

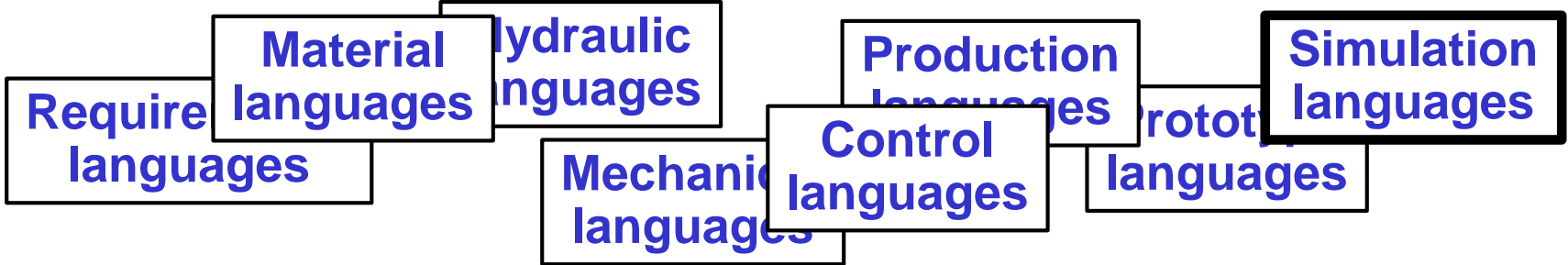
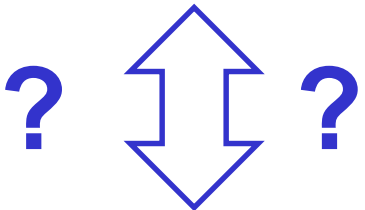
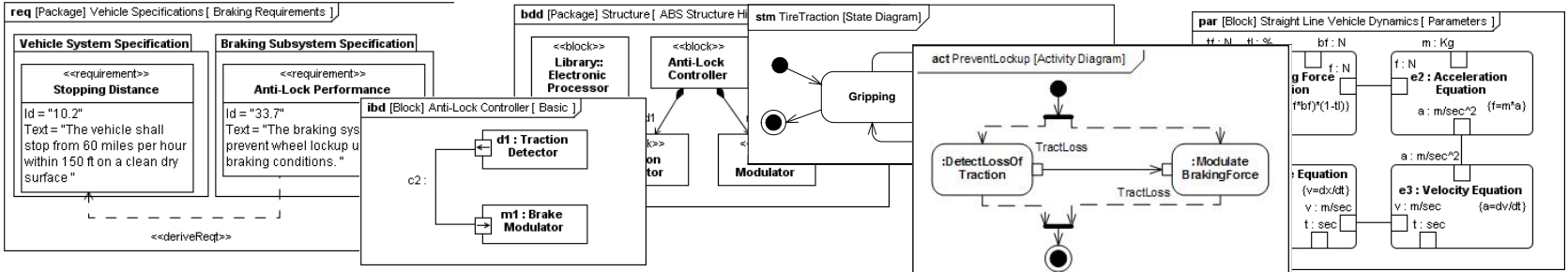
# Platform-independent Integration of SysML with Physical Interaction and Signal Flow Simulation Tools

**Conrad Bock, NIST**



# Engineering Language Integration

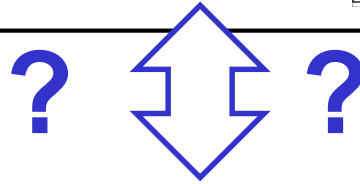
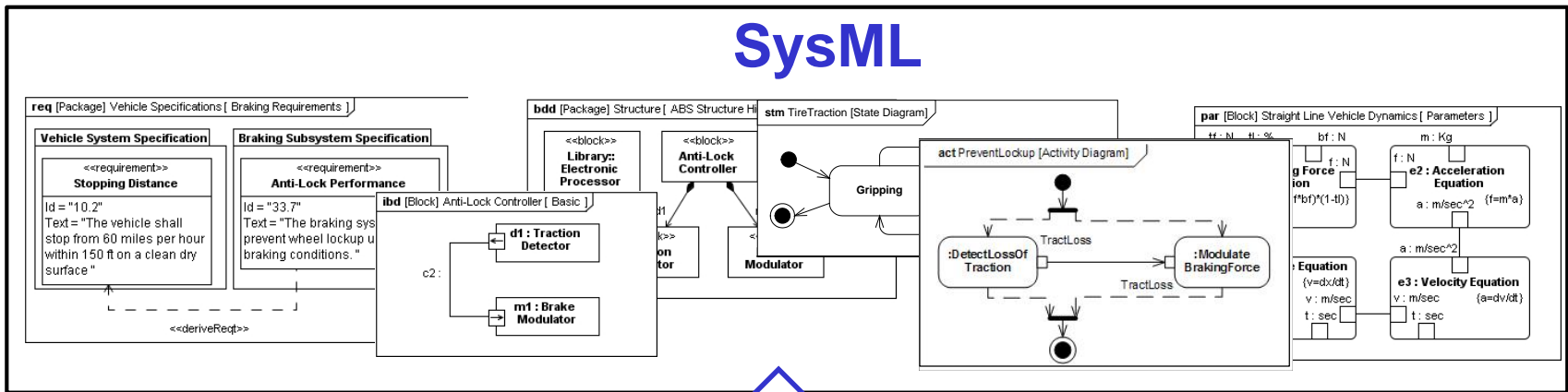
## SysML



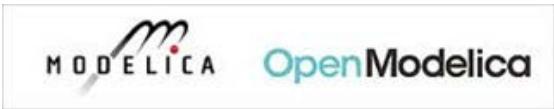
- Overlapping and inconsistent system specifications in multiple languages.

# Physical Interaction and Signal Flow Simulation Language Integration

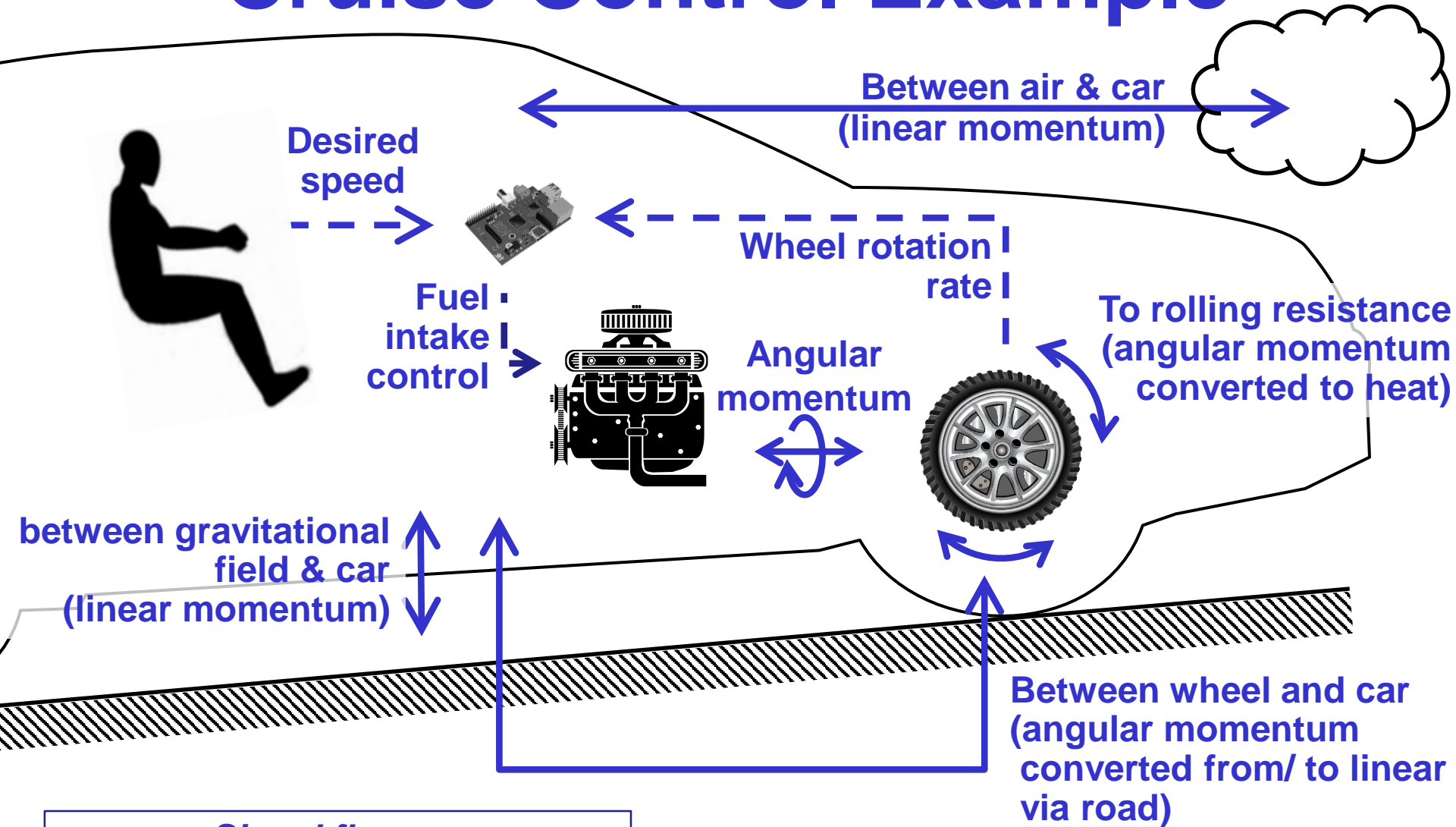
- Covers multiple engineering disciplines.
- Fewer languages involved.



**PI & SF simulation languages & tools**



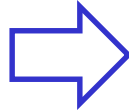
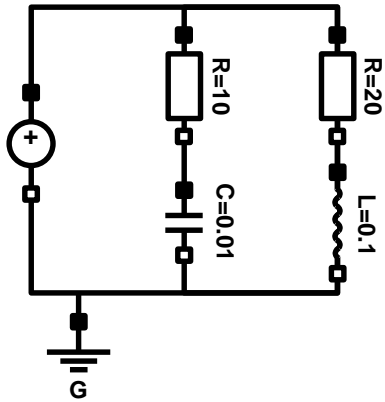
# Cruise Control Example



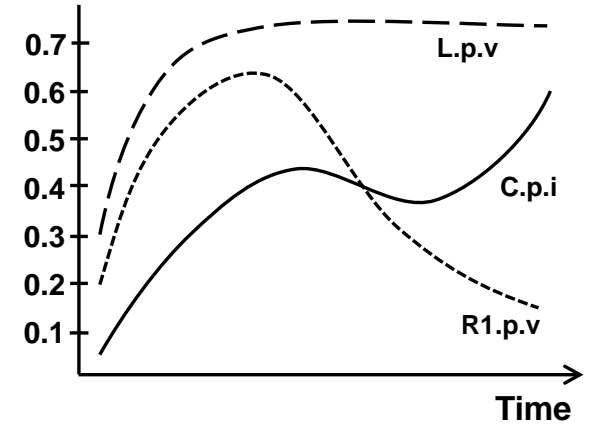
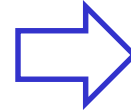
**Signal flow:** - - - - ->  
**Physical interaction:** <- - - - ->

- All flows modeled with rate & potential, regardless of what is flowing.

# PI & SF Simulators



```
rc.R*iThru = rc.vDrop
Ri.R*iThru = ri.vDrop
c.C*der(c.vDrop) = i.iThru
rc.p.i = s.p.i + ri.p.i
rc.p.v = s.p.v
rc.p.v = ri.p.v
i.L*der(i.iThru) = i.vDrop
s.vDrop=220*sin(728*t)
c.n.i = s.n.i + i.n.i
c.n.v = s.n.v
c.n.v = i.n.v
G.p.v=0
```

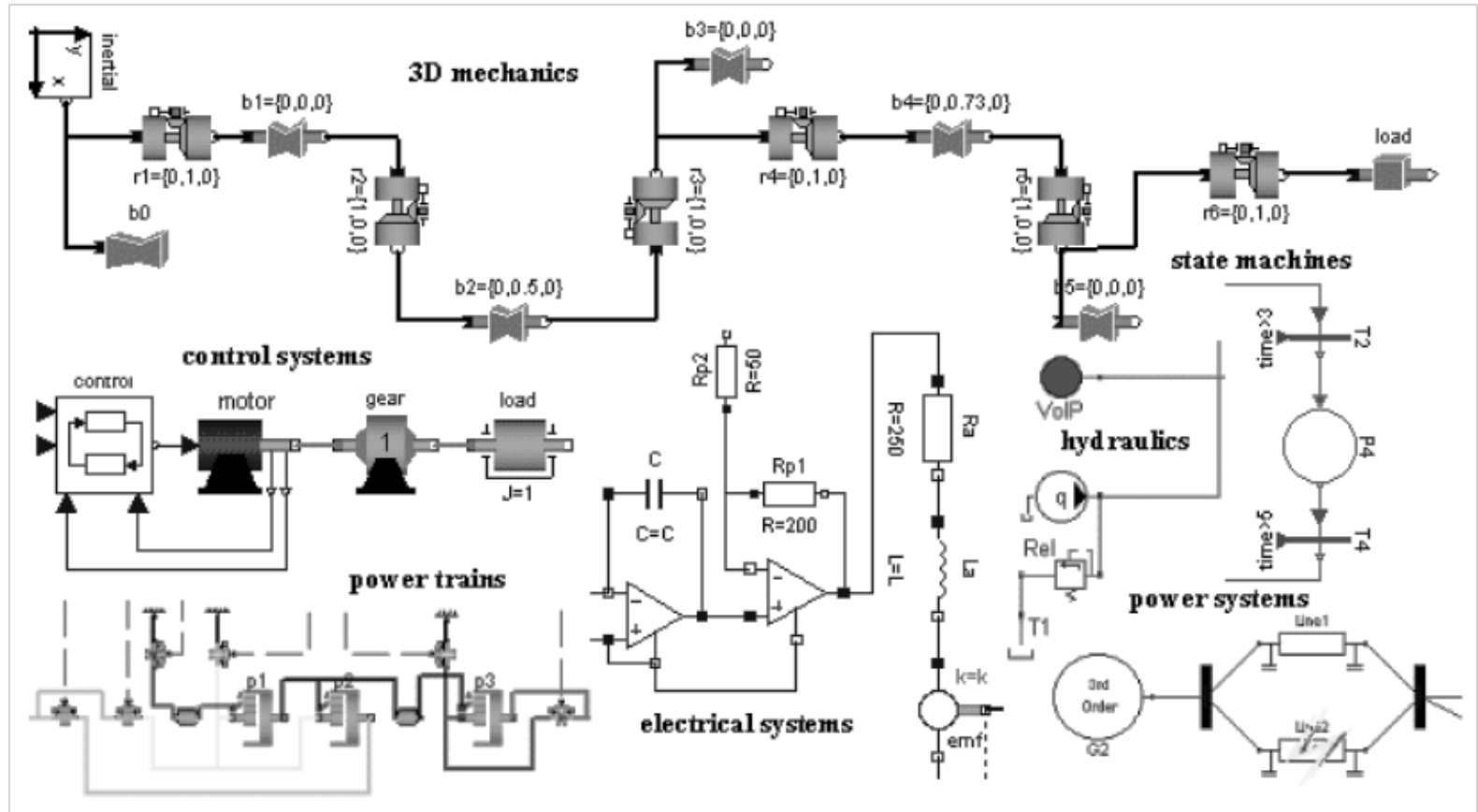


**Engineering  
diagrams**

**Differential  
Equations**

**Numerical  
analysis**

# Support Multiple Engineering Disciplines



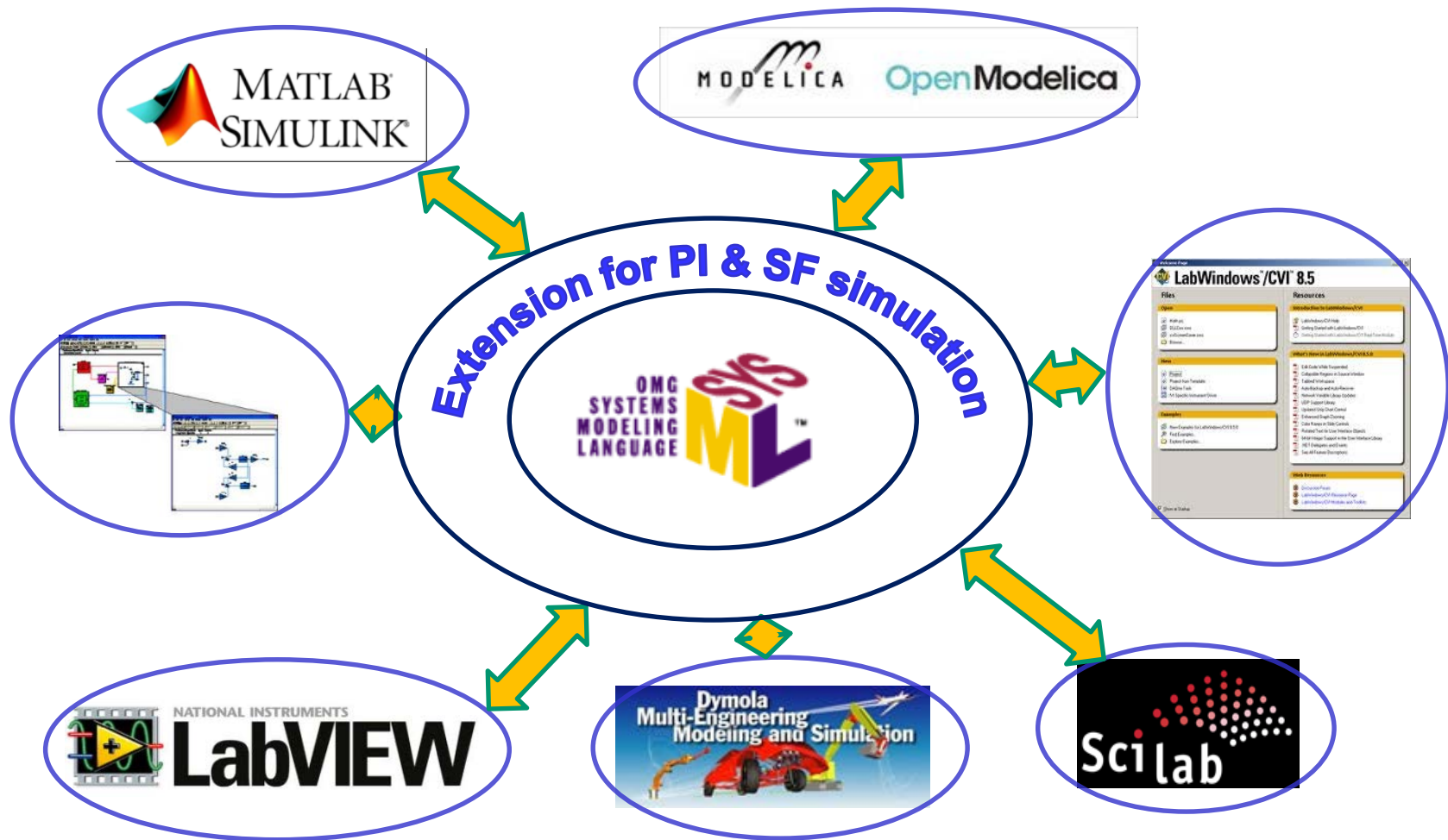
# How? Common Physics

Same laws for  
all domains

Domain	Kind of thing flowing	Flow rate	Potential to flow
Electrical	Charge	Current	Voltage
Mechanics, translational	Momentum	Force	Velocity
Mechanics, angular	Angular momentum	Torque	Angular velocity
Hydraulics	Volume	Volumetric rate	Pressure
Thermal	Entropy	Entropy flow rate	Temperature

Substance flow rate x potential  
= energy flow rate (power)

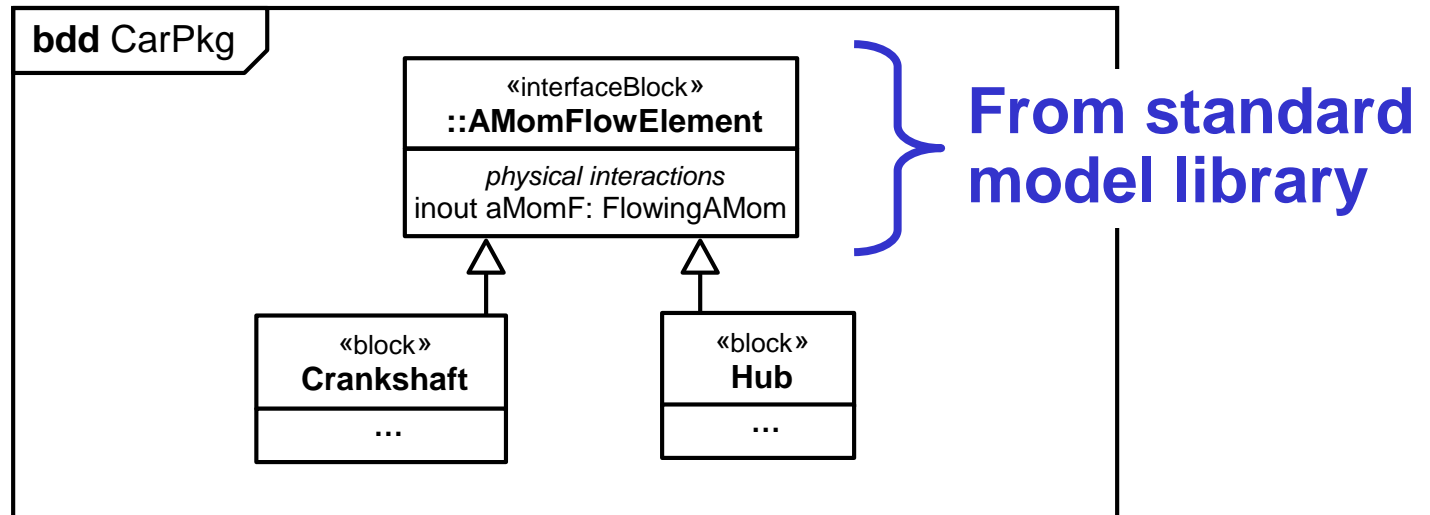
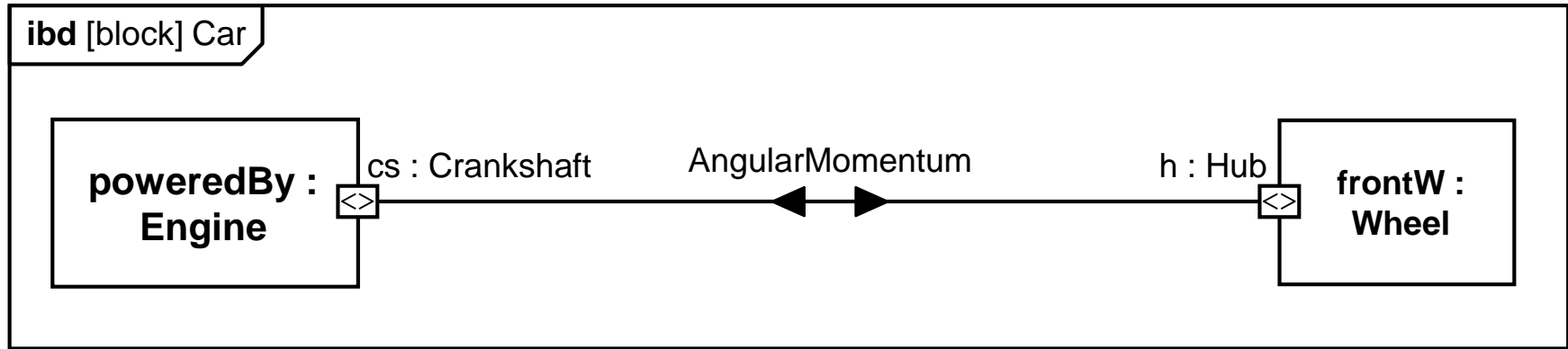
# Reduce Specialized Mappings



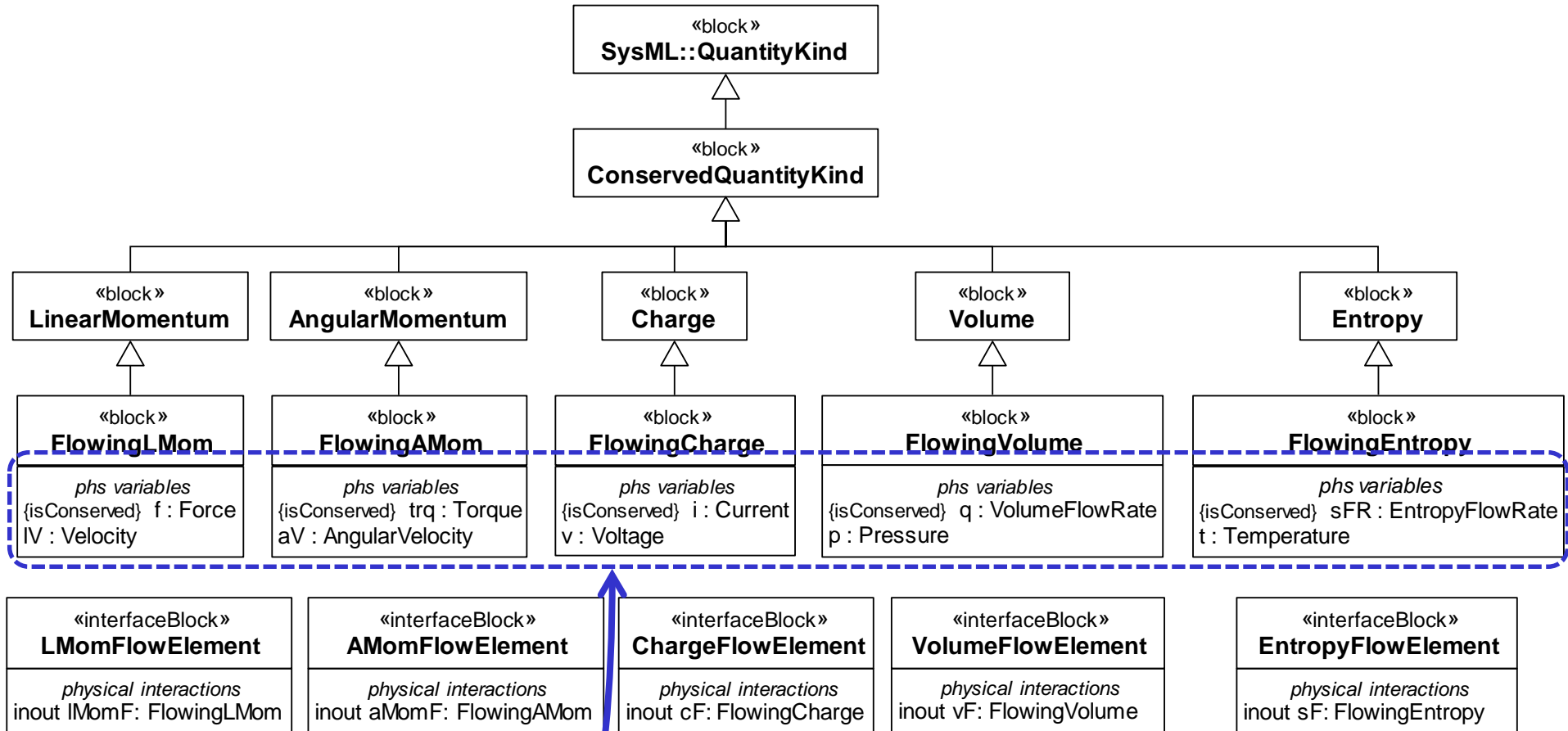
- Extend SysML with a general simulation profile.



# Flow of Angular Momentum

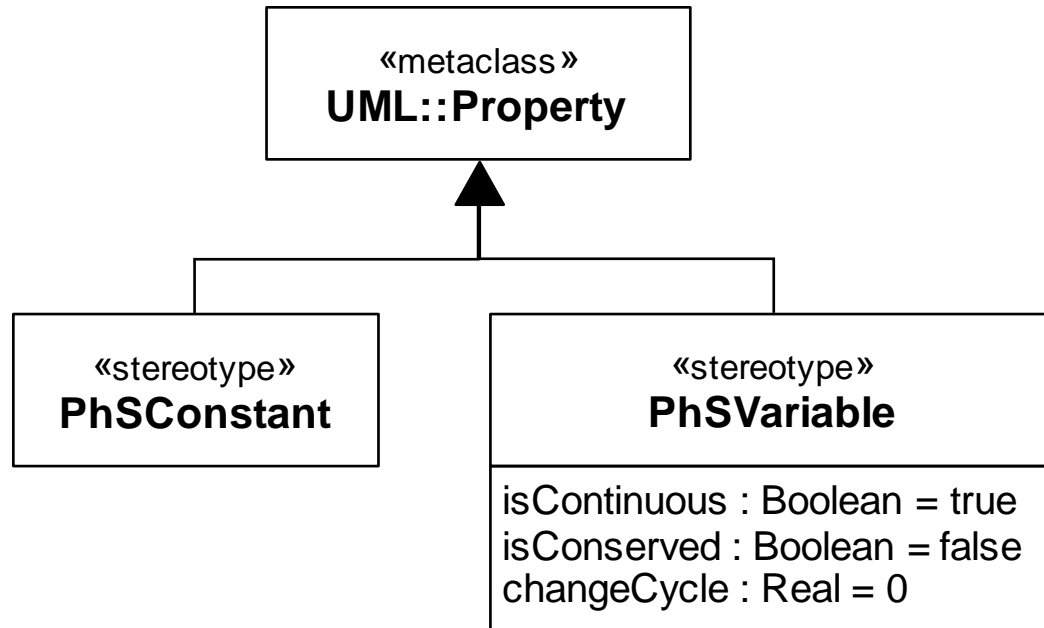


# Model Library (Physical)

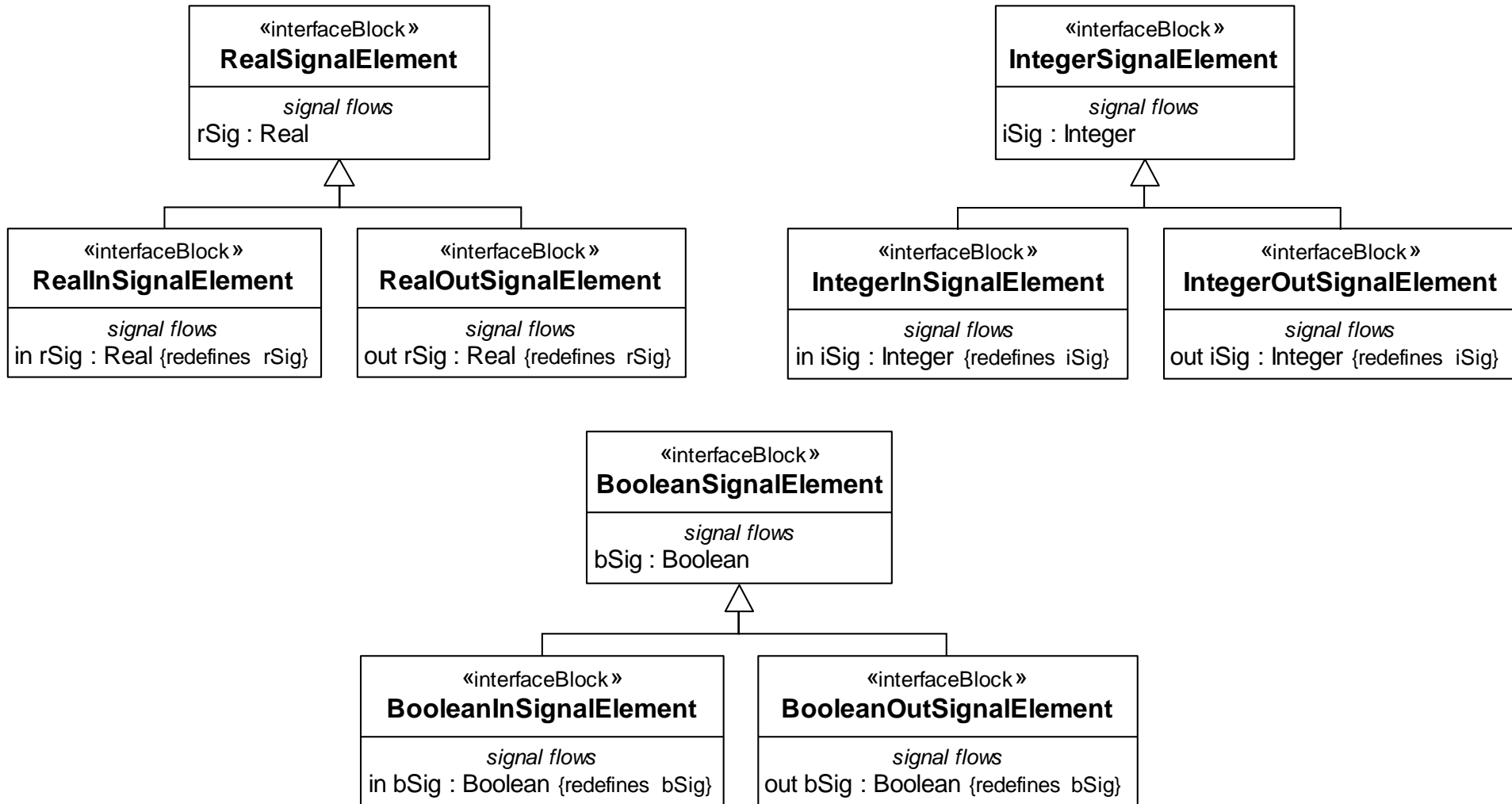


Modeled with one of the  
PI&SF stereotypes

# Stereotypes



# Model Library (Signal)



# Other Libraries

- **Vector & matrix signals**
- **Domain-specific components**
  - **Real-valued**
    - **Continuous**
    - **Discrete**
    - **Non-linear**
    - **Mathematical**
    - **Sources and sinks**
    - **Routing**
  - **Logical**
  - **Electrical**

# Expression Syntax

```
equation :
( simple_expression "=" expression
| if_equation
| name function_call_args
)

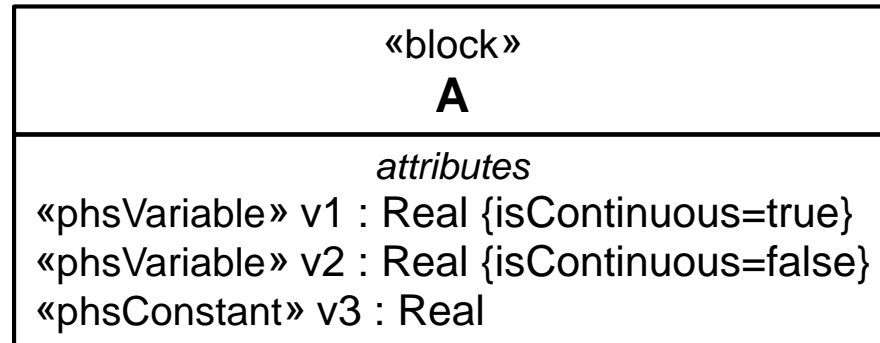
statements : { statement ";" }

statement : ( component_reference ( "!=" expression |
function_call_args )
| "(" output_expression_list ")" "!=" component_reference
function_call_args
| if_statement
| for_statement
| while_statement
)
```

- Identifies subset of Modelica + 1.
- = MATLAB, with a few substitutions

# Translation

## Extended SysML



## Modelica

```
model A
  Real v1;
  discrete Real v2;
  parameter Real v3;
end A
```

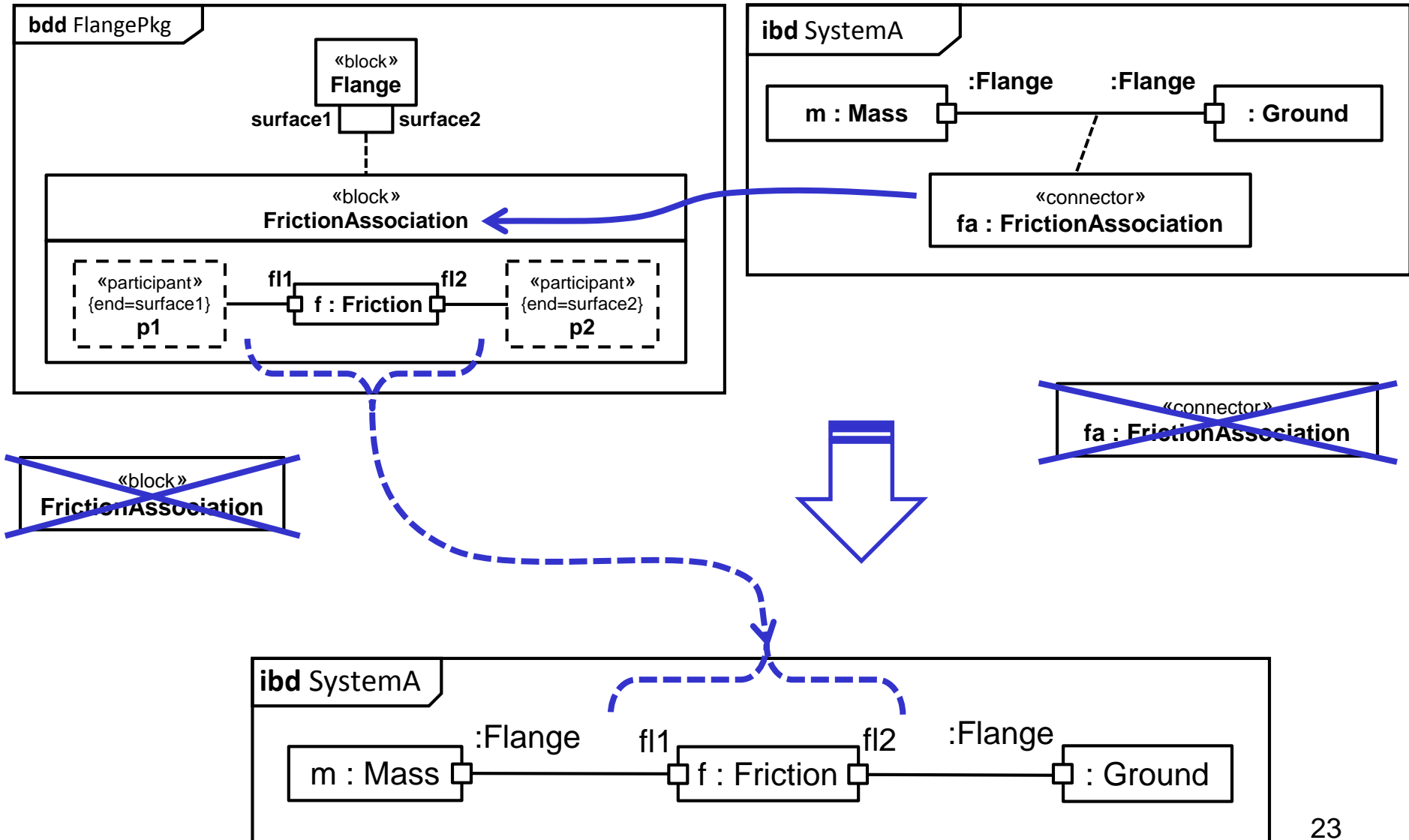
## Simscape

```
component A
  variables
    v1;
  end
  parameters
    v3;
  end
end
```

## Simulink

N/A

# SysML Preprocessing

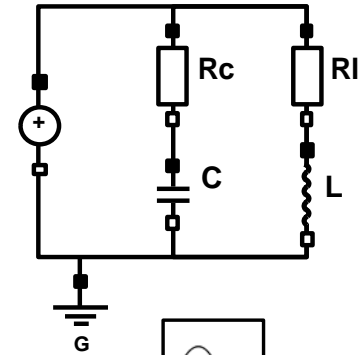




# Examples in Annex

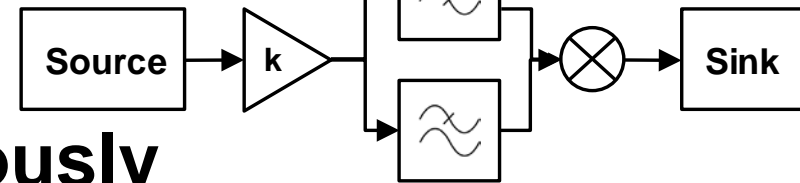
- **Electric circuits**

- Analog electrical interactions



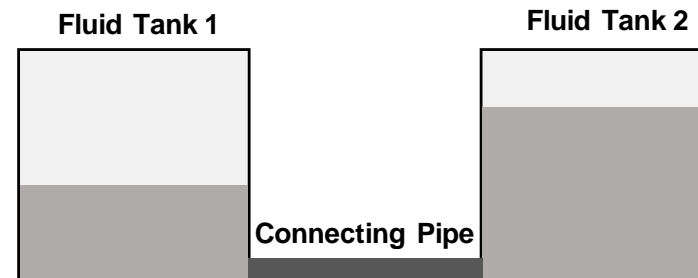
- **Signal processing**

- Manipulation of continuously varying numeric signals



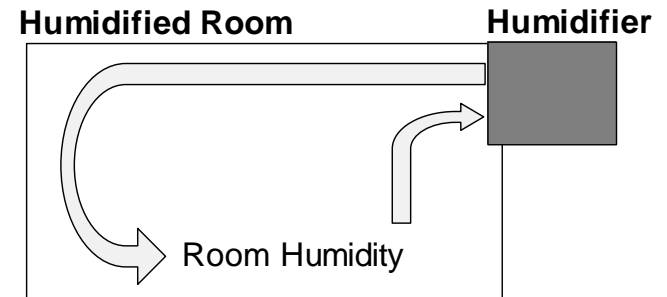
- **Hydraulics**

- Fluid interactions



- **Humidification**

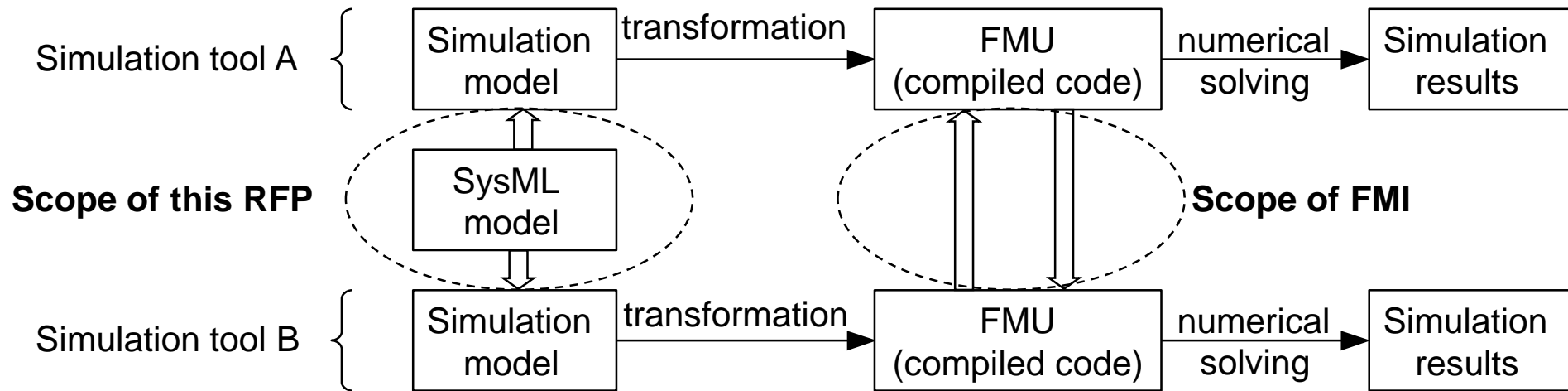
- Physical control modeled with signal flows and state machines



# Open Implementation

- **Automated translation based on spec**
  - **OMG-compliant SysML XMI to Modelica and Simulink / Simscape input files.**
  - **Standalone Java application**
  - **MagicDraw plugin for running it.**
- **This is not a recommendation regarding systems or simulation modeling tools.**

# Related Standards: FMI



- **For integrating executable simulation code, not system models and simulation models.**
- **Does not support physical interaction simulation (currently).**

# Summary

- **Platform-independent extension of SysML for physical interaction and signal flow simulation.**
  - Including libraries and expression language.
  - Preprocessing SysML where needed.
  - Translation to popular platforms.
- **Example applications.**
- **OMG specification available soon.**
- **Translator implementation available.**

# More Information

## ■ Papers:

– **Conference:** <https://www.nist.gov/publications/improved-method-physical-interaction-and-signal-flow-modeling-systems-engineering>

- **Slides:** <http://www.modprod.liu.se/filarkiv/1.716096/modprod2017-day2-talk03-ConradBock-Keynote-SysML-PISF-PhysicalInteraction.pdf>

– **Journal:** <https://www.nist.gov/publications/extension-systems-modeling-language-physical-interaction-and-signal-flow-simulation>

## ■ Simplified in standardization:

- Will be available from OMG soon.
- Open implementation based on this.
- Contact [conrad.bock@nist.gov](mailto:conrad.bock@nist.gov) for links.