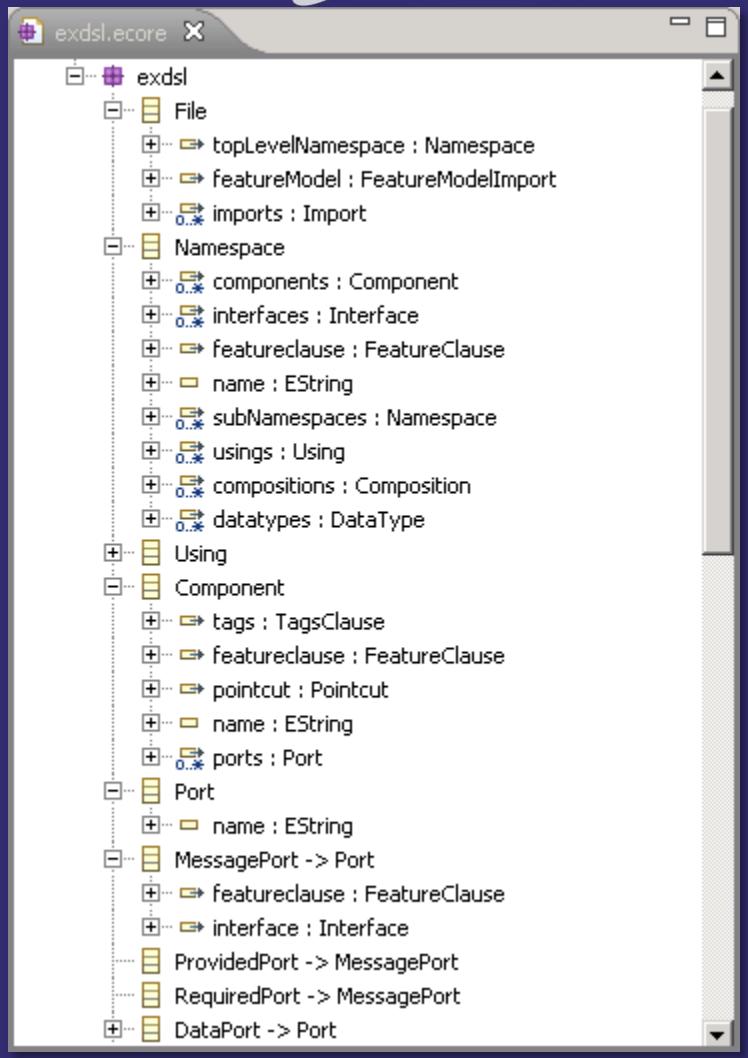
Code Generation Tools


eclipse
modeling
PROJECT

EMF

Metamodel As Tree

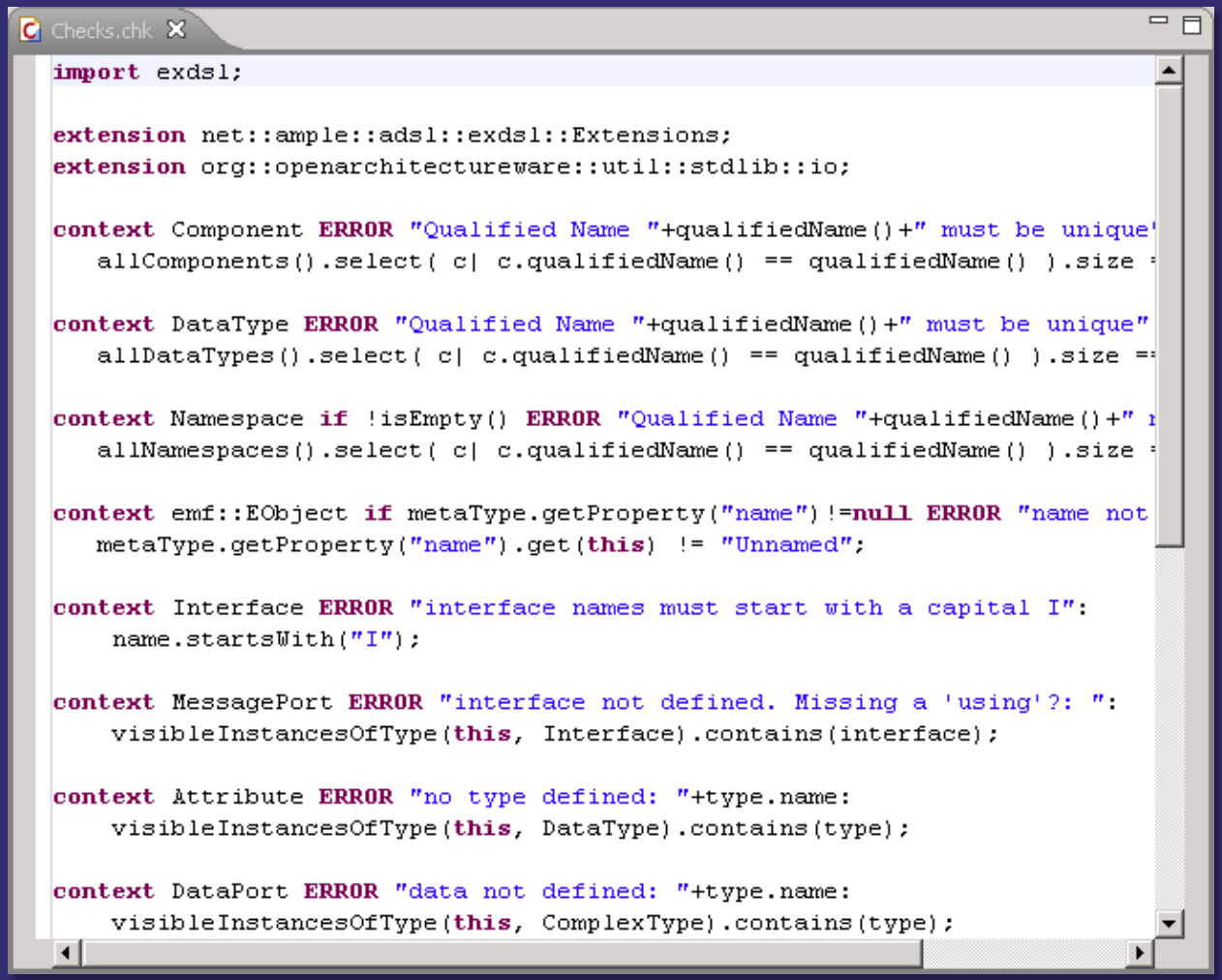
can also be edited
as UML-like diagram



EMF

Constraints

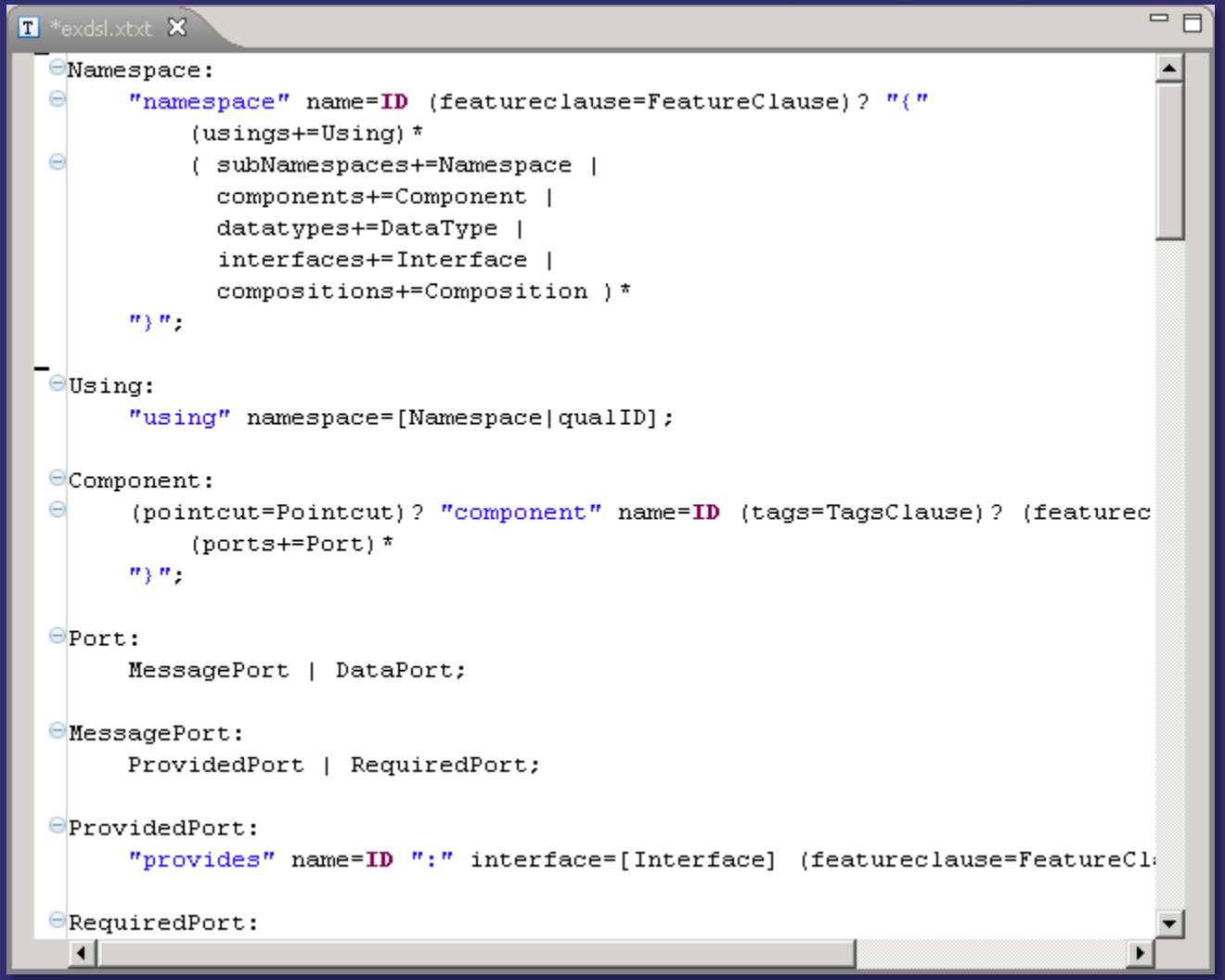
with OCL
and dialects



TMF / Xtext

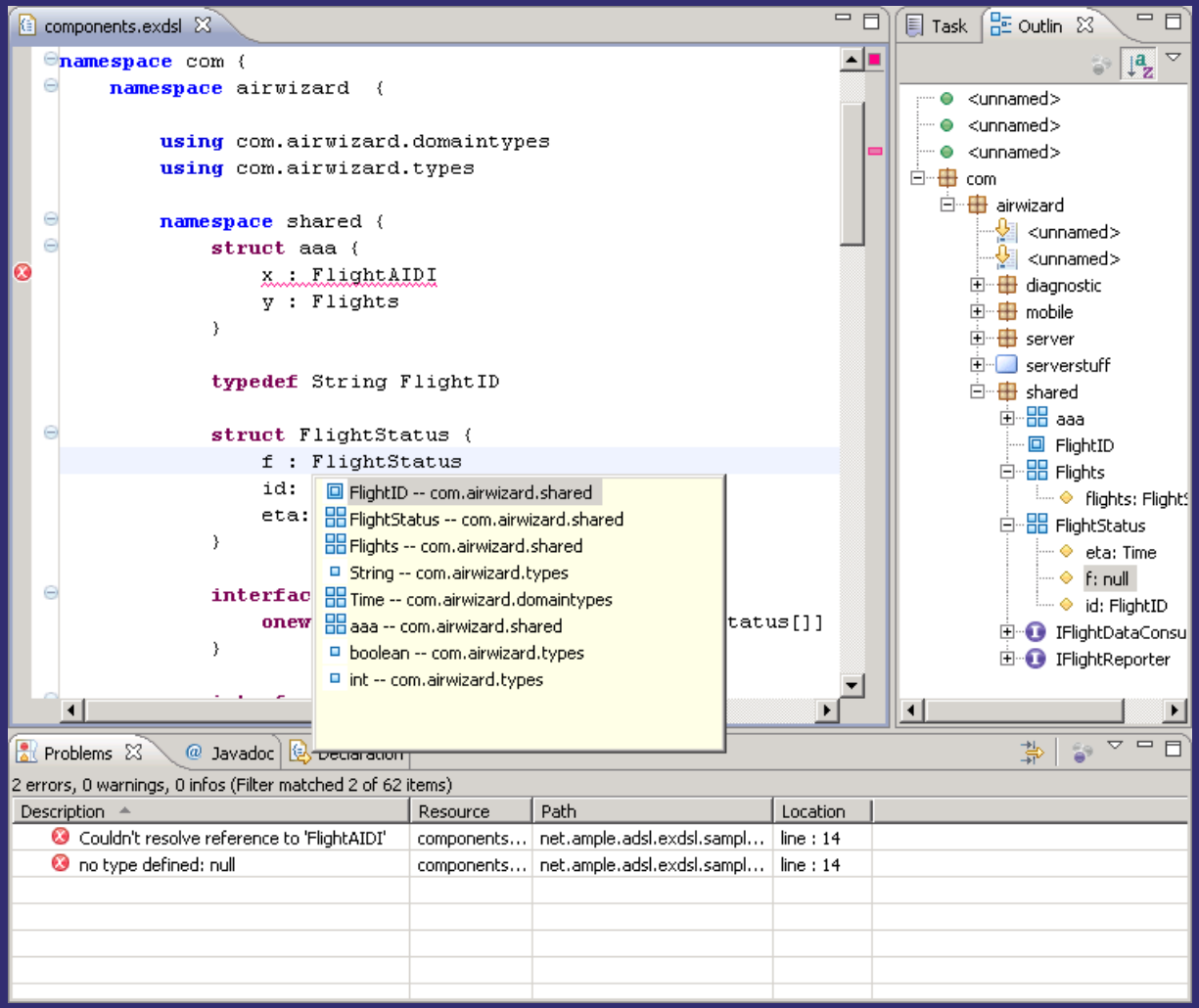
eclipse modeling PROJECT

Building Textual Editors



TMF / Xtext

Building Textual Editors

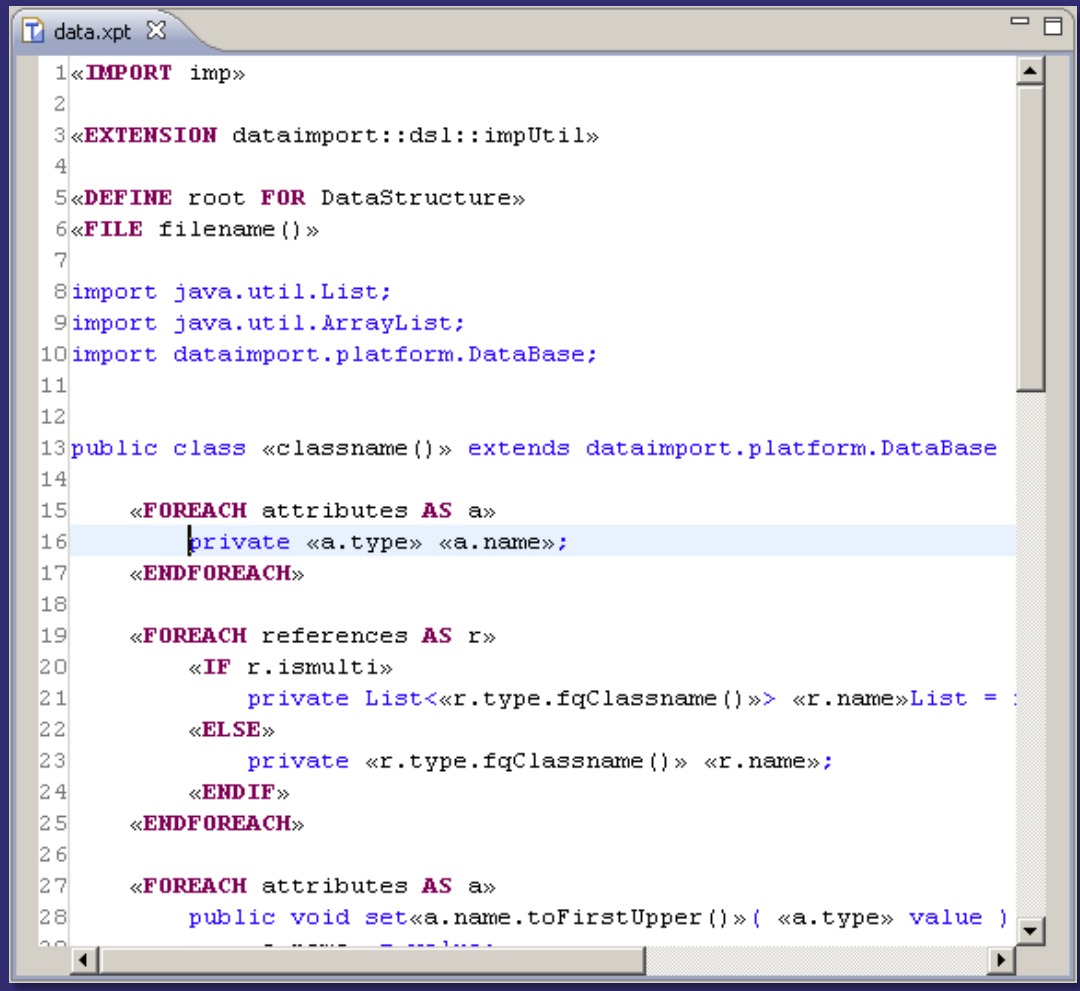


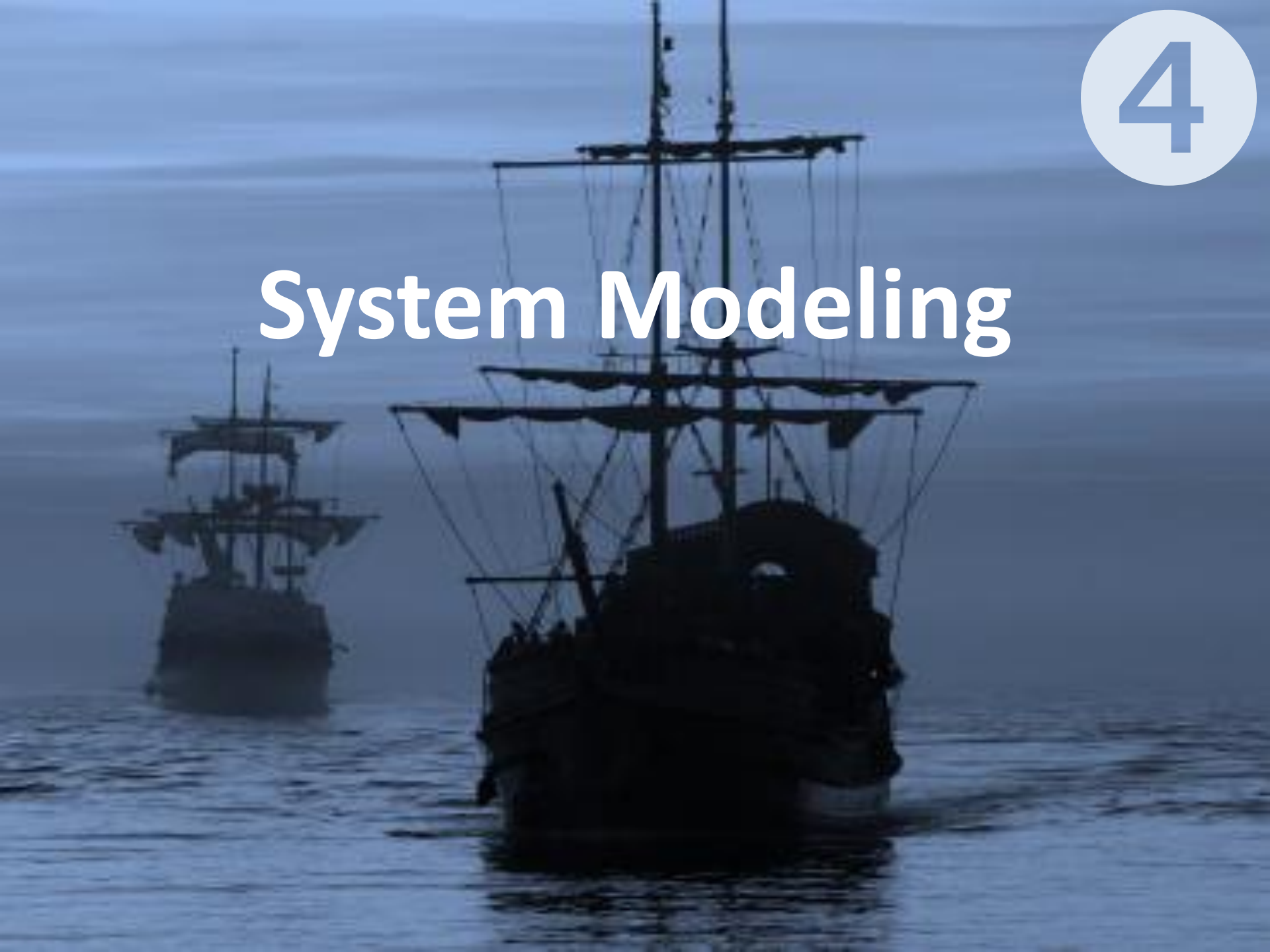
M2T

eclipse modeling PROJECT

Model-to-Text Transformations

- JET: Java Emitter Templates
- Xpand: oAW's template engine





4

System Modeling

Leitstandssoftware

Leitstandssoftware

A central coordinator

Leitstandssoftware

A central coordinator

Many „plug-in“ cards

Leitstandssoftware

A central coordinator

Many „plug-in“ cards

With different configs

Leitstandssoftware

A central coordinator

Many „plug-in“ cards

With different configs

With different hardware

Leitstandssoftware

A central coordinator

Many „plug-in“ cards

With different configs

With different hardware

Running components

Leitstandssoftware

A central coordinator

Many „plug-in“ cards

With different configs

With different hardware

Running components

Communicating via bus

component definition

```
processing DigitalIn "BI" moduletype 0x08 hal = DigitalInHAL  {

    datatypes {
        SinglePointIndicationWithoutTime;
        SinglePointIndicationWithTime;
        DoublePointIndicationWithoutTime;
        DoublePointIndicationWithTime;
        BitStringTypeI8BitWithoutTime;
        BitStringTypeI8BitWithTime;
    }

    parametertypes {
        DataType default {
            subattr db0 # intendedDataType == pdt SinglePointIndicationWithTime;
        };
        DebounceFilterTime default {
            attr filterTimeInMs == 0x02;
            subattr db1 # SP == 0x00;
            subattr db1 # IN == 0x00;
        } ;
        MaximumOscillatingFrequency;
    }

    function READDATA () : ProcessData;
    function WRITEDATA(input : ProcessData);

    struct ProcessData {
        int8 channel;
        int8 fixData[4];
    }

    struct Memory {
        int8 state;
        ProcessData data;
    }

    instance memory Memory ;
}
```

Hardware specifics

```
hal DigitalInHAL memory DID {
    command HighSpeedCounterInit;
    command HardwareInit;

    struct DID {
        int16 ch1_16;
        int32 hs_counter;
    }
}

halImpl DigitalInHALImpl for DigitalInHAL;
halImpl WinBiHALImpl for DigitalInHAL;
```

bus protocol spec

```
procedure writeRegisterNumber2 requestCode 0x29 {
    request: struct request1 {
        int8 acc pattern {
            2:b00;
            6:parentRequestCode;
        };
        int8 registerAddress;
    } ;
    reply: struct dontCareReply {
        int8 statusByte patternref statusByte;
        int8 dontCare patternref defaultReturn;
    } ;
    request: struct request2 {
        int8 registerType pattern {
            4:b0000;
            4:registerType;
        };
        int8 registerAddress;
        int8 registerdata [2];
    } ;
}
```

System/card definition

```
system DemoInput target atmel extendedModuleType 0x30 rack 1 {

    dip: DigitalIn slot 1 with DigitalInHALImpl channels 16
        using datatypes {
            SinglePointIndicationWithoutTime;
            SinglePointIndicationWithTime;
            BitStringTypeI8BitWithoutTime;
            BitStringTypeI8BitWithTime;
        };

    dispatcher {
        processingcomponent DigitalIn {
            on normalizeModule;
            on readStandardStatus;
            on setModuleInService;
            on readDataOfInputChannelX;
            on repeatLastReply;
            on resetModule;
            on writeRegisterNumberZ;
        }
    }
}
```

testing

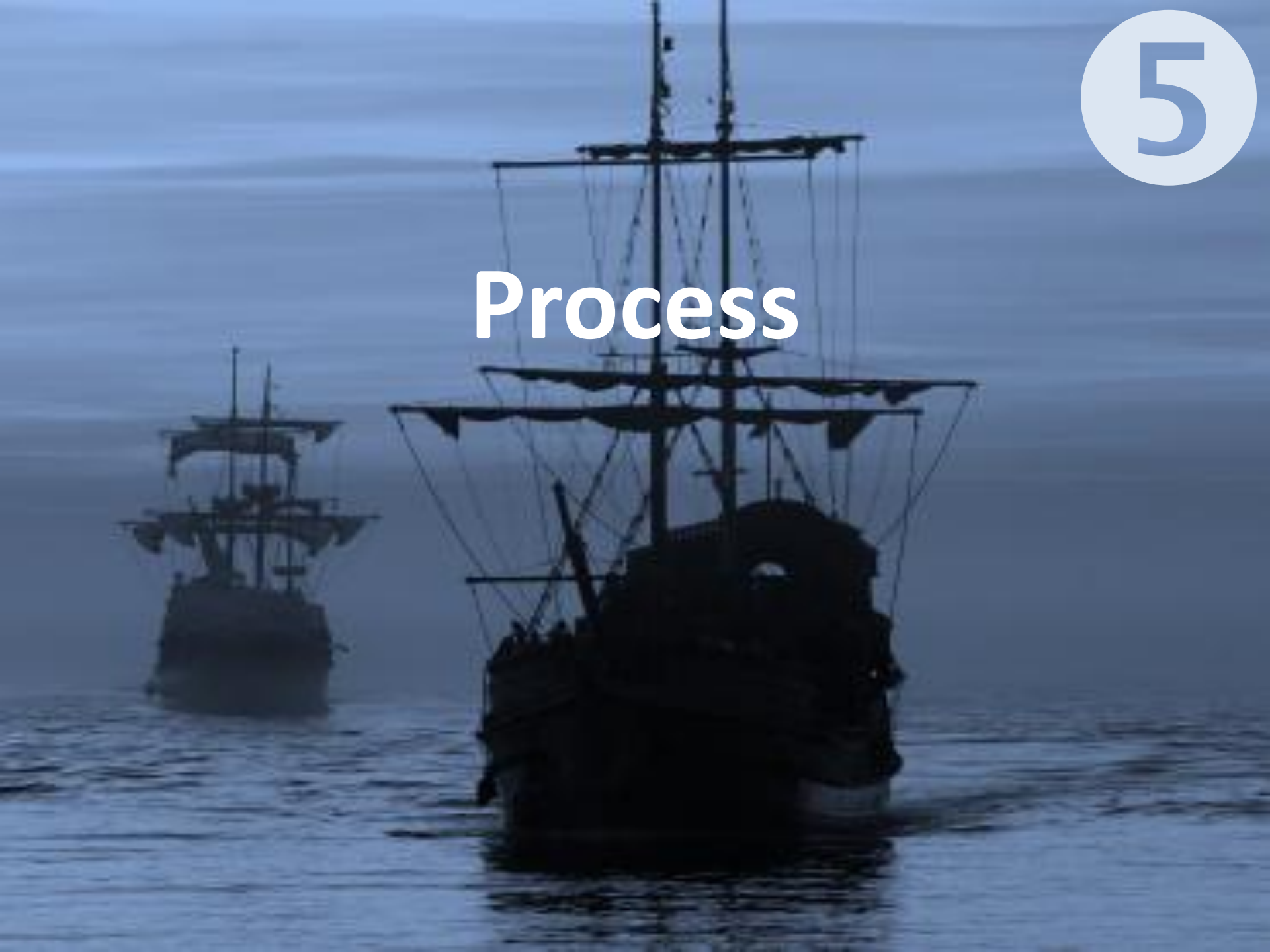
```
procedure writeRegisterNumberZ requestCode 0x29 {
    request: struct request1 {
        int8 acc pattern {
            2:b00;
            6:parentRequestCode;
        };
        int8 registerAddress;
    } ;
    reply: struct dontCareReply {
        int8 statusByte patternref statusByte;
        int8 dontCare patternref defaultReturn;
    } ;
    request: struct request2 {
        int8 registerType pattern {
            4:b0000;
            4:registerType;
        };
        int8 registerAddress;
        int8 registerdata [2];
    } ;
}
```

tests

refines

```
test writeRegisterNumberZ for dip writeRegisterNumberZ {
    send request1 {
        attr registerAddress == reg parameterInstruction;
    };
    expect dontCareReply {
        subattr statusByte # standardStatus == 2;
    };
    send request2 {
        subattr registerType # registerType == 3;
        attr registerAddress == reg parameterInstruction;
        attr registerdata == 0x77;
        subattr registerdata # channelNumber == 5;
    };
}
```

```
register parameterInstruction address 0x37 struct {
    int8 db1 pattern {
     2:b00;
     6:channelNumber;
    };
};
```


5
Process

Initial Familiarization Workshop

Initial Familiarization Workshop

Reference Implementation

Initial Familiarization Workshop

Reference Implementation

„Meta Stuff“ in parallel

Initial Familiarization Workshop

Reference Implementation

„Meta Stuff“ in parallel

DSL developed incrementally

Initial Familiarization Workshop

Reference Implementation

„Meta Stuff“ in parallel

DSL developed incrementally

DSL forces decisions -> spec++

Initial Familiarization Workshop

Reference Implementation

„Meta Stuff“ in parallel

DSL developed incrementally

DSL forces decisions -> spec++

Fallback: continue manually

Initial Familiarization Workshop

Reference Implementation

„Meta Stuff“ in parallel

DSL developed incrementally

DSL forces decisions -> spec++

Fallback: continue manually

Testing: first class citizen

6

Expected Benefits

Capture Domain Knowledge

formalized into languages and models

… Formal Definition of Bus Protocol and Data Structures

… Components, Interfaces

Capture Implementation Strategy

in the generators

… How to implement Dispatcher
… Define the API for accessing data and interfaces
… Data Structures (down to bit level)

Automation

faster, deterministic

Increased Quality

well defined structures allthrough the system

Meaningful Validation

more semantics in the model

… Are all protocol messages handled?

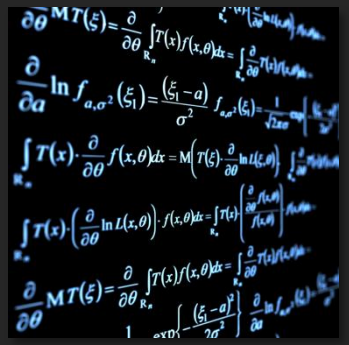
… Runtime: Diagnostics

Testing Support

more semantics in the model

… models to “base” test cases on

… generate test cases from separate test models using the protocol definition



Suitable Notations

textual, graphical, tabular

… models as documentation
… generated diagrams/visualizations
… traceability to requirements docs

Technology Independence

generate „technology glue code“

… simple migration to new platforms (through regeneration)

… hand-written code against generated, platform-independent APIs

… reuse components

Abstraction w/o Runtime Overhead

generator „optimizes away“

… meaningful architectural concepts
… generator generates efficient code
… PLE variability is statically resolved

Everything is a model

including for example (some) hardware

… bus protocol
… hardware structures
… channels

7
Lessons Learned

MDSD

does not result in

loss of

efficiency

for embedded systems

Open Source MDSD tools are **mature**

MDSD increases

quality of requirements.

MDSD is

cost-effective.

Strong benefits in

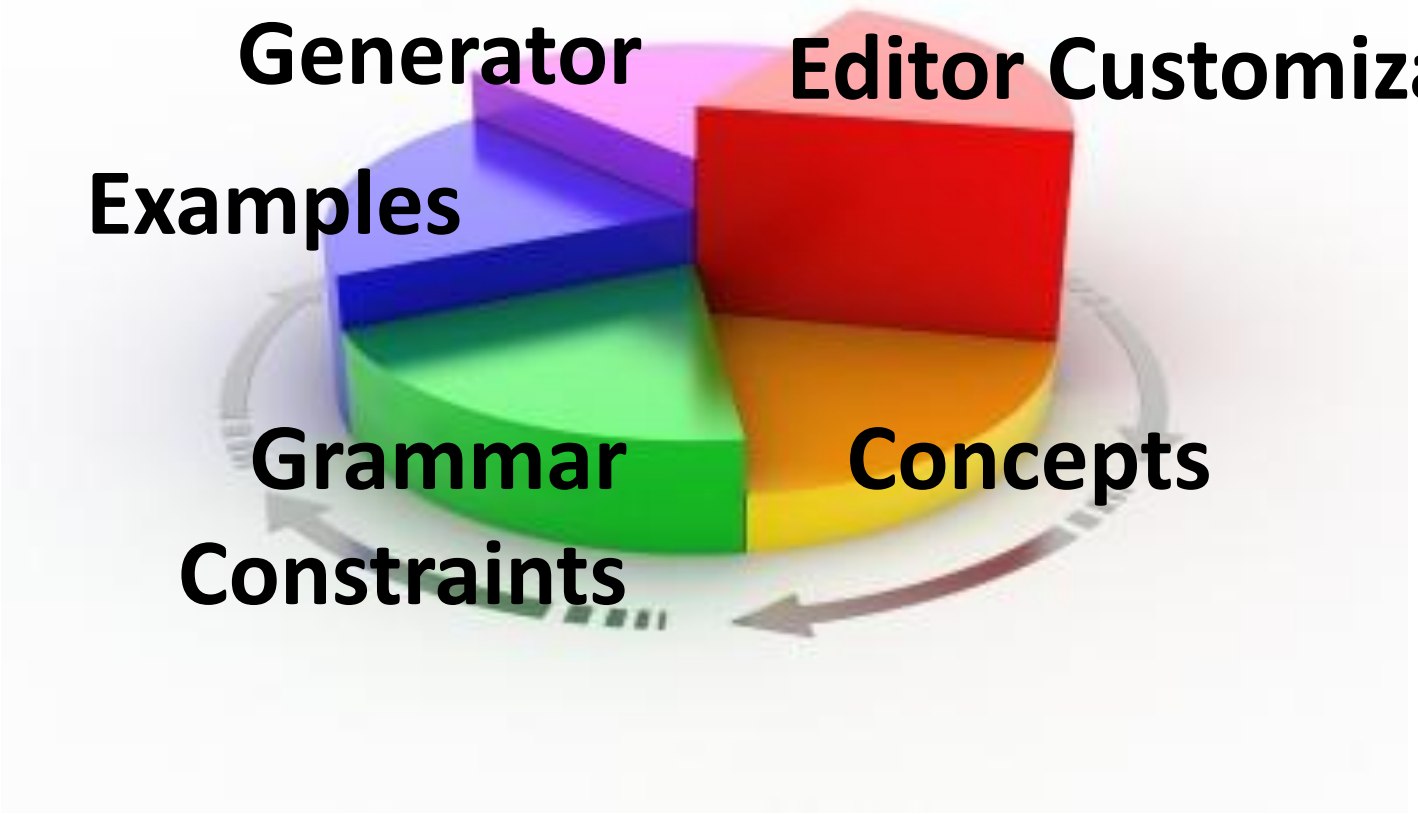
automated testing.

Enforces

Modularization.

External Coach
can help to
introduce
the new approach

Iterate!


Generator
Editor Customization
Examples
Grammar
Concepts
Constraints

THE END.