Modeling for Everyone

developing high-end production print systems

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Systems Modeling Architecture Team

STAF Industry Day 2019

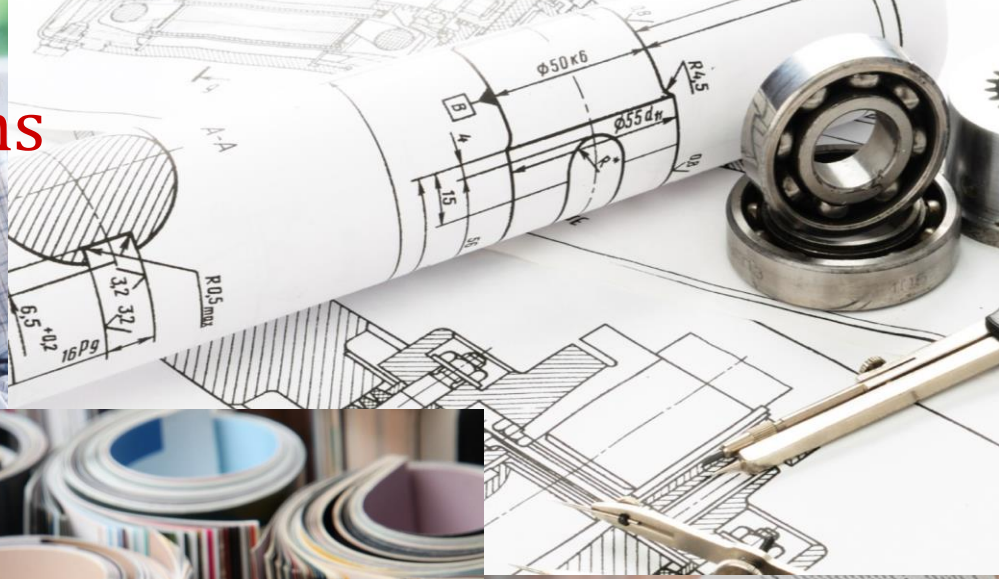
R4 - Public

Agenda

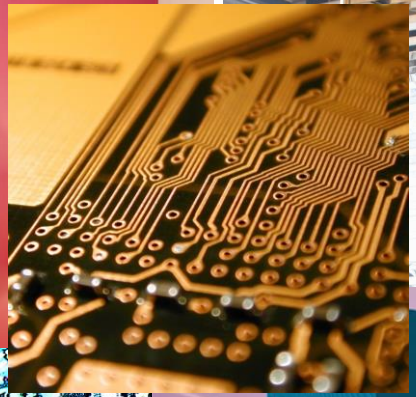
- Applications & Products
- Software: Controller & Embedded
- Variability of Print Systems
- General Examples MBD at Océ/Canon
- Illustrate scaling-up of MBD at Océ/Canon
- Detailed examples
- Next steps & application
- Challenges in applying MBD at Océ/Canon & Conclusions

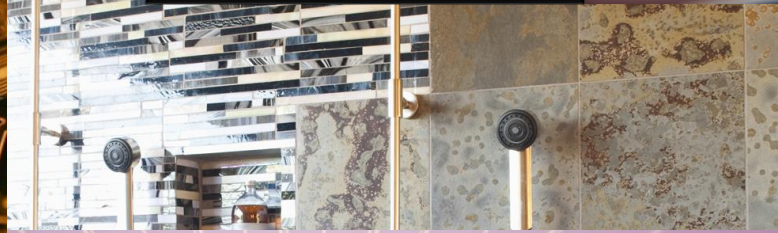
“Typical” print applications?

“Typical” Print Applications



Also print appications





Newest Océ Product Families

ColorWave 700

500 posters per day

Arizona 6170 XTS

200 signs per day

ProStream 1000

425,000 direct mail pieces per day

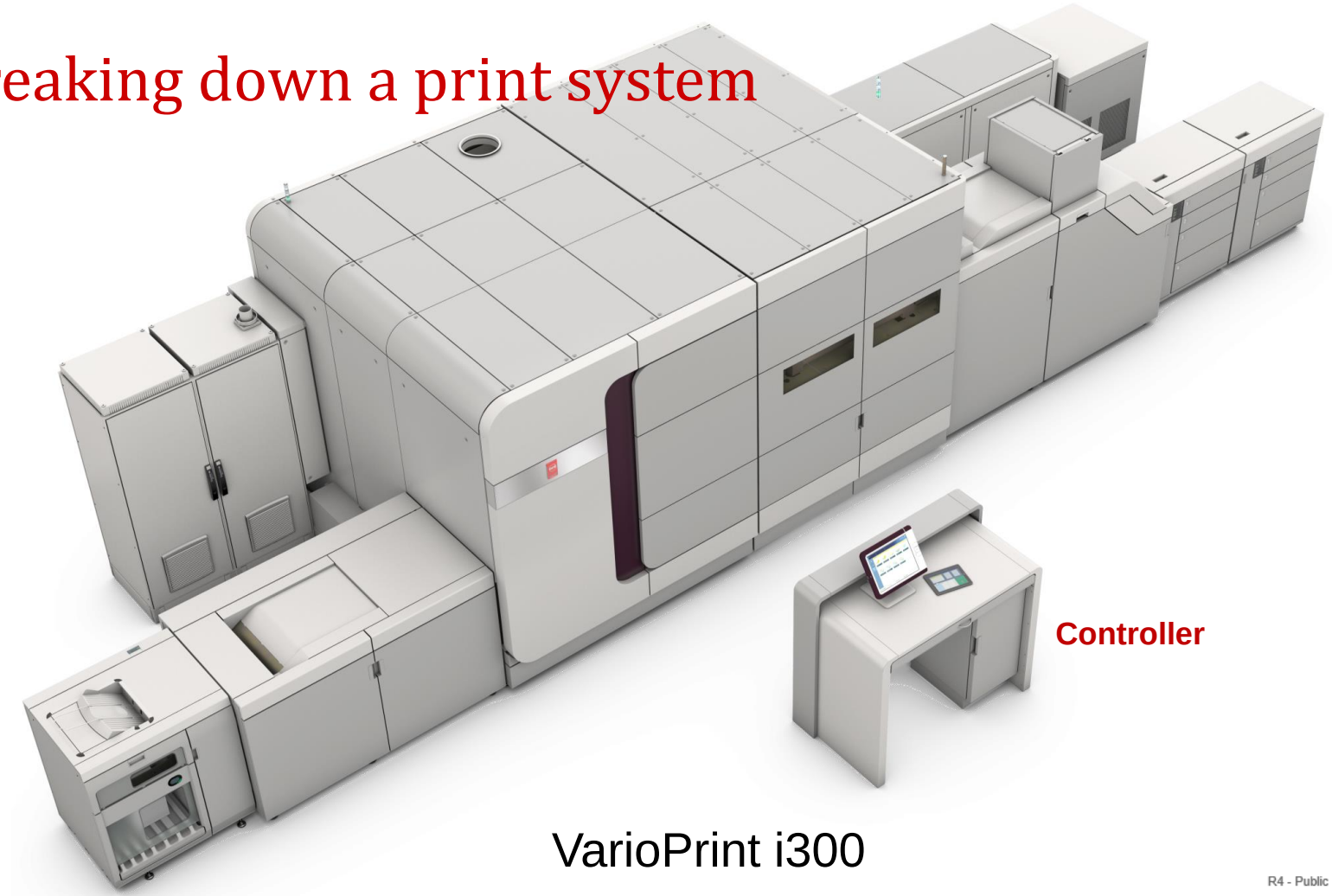
Colorado 1640

Up to **600 banners** per day

VarioPrint i-series

100,000 brochures per day

Breaking down a print system



Engine

Controller

VarioPrint i300

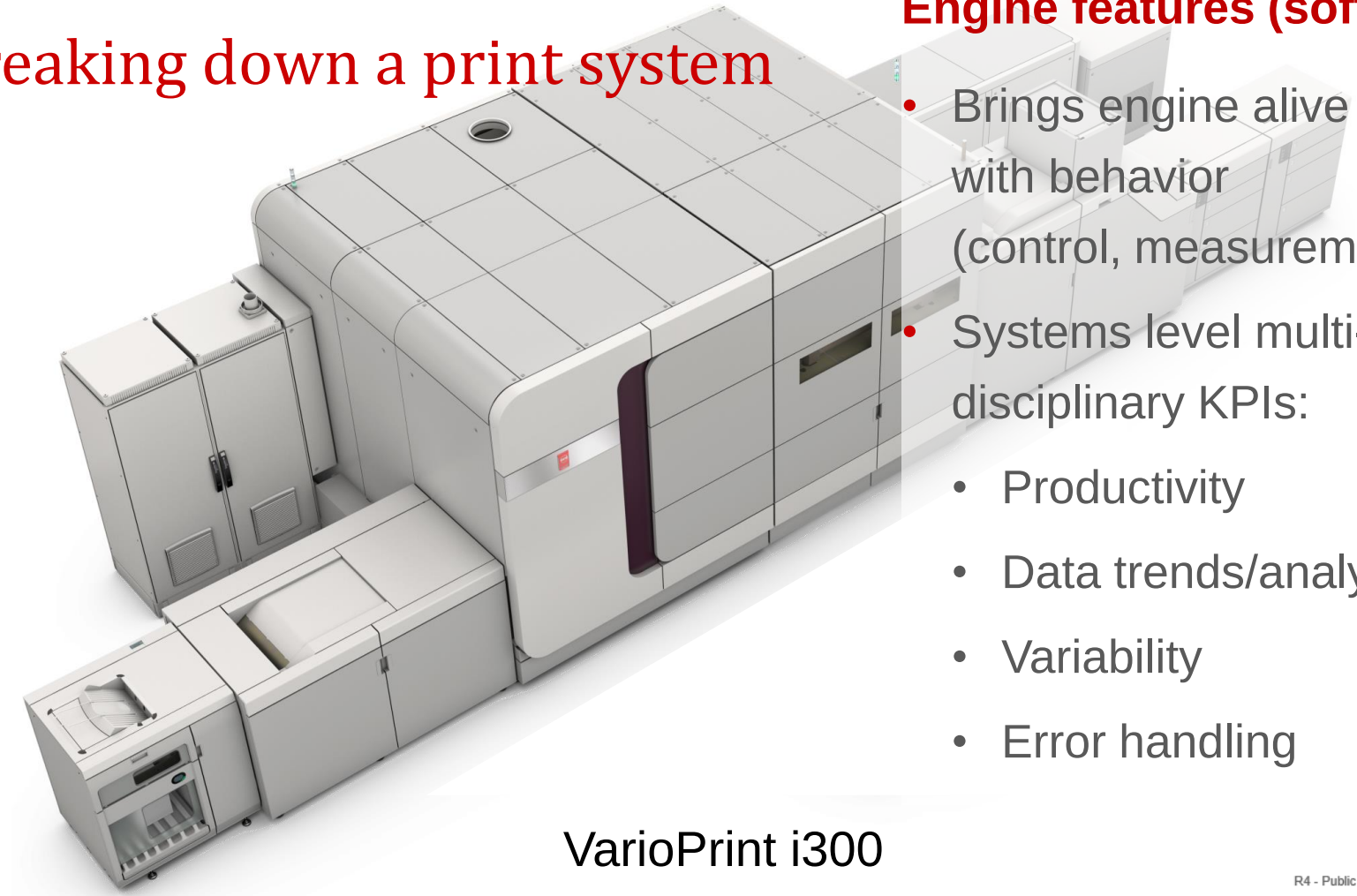
Breaking down a print system

Controller features

- UI
- Job management
- Workflows, planning
- Fleet management
- Color management
- Media management

VarioPrint i300

Breaking down a print system



VarioPrint i300

Engine features (software)

- Brings engine alive with behavior (control, measurement)
- Systems level multi-disciplinary KPIs:
  - Productivity
  - Data trends/analysis
  - Variability
  - Error handling

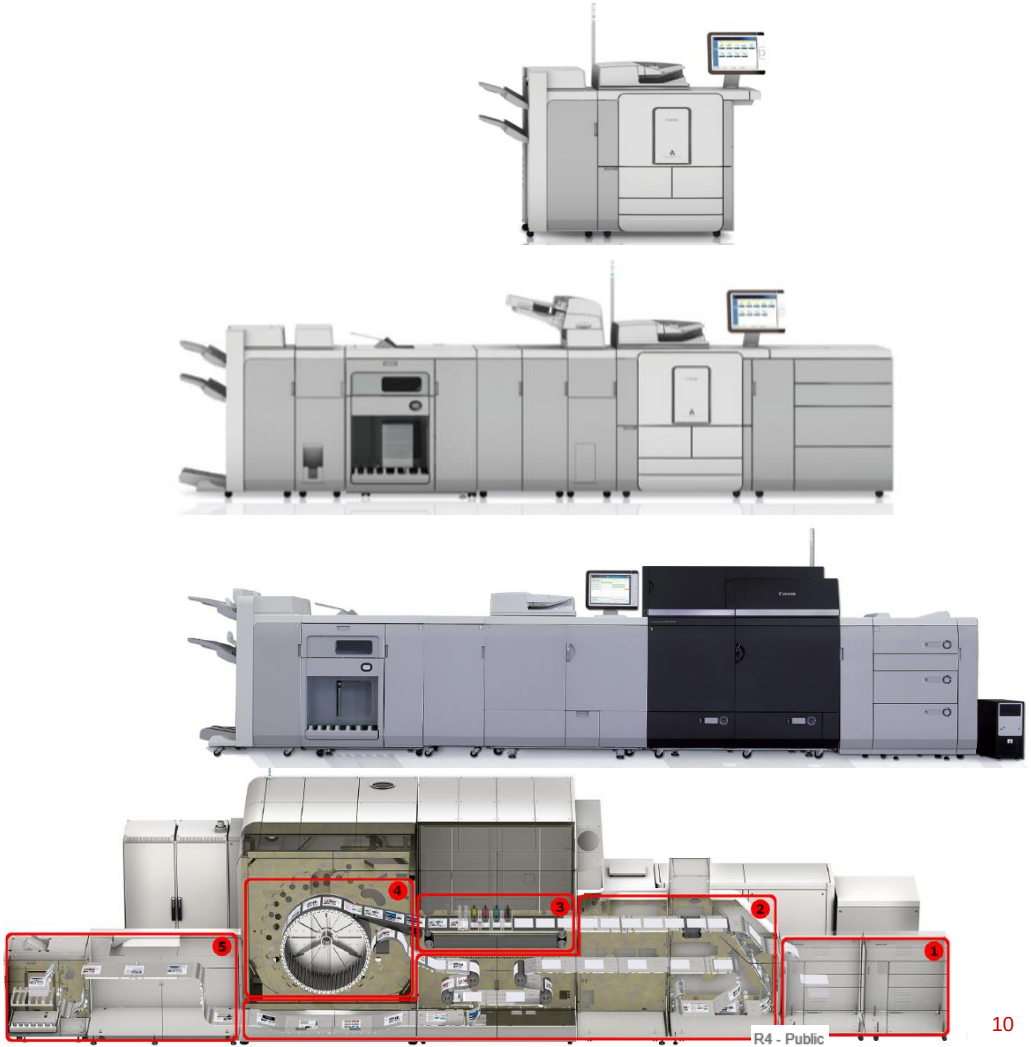
Variability

Same engine, different configuration (input and finishing/output)

Comparable configuration, different engines

Variability within the engine:

1. Paper input module
2. Paper transport module
3. Print module
4. Fixation module
5. Finishing equipment



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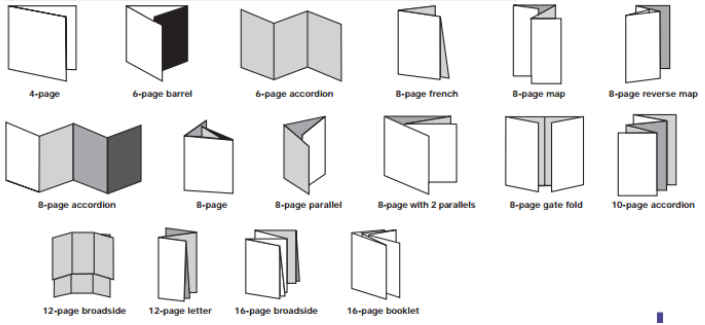
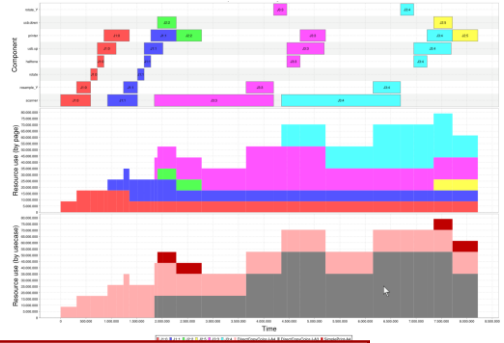
model-based development is of strategic importance to realize continuous improvement ambition

Model Based Development examples

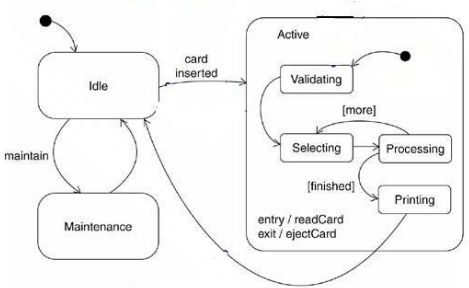
Impositions
(Finishing vs Applications)



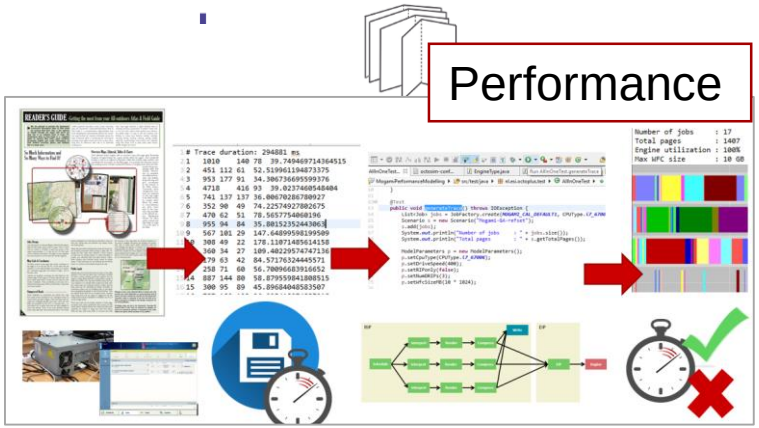


Integral productivity
(job, SW, HW, operator behavior, floor plan)

- Interface specifications
- System capabilities
- Features



State Machines
(Component & Interface)

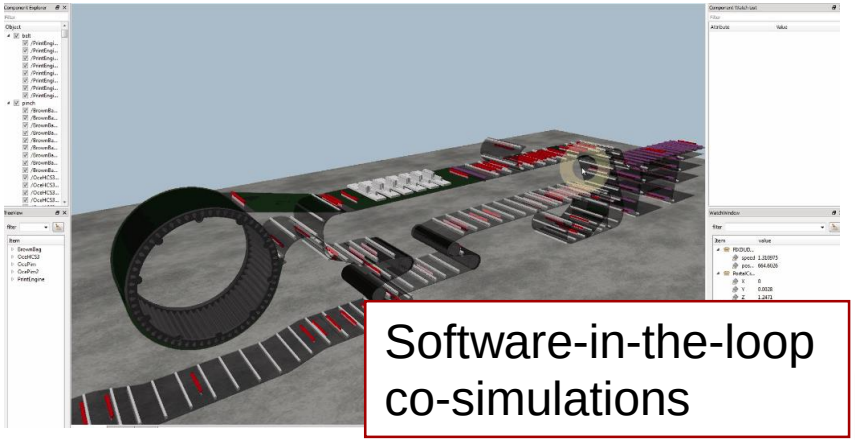


Performance

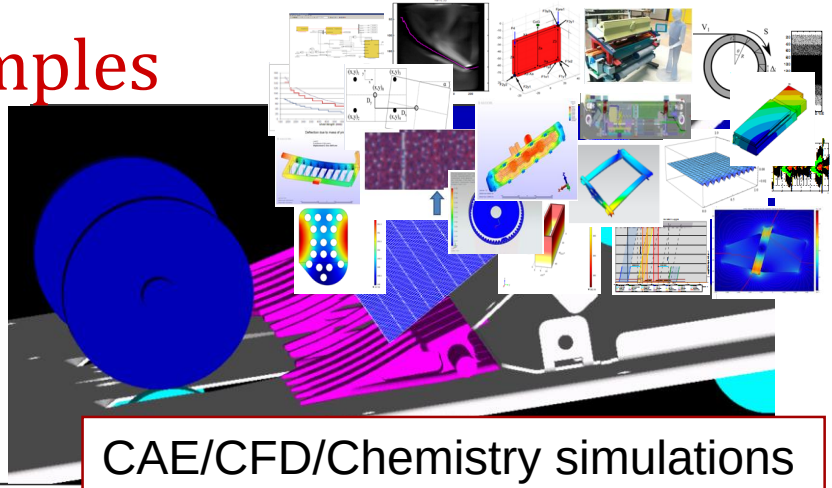
```
<?xml version="1.0" encoding="UTF-8"?>
<report>
    <toc>
        <tocitem chapter="c1"/>
        <tocitem chapter="c2"/>
    </toc>
    <chapter id="c1" title="Summary">
        <sentence>This report describes the core concepts of XML, how to deploy it and
            its capabilities</sentence>
        <sentence>... </sentence>
    </chapter>
    <chapter id="c2" title="Description">
        <sentence> eXtensible Markup Language (XML) is a language subset of the Standard
        Generalized  Markup Language (SGML). SGML is a meta language, therefore, a </sentence>
        <sentence ref="something">... </sentence>
    </chapter>
</report>
```

R4 - Public

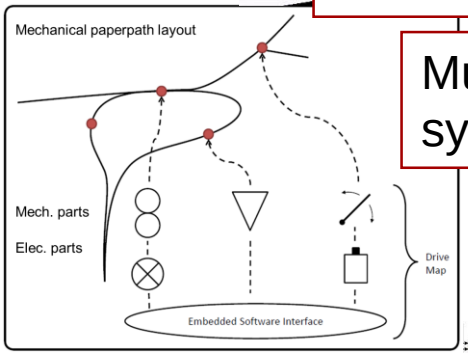
Model Based Development examples



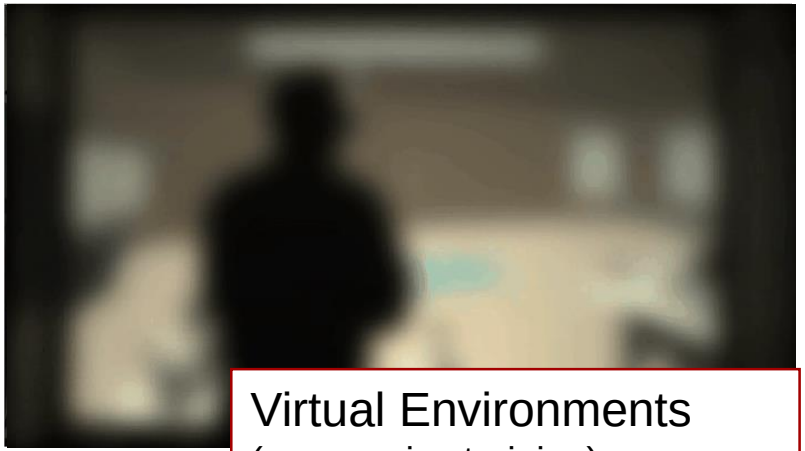
Software-in-the-loop co-simulations



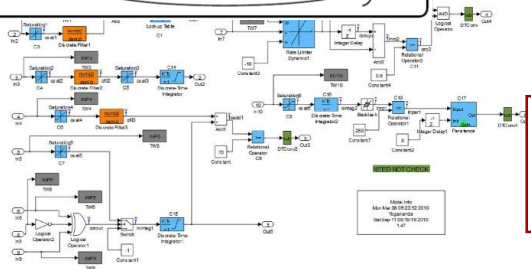
CAE/CFD/Chemistry simulations



Multi-disciplinary system models



Virtual Environments
(e.g. service training)



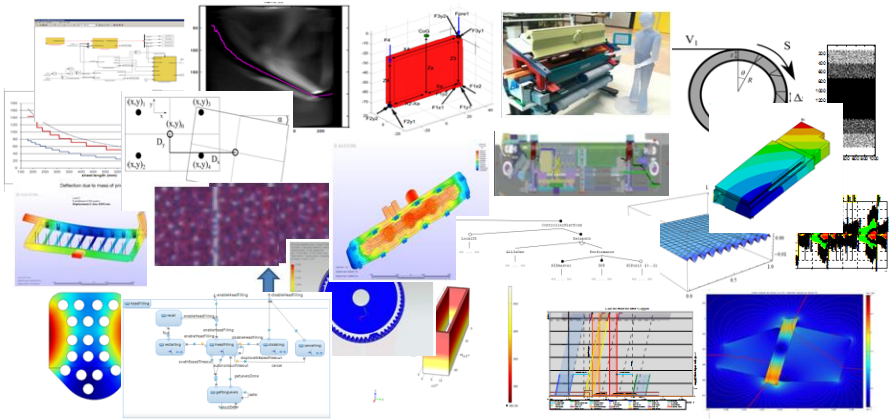
Model-based control

model-based development is of strategic importance to realize continuous improvement ambition

we don’t make software,
we make models!

Replacing Documents by Models → Modelling Isles

- During development, lot of knowledge captured in many different models



Modelling Isles

Variety in languages, models & tools

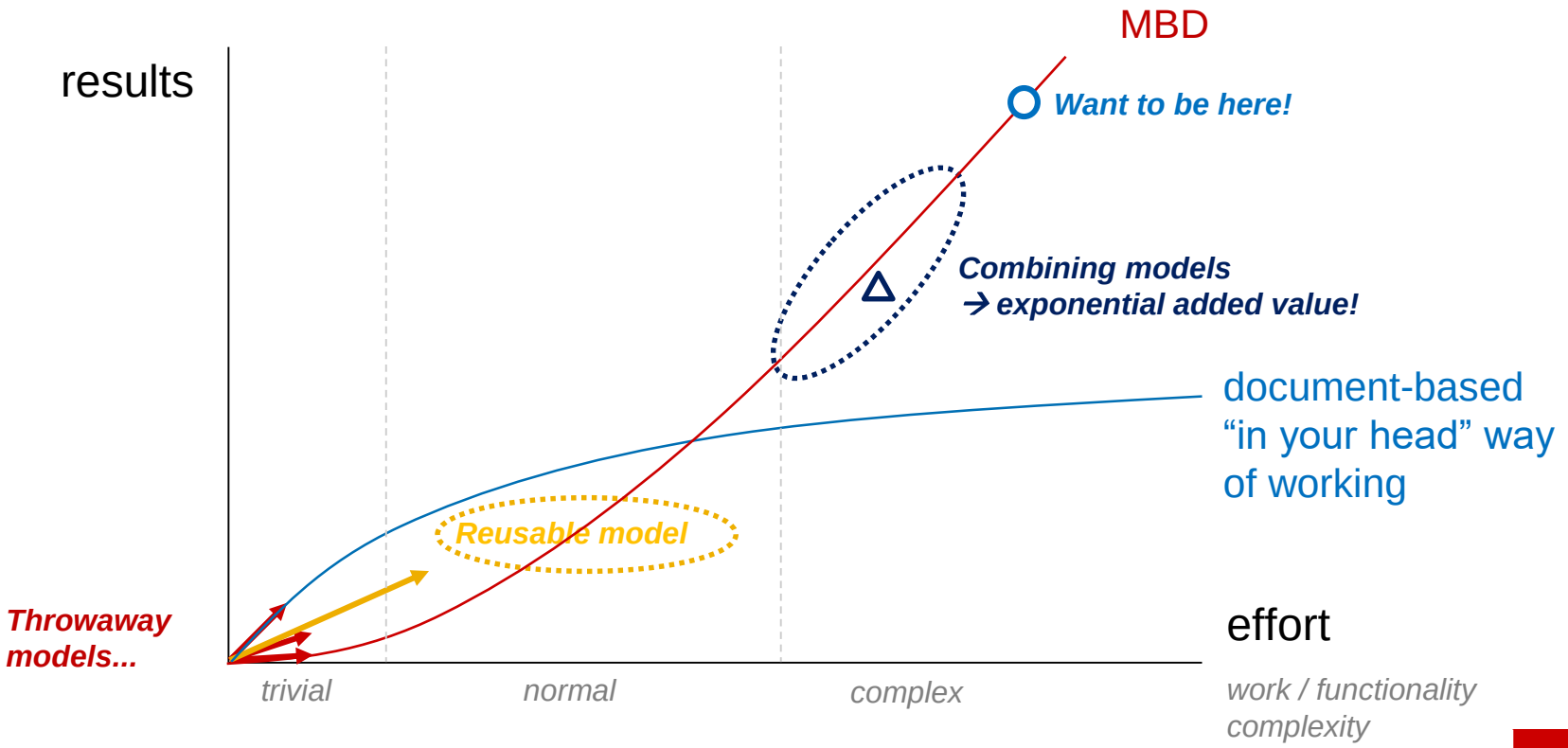
Variety in purposes

- Knowledge comes together in physical (prototype) implementations

model-based development is of strategic importance to realize continuous improvement ambition

we (R&D) don’t make documents/machines,
we make models (i.e. production specs)!

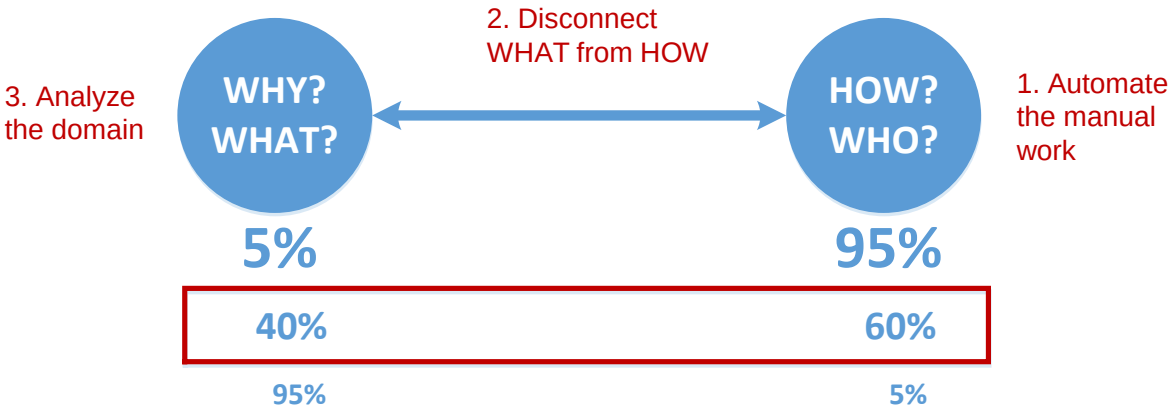
Isles → Maintainable & reusable modeling



There are already a lot of MBD success stories

and it is not enough!

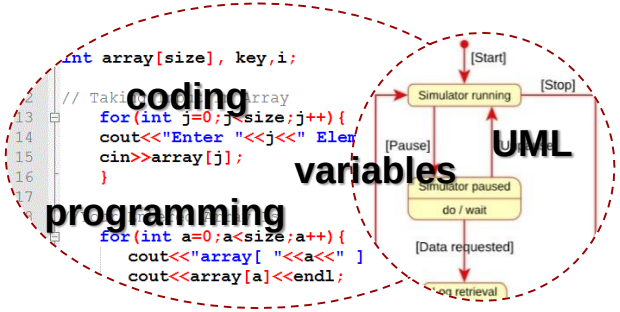
“faster, better, cheaper”



But we need more...

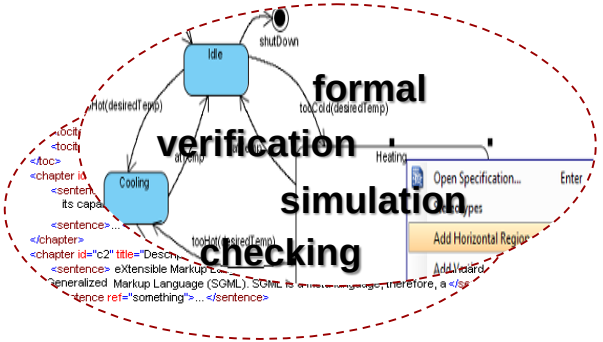
Many times a bit = a lot!

- Instead of being too specialistic...
  (e.g. solving complex problems in an optimal way that affect only a few people on the floor)
- Focus on issues that affect everyone.



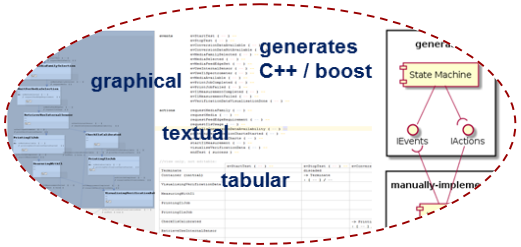
Everyone understands that

?



Too far away

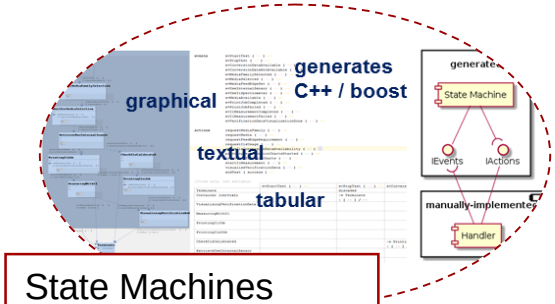
supports the current way of working



Make the modeling users into developers

- Instead of being too narrow...
  (e.g. just a selected group of people is able and willing to do it)
- They come with improvements and new ideas

Supports the current way of working



model simulation

test generation

support other languages

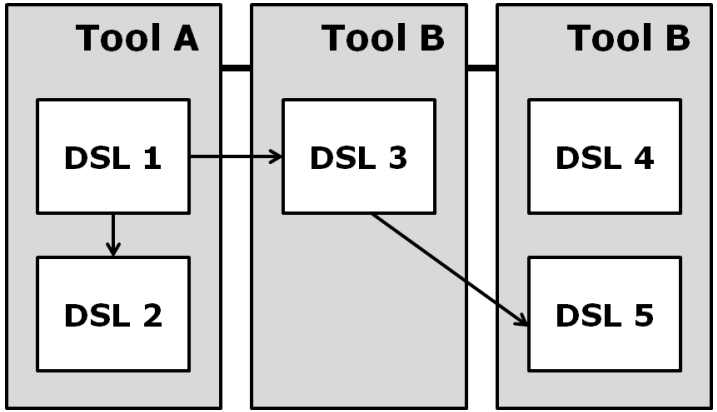
...

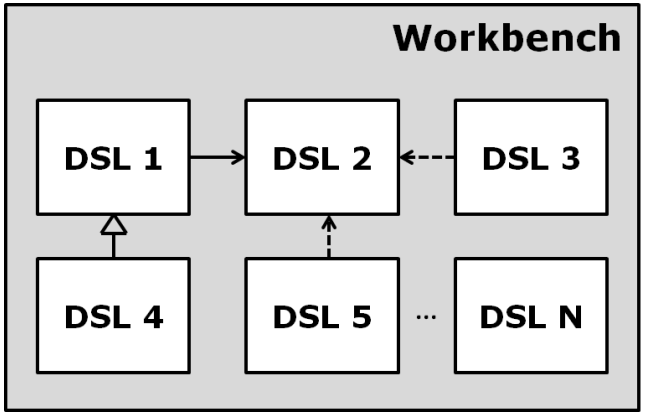
model interfaces

capabilities

Next steps in modeling

- “Modeling islands” established
- Challenge to scale up modeling, make it “boring”:
  - Accessibility of models & tools for “everyone”
  - Proper interfacing and lifecycle management of models
  - Connecting models leads to exponential value

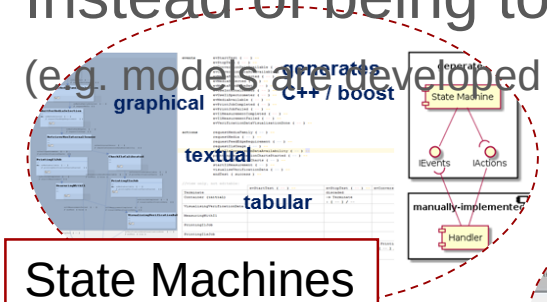




Example: Controller Software Modeling

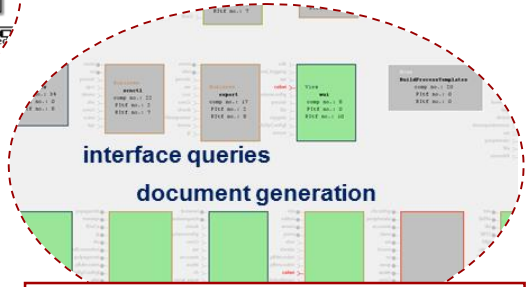
- Instead of being too isolated...

  (e.g. models are developed in isolation)

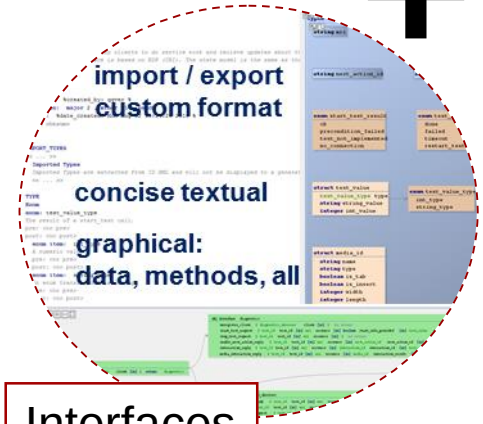


State Machines

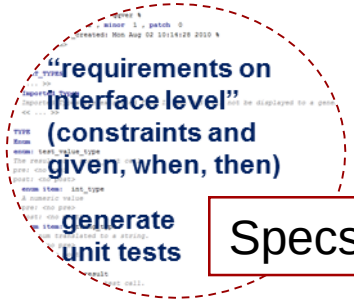
+



Software Architecture



Interfaces



Specs

■ ■ ■

impact analysis

less errors

better quality

consistency

correctness by specification

faster development

separation of concerns

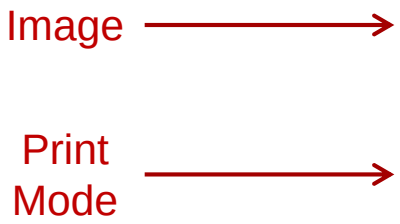
verification

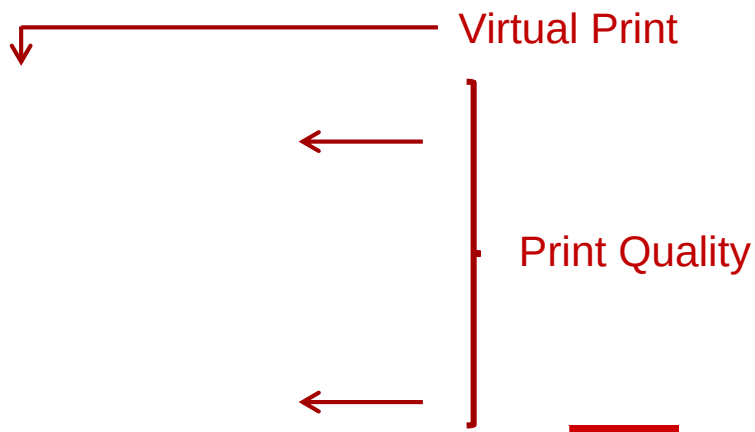
better communication

“faster, better, cheaper”

Example: Engine Specification Modeling

Example: Engine System-simulation





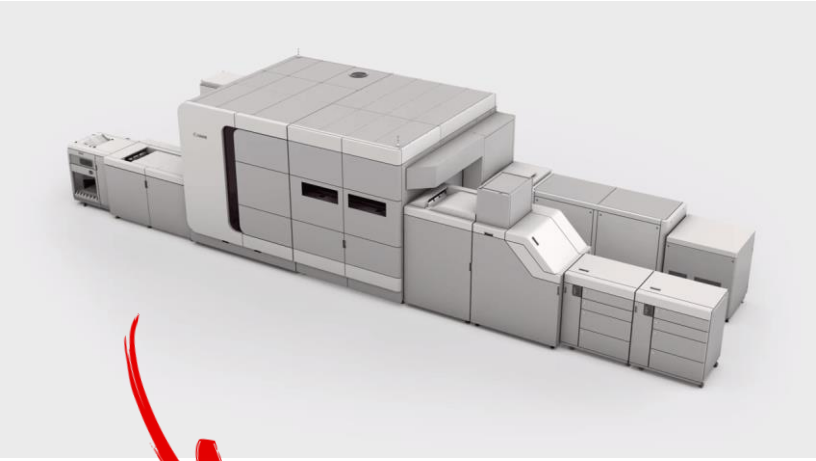
Integration of models for simulation

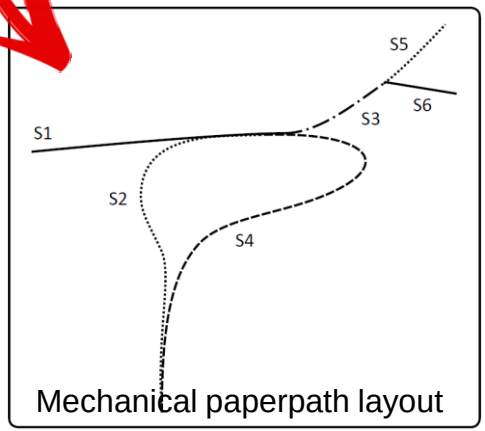
software discipline enables model-based development for all disciplines

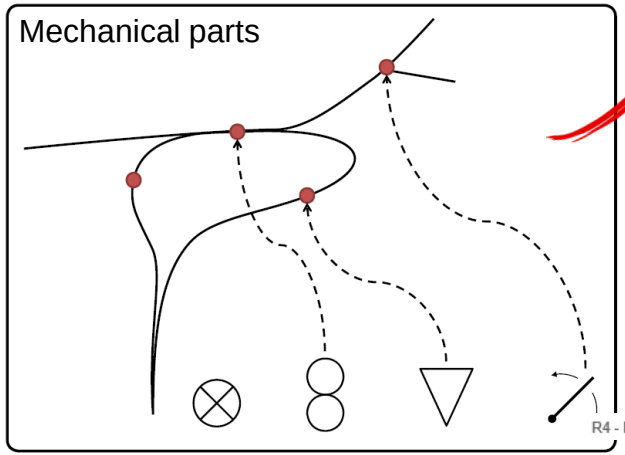
develop your development environment

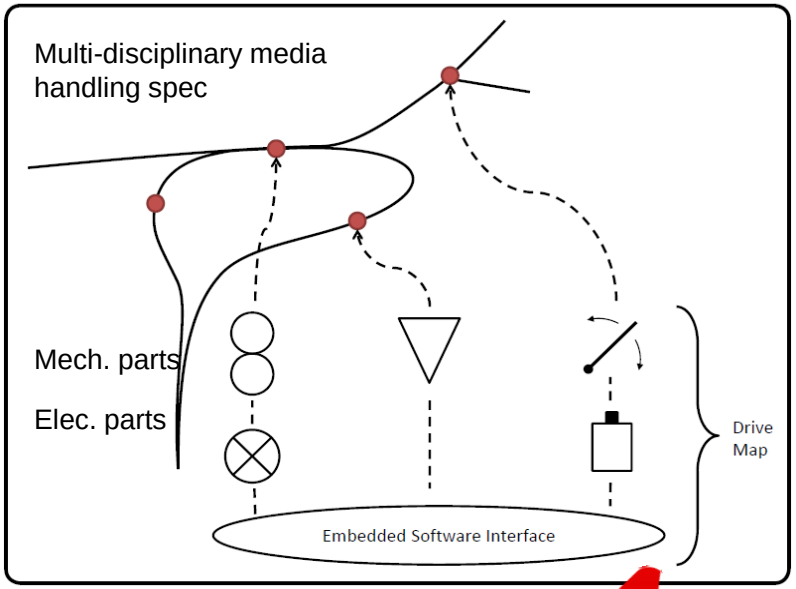
Detailed Example for Engine Specification Modeling

Mechanics/Software interface



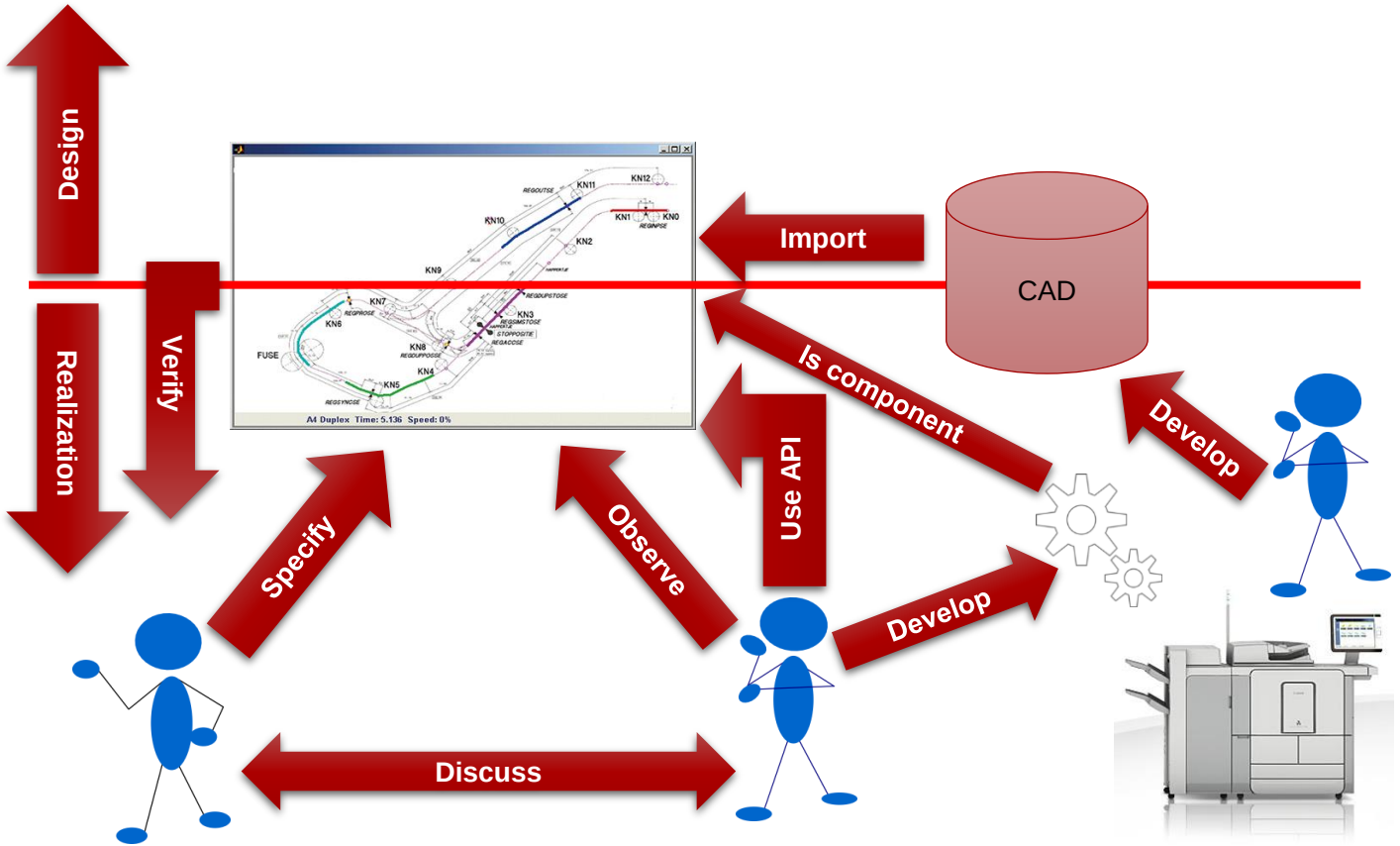




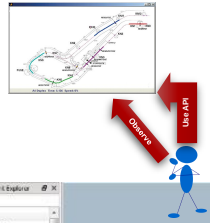


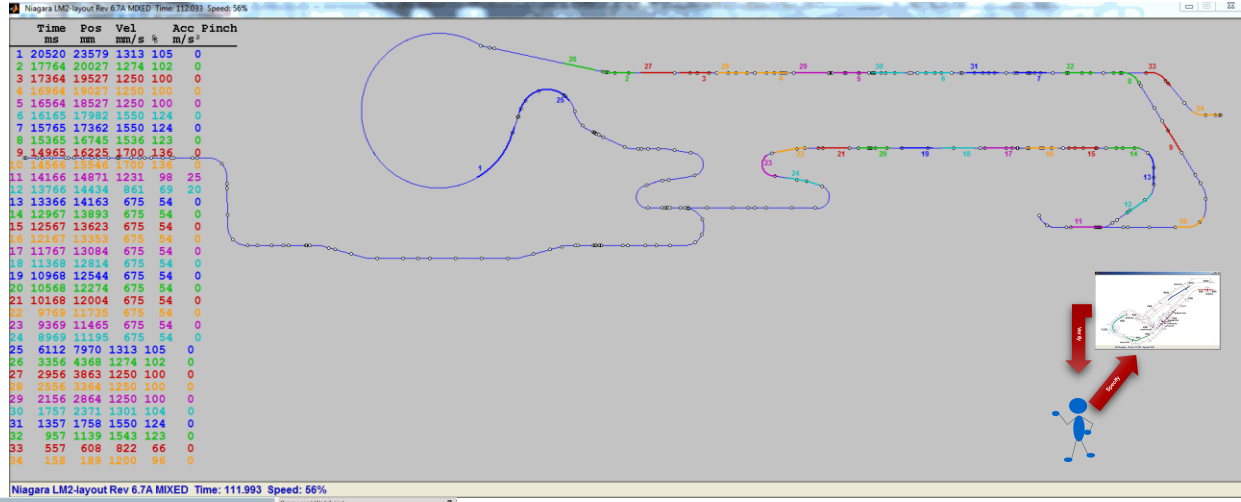
R4 - Public

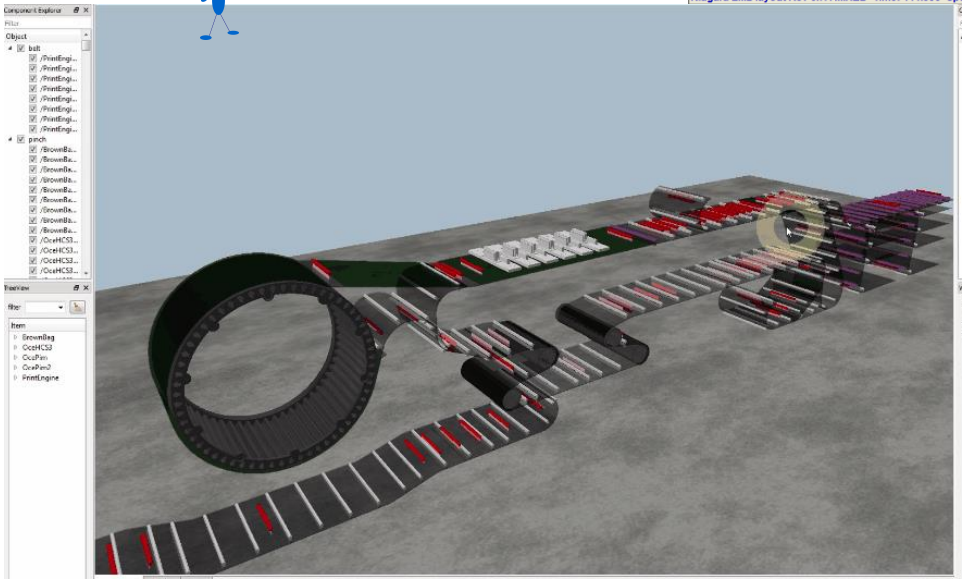
Mechanics/Software interface and media handling

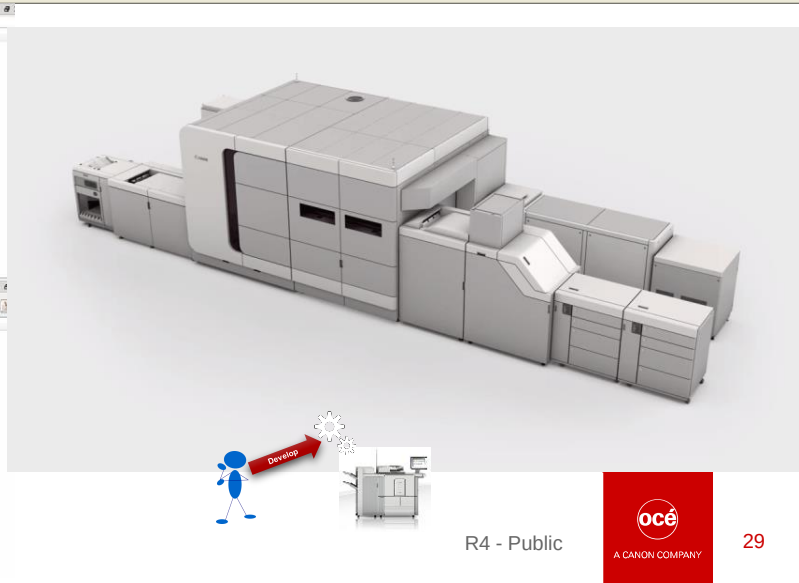


What's it for?

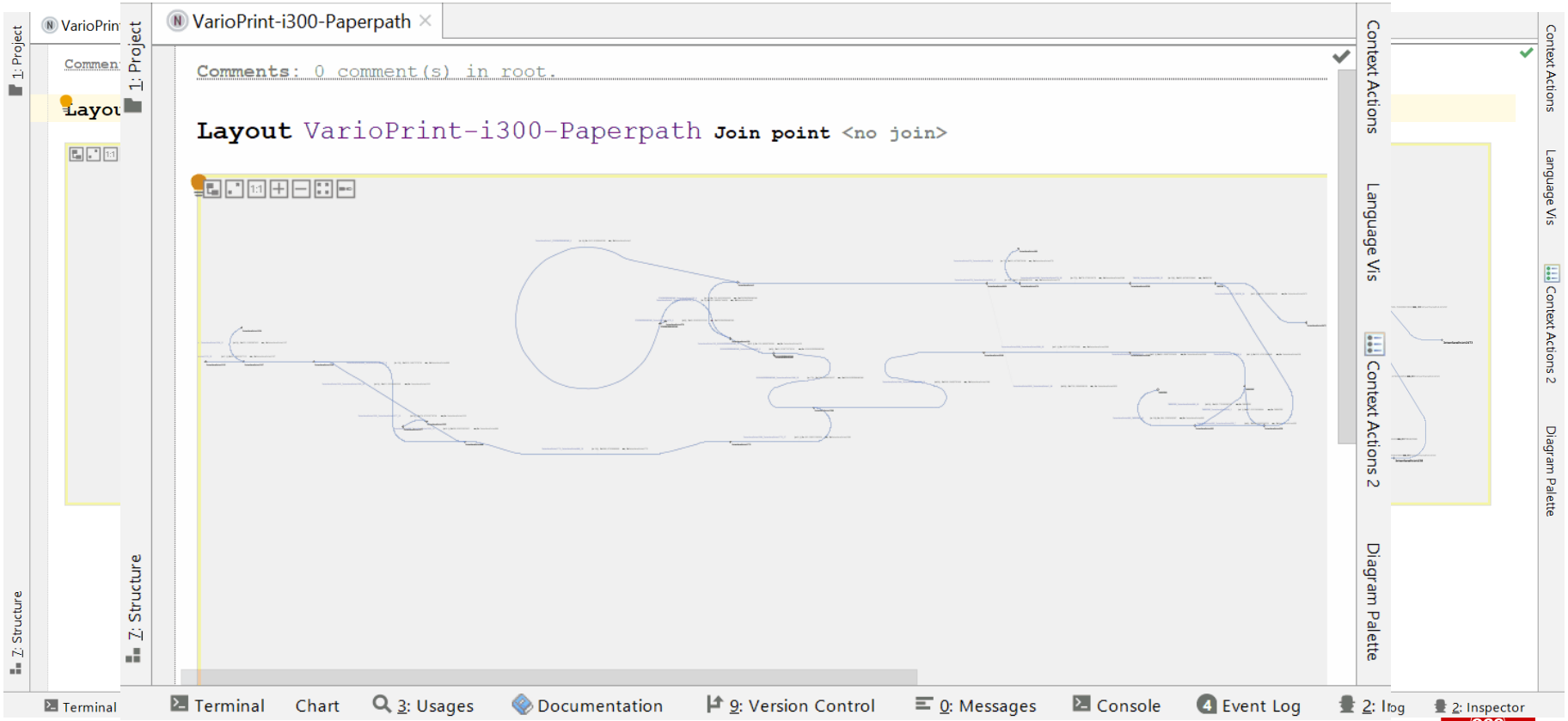

Observe
Use API


Time Pos Vel Acc Pinch
ms mm mm/s % m/s² Pinch
1 20520 23579 1313 105 0
2 17764 20027 1274 102 0
3 17364 19527 1250 100 0
4 16964 19027 1250 100 0
5 16564 18527 1250 100 0
6 16165 17982 1550 124 0
7 15765 17362 1550 124 0
8 15365 16745 1536 123 0
9 14965 16225 1700 136 0
10 14565 15640 1700 136 0
11 14166 14871 1231 98 25
12 13766 14434 861 69 20
13 13366 14163 675 54 0
14 12967 13893 675 54 0
15 12567 13623 675 54 0
16 12167 13353 675 54 0
17 11767 13084 675 54 0
18 11368 12814 675 54 0
19 10968 12544 675 54 0
20 10568 12274 675 54 0
21 10168 12004 675 54 0
22 9769 11735 675 54 0
23 9369 11465 675 54 0
24 8969 11195 675 54 0
25 6112 7970 1313 105 0
26 3356 4368 1274 102 0
27 2956 3863 1250 100 0
28 2556 3364 1250 100 0
29 2156 2864 1250 100 0
30 1757 2371 1301 104 0
31 1357 1758 1550 124 0
32 957 1139 1543 123 0
33 557 608 822 66 0
34 158 189 1200 96 0
Niagara LM2-layout Rev 6.7A MIXED Time: 111.993 Speed: 56%




Develop

Mechanics/Software interface (layout)



Layout + routes

File Edit View Projection Navigate Code Analyze Build Run Tools VCS Window Help

RouteSpec

```
Routelist RouteSpec for ExamplePaperpath
Routes
  Route Simplex = ( [input - process - output] )
Sectors
  Sector input : | C1, C2 |
  Sector process : | C2 (C3_C2_1), C3, C4 |
  Sector return : | C4, C6, C11, C7, C11, C8, C2 |
  Sector output : | C4, C10 |
Entries
  entry c1 connector : C1
Destinations
  destination c10 connector : C10
First turn point:
Turn point tolerance (amount of extra segment after a turn point)
  0 mm
```

Sector input : | C1, C2 |

ExamplePaperpath

Layout ExamplePaperpath **Join point** <no join>

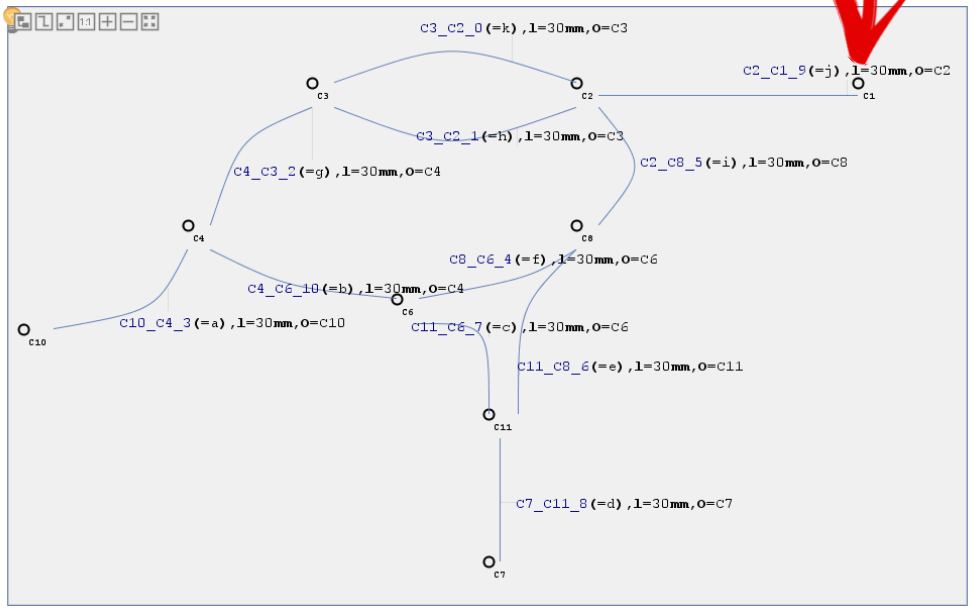


Diagram Palette | Context Actions 2 | Context Actions

1: Project | 7: Structure

Job specifications, media catalog, timing behavior

```
Job Specification Varioprint-i300-Schedule for DL908490Mitsubishi x 70:
  Orient sheet with LongEdgeFirst
  Follow route Duplex
  Adhere to timing behavior Varioprint-i300-TimingBehavior
  Use scheduler MONOTONIC with period 0.9 s ( period random: ☒ , then period is the max. period)
  Use profile recipe: VP-i300-ProfileRecipe
```

```
Timing Behavior Varioprint-i300-TimingBehavior
  /*Transport ( << ... >> )*/
  BeltCrossing ( speed vNom1 = 0 mm/s, speed vNom2 = 0 mm/s )
  XCorrection ( speed vIn = 0 mm/s, speed vCorr = 0 mm/s, speed vOut = 0 mm/s )
  BufferInterweave ( << ... >> )
  Turn ( speed vInitial = 0 mm/s, speed vMax = 1 mm/s )
```

```
Media Catalog MediaCatalog
  A4
    Width: 2100 thenths of mm
    Height: 2970 thenths of mm
    Weight: 80 g/mm²
    Color: White
  DL908490Mitsubishi
    Width: 2100 thenths of mm
    Height: 2970 thenths of mm
    Weight: 90 g/mm²
    Color: White
  MagnoMatt115Sappi
    Width: 2100 thenths of mm
    Height: 2970 thenths of mm
    Weight: 115 g/mm²
    Color: White
```

```
Action Turn ( speed vInitial, speed vMax ) using <choose optional parameter calculation model>
{
  Entered with speed vInitial
  Speed is vMax with LeadingEdge starting at at TMJOIN_InterfacePoint2598_25_SENSHMSRSE - 5 mm
  Stopped with TrailingEdge at InterfacePoint1225_InterfacePoint1365_14_FIXOURUSRPI + 10 mm and waited for 0.03 s
  Flip Edges
  Accelerated to speed vMax
  Speed is vInitial with LeadingEdge starting at at SCOOLSCEUERRORFLAP_InterfacePoint1588_16_SCOOLSCUPI1 mm during 0 s
}
```

Why this Position?

23/11/16 02:34 (Nov 23, 2016 (28 months ago)) by eug

KernelF with math notation, unit type tags, interpreter

```
library OceUnits        imports: SIUnits reexport

unit mm := mm for millimeter
conversion m -> mm {
 val as number -> val / 1000
}
unit mmps := mm*s^-1 for speed
unit mmps2 := mm*s^-2 for acceleration
```

```
timing behavior VPi300Timing        imports: OceUnits

job: Varioprint-i300-Schedule

transportfunction xportToPrintBelt(velocity: number, velocity2: number, acceleration: number | start: FIXDEXUSXLSE end: FIXHTURSE3)
    {
  val z = BYPPI4 + 50 * √|(velocity^2 - velocity2^2) / (2 * acceleration)|
  accelerate ( vStart: z vEnd: 200 mmps acc: 10 mmps2 t: 20 s s: 22 mm ): get sheet to printing speed
}
transportfunction xportToCooling( | start: POMIN - 1 end: POMOUT + 10) {
  xportToPrintBelt (10, 20, 30)
```

R4 - Public

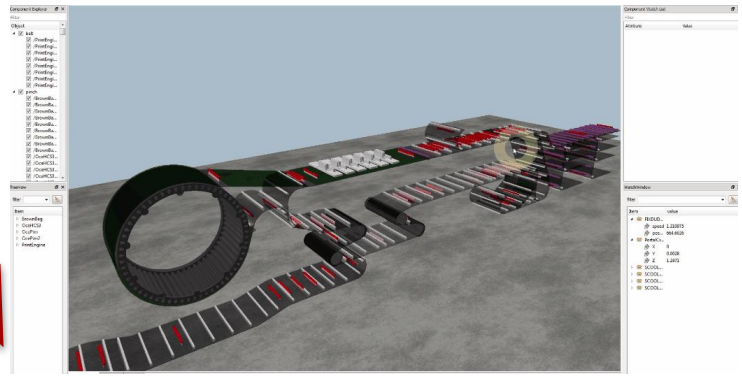
```
Job Specification Varioprint-i300-Schedule for DL908490Mitsubishi x 70:
  Orient sheet with LongEdgeFirst
  Follow route Duplex
  Adhere to timing behavior Varioprint-i300-TimingBehavior
  Use scheduler MONOTONIC with period 0.9 s ( period random: ⊡ , then period is the max. period)
  Use profile recipe: VP-i300-ProfileRecipe
```

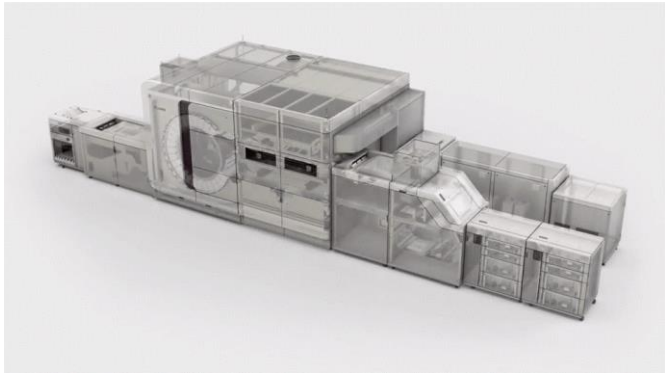
```
double decelerationDistance(double vNew, double vOld, double a) {
  return | (vNew^2 - vOld^2) / (2 * a) |;
} decelerationDistance (function)
```

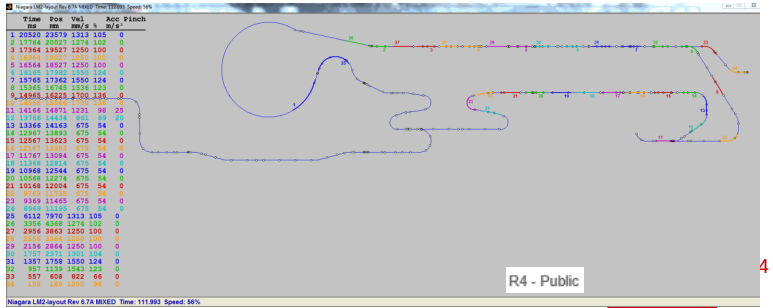
```
Action Turn ( speed vInitial, speed vMax ) using <choose optional parameter calculation model>
{
  Entered with speed vInitial
  Speed is vMax with LeadingEdge starting at at InterfacePoint1107_InterfacePoint1115_10_POMEBUSXLSE
  Stopped with TrailingEdge at InterfacePoint1225_InterfacePoint1365_14_FIXOURUSRPI + 10 mm and waite
  Flip Edges
  Accelerated to speed vMax
  Speed is vInitial with LeadingEdge starting at at InterfacePoint1107_InterfacePoint1115_10_POMEBUSXL
}
  FIXDEXUERRORFLAP_InterfacePoint156_4_FIXDEXUPI1(=7580.081924438477)
```

```
Routelist RouteSpec for ExamplePaperpath
  routes
    Route Simplex = ( [input - process - output] )
  Sectors
    Sector input : | C1, C2 |
    Sector process : | C2 (C3_C2_1), C3, C4 |
    Sector return : | C4, C6, C11, C7, C11, C8, C2 |
    Sector output : | C4, C10 |
  Entries
    entry c1 connector : C1
  Destinations
    destination c10 connector : C10
  First turn point:
  Turn point tolerance (amount of extra segment after a turn point)
    0 mm
```

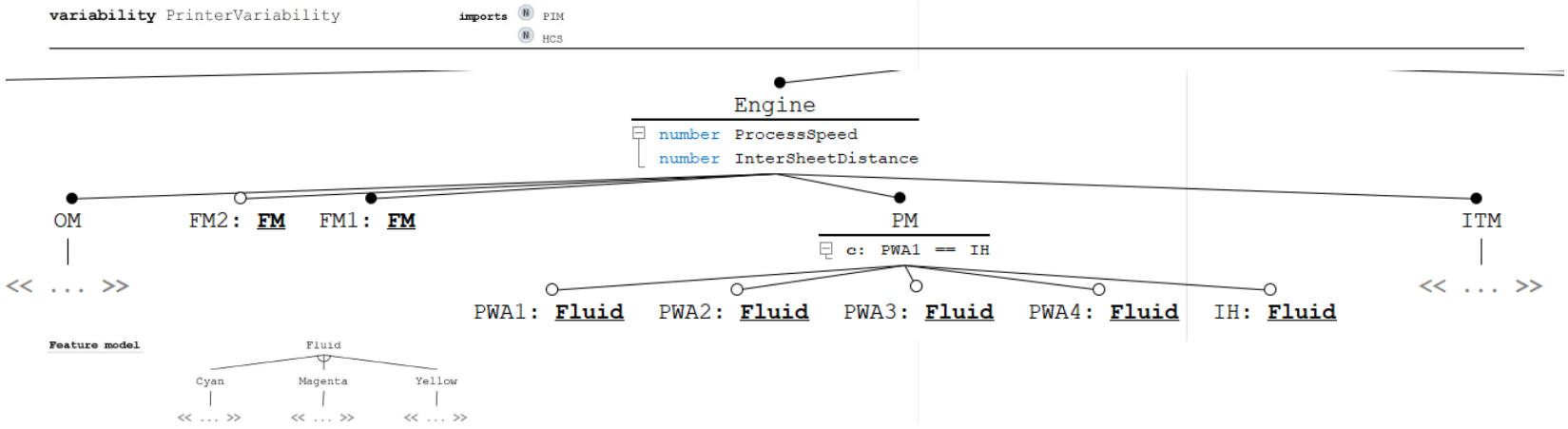
Timing DSLs

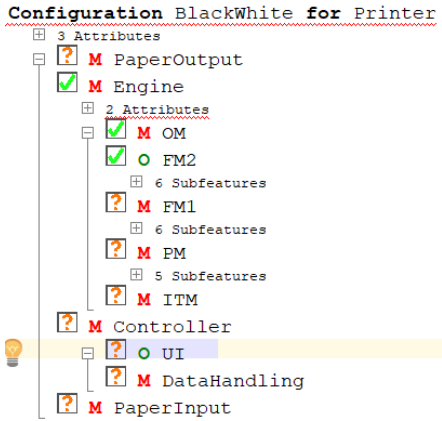






Variant management



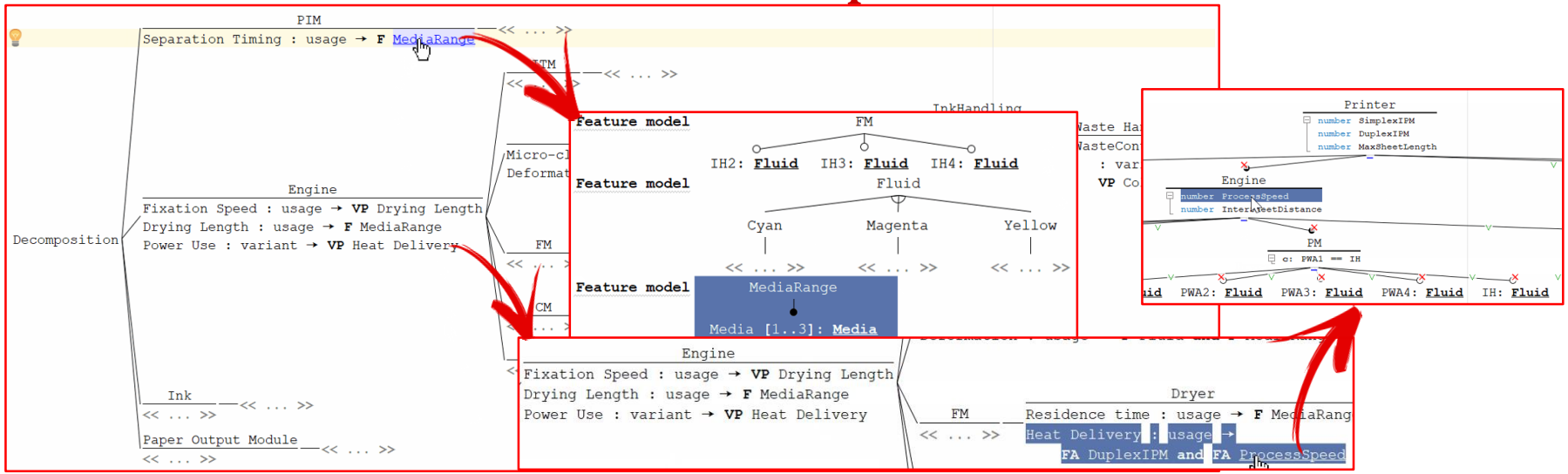


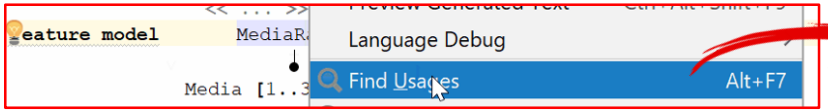
Variants & modular design

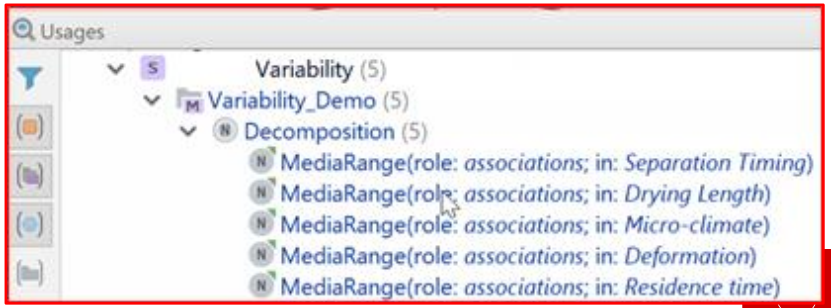
Layout Module Mod1
Join point <no join>

Layout Module Mod2
Join point <no join>

Variants & functional decomposition







Variants & cost price

PrinterProductLine | PrinterConfigurations | Parts | PM | ITM | FM

Part List Parts

	Name	Type	Code Number	Cost	Currency	Minimum Quantity	Nr of Circuits	Nr of Wires
1	Optical sensor	Sensor	133773311	10	USD	250	1	3
2	Temperature sensor	Sensor	133773312	5	USD	0	1	2
3	Pressure sensor	Sensor	133773313	100	USD	28	1	6
4	Distance sensor	Sensor	133773314	80	USD	0	1	0
5	Solenoid	Actuator	133773315	5	USD	0	1	2
6	Stepper motor	Actuator	133773316	10	USD	3480	1	4
7	BLDC motor A	Actuator	133773317	25	USD	500	1	8
8	BLDC motor B	Actuator	133773318	20	USD	5	1	8
9	BLDC motor C	Actuator	133773319	50	USD	10	1	8
10	Heater	Actuator	133773310	15	USD	0	2	10

Challenges

- Model Lifecycle Management, Way of working, and Organization
- Requires (partial) domain-specific interpretation of models

- Cross-disciplinary consistency and model lifecycle management
- Consistent co-evolution
- Instantiation of Virtual/Hybrid Prototypes
- Model Governance
- Automated Abstraction
- Horizontal & Vertical Traceability
- Model-Based Product-Line Test & Accreditation
- Product lines and variants
- Design space exploration
- Functional & System KPI Interactions
- Semantics & Thinking Framework for Model Interoperability & Lifecycle Management
- Usability Challenges
  - Modelling for many roles (engineers, designers, architects)
- Democratization Challenges
  - Teaching, Selling, Attitude, Value Propositions
- Practical (re-)use of simulation results
  - Loading/caching, EDGE, HPC
- Analysis of System KPIs
  - Formal analysis, simulation, test
- Parameter Extraction
  - Simulations/Experiments Conclusions for Higher-Abstraction Calculations/Simulations
- Domain modelling
  - Analysis, method, process
- Model-based development process
  - When to use what models for which purpose?
- Requirements modelling
  - Focus on ‘What’ not on ‘How’
- Design rationale tracking
- Connecting Models with Data-Science and (Machine) Learning
  - (Domain) Models for Rich Interpretation of Data
- Model life-cycle management as link between requirements, virtual prototyping and multi-disciplinary verification / validation / test
- Structural Organizational Embedding
  - Bottom-up: Unobtrusive, Effective, and Scalable Tools
  - Top-down: Structure, Shared Values, Skills, Staff, Style

Conclusions

- Océ is heavily applying MBD: we don’t make software, we make models!
- Complex, holistic field: many open challenges still exist
- Complete (commercial/open source) solutions are not available
- Research is direly needed

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