Resource-Aware Functional Programming in the Automotive Domain

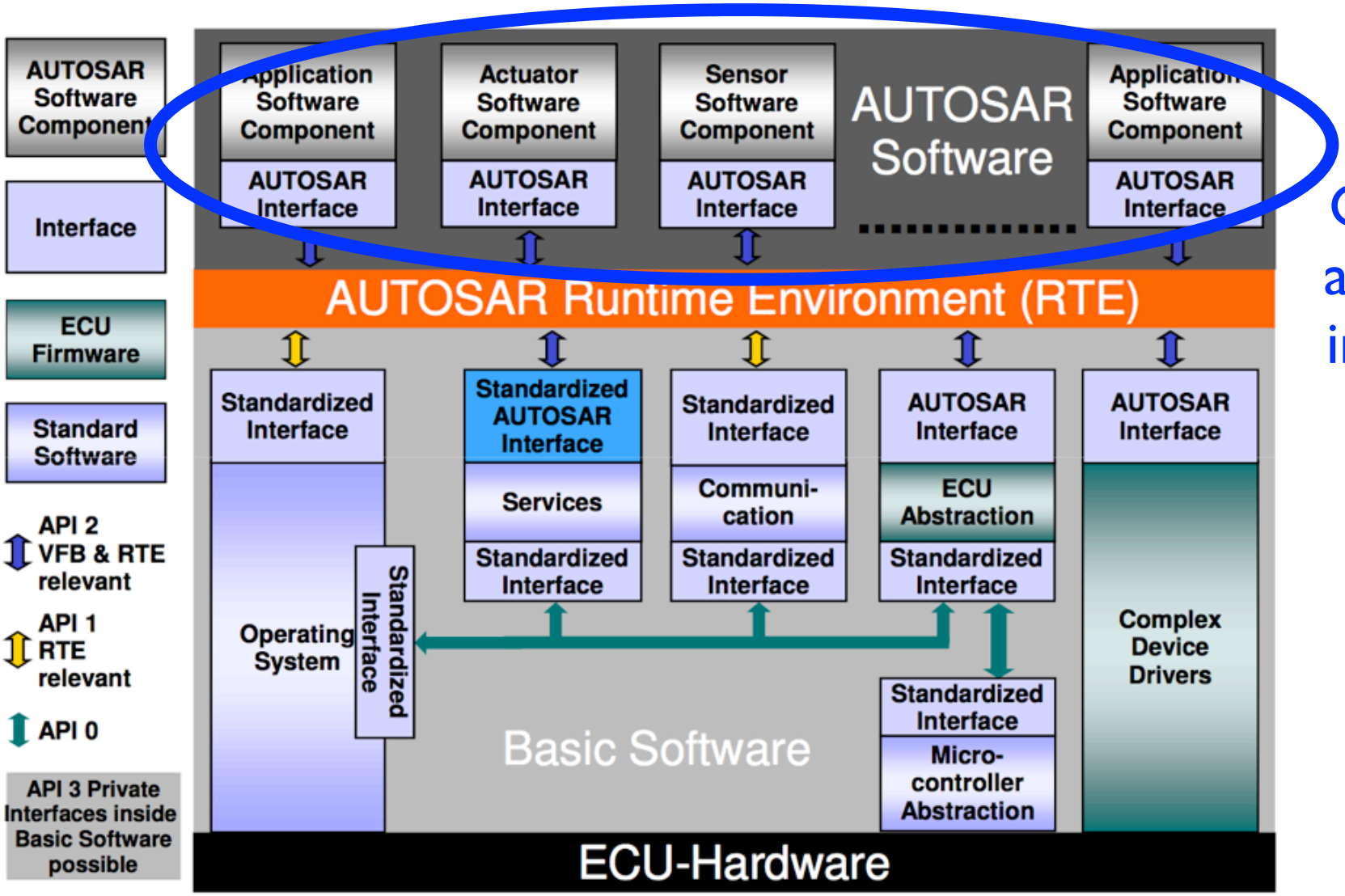
Applying *Domain-Specific Embedded Language* (DSEL) technology to concurrent, distributed and real-time software under the AUTOSAR standard

SSF project *RAW FP*
Automotive track status report
November 2013

AUTOSAR

- A vendor-independent software architecture standard for the automotive industry
- Platform-independent application layer
- Standardized APIs / Basic Software modules
- Standardized system constraint formats
- Extensive tool support for semi-automatic system configuration and code generation
- A detailed design-step methodology

AUTOSAR architecture



Captured as a DSEL in Haskell

An AUTOSAR DSEL
Why?

1. *The importance of Swedish automotive industry*

   - 110 000 people employed, 12% of export value, 25% of manufacturing industry R&D, 13% of industrial investments (2012) (2008)
   - 40% of modern car production costs pertain to electronics & software
   - Software amounts to 50-70% of electronic system development costs

An AUTOSAR DSEL
Why?

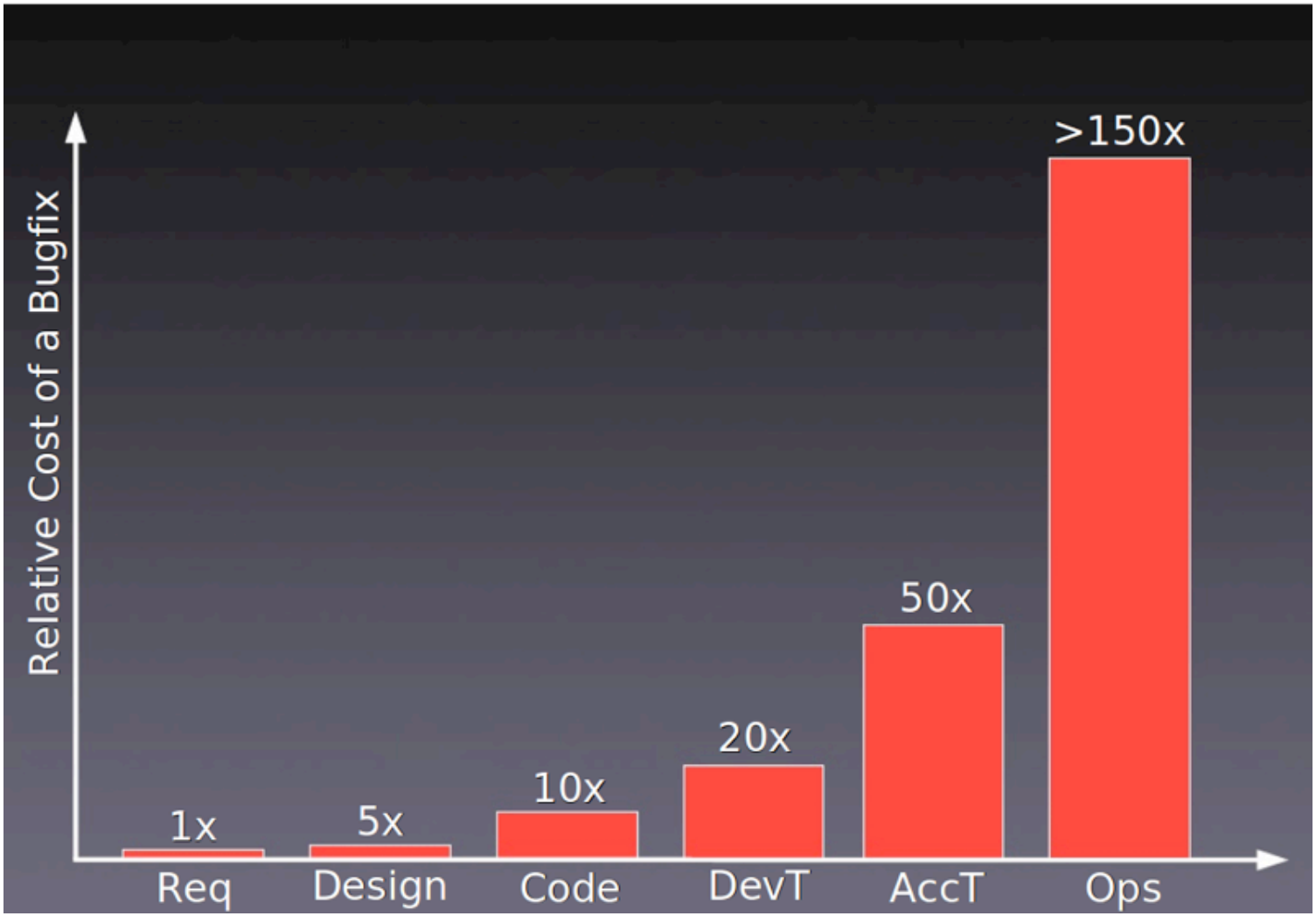
2. *The specific problem of testing automotive software*
   - > 70 ECUs, 5 busses, > 10 000 000 lines of code
   - Tight integration and interdependencies between subsystems
   - Security concerns ⇒ mandatory resource awareness
     ⇒ platform dependencies ⇒ desktop testing unrealistic
   - Full-scale testing on a real moving car is both costly and impractical

An AUTOSAR DSEL
Why?

3. *The gaps in AUTOSAR's behavioral modeling*

- AUTOSAR only specifies program structure & APIs
- *Functional behavior* is assumed to be given in Matlab/ Simulink or as plain C code
- Software components are also expected to map onto OS tasks and low-level concepts, and the standard makes no clear separation of these abstraction levels
- Testing/simulation of *models* rather than code is thus not supported by AUTOSAR

An AUTOSAR DSEL
Why?



Sources: Stefan Priebsch, Advanced OOP and Design Patterns, Barry Boehm "EQUITY Keynote Address", March 19th, 2007

An AUTOSAR DSEL
Why?

4. *The daunting AUTOSAR standard specification*

   - Counting ~100 documents, ~12 500 pages
     (plus just as much auxiliary material)
   - ~20 documents relate to software components, with ~1600 pages in just the two primary ones
   - The contents define a complex programming model, with subtle and sometimes unclear semantic detail

An AUTOSAR DSEL
Why?

5. *The challenges of concurrency, distribution & real-time*

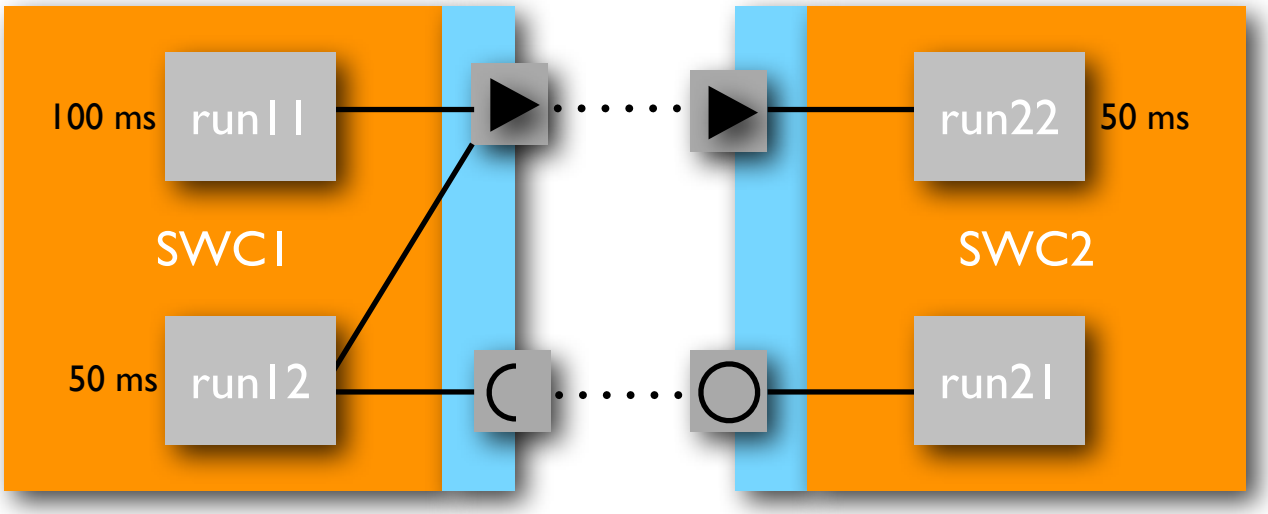
- Automotive specifics aside, the construction of concurrent, distributed & real-time software is far from a mature field
- A technology improvement in any of these dimensions is a contribution in itself

Simple example (trad)

```
FUNC(void, RTE APPL CODE) run11(void) {
    Int16 val;
    ...
    Rte_Write_pport1_intValue1(val);
    ...
}
```

```
FUNC(void, RTE APPL CODE) run22(void) {
    Int16 val;
    ...
    Rte_Read_rport2_intValue(&val);
    ...
}
```

```
TASK(Task1) {
   Rte RECount_Task1_divby2_0--;
   if ( Rte_RECount_Task1_divby2_0 == 0 ) {
      run11();
   }
   run12();
   if ( Rte_RECount_Task1_divby2_0 == 0 )
      Rte_RECount_Task1_divby2_0 = 2;
   TerminateTask();
}
```




```
FUNC(void, RTE APPL CODE) run12(void) {
    String8 val1;
    Int16 val2;
    ...
    Rte_Call_rport1_parse(val1, &val2);
    ...
    Rte_Write_pport1_intValue1(val2);
    ...
}
```

```
FUNC(void, RTE APPL CODE) run21(String8 arg, Int16 *res ) {
    ... arg ...
    ...
    *res = ...
}
```

Simple example (trad)

```
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  <ELEMENTS>
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          /swc root/swc2/pport1
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          /interfaces/CS string to int/parse
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              /swc root/swc2/rport1
            </R-PORT-PROTOTYPE-REF>
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              /interfaces/SR Int16/intValue1
            </DATA-ELEMENT-PROTOTYPE-REF>
          </DATA-ELEMENT-IREF>
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</IMPLEMENTATION>
</ELEMENTS>
</AR-PACKAGE>
```

Simple example (*RAWFP*)

```
swc1 =  component $ do
        pport1 <- providedDataElement
        rport1 <- requiredOperation
        runnable (MinInterval 0) [Timed 0.1] (run11 pport1)
        runnable (MinInterval 0) [Timed 0.05] (run12 pport1 rport1)
        return (pport1, rport1)

swc2 = component $ do
        rport2 <- requiredDataElement
        pport2 <- providedOperation
        serverRunnable Concurrent [pport2] run21
        runnable (MinInterval 0) [Timed 0.05] (run22 rport2)
        return (pport2, rport2)

root = do
        (pdata,rop) <- swc1
        (pop,rdata) <- swc2
        connect pdata rdata
        connect rop pop
```

```
run11 pport1 = do
        ...
        rte_write pport1 val
        ...

run12 pport1 rport1 = do
        ...
        val2 <- rte_call rport1 val1
        ...
        rte_write pport1 val2

run21 arg = do
        ... arg ...
        ...
        return res

run22 rport2 = do
        ...
        val <- rte_read rport2
        ...
```

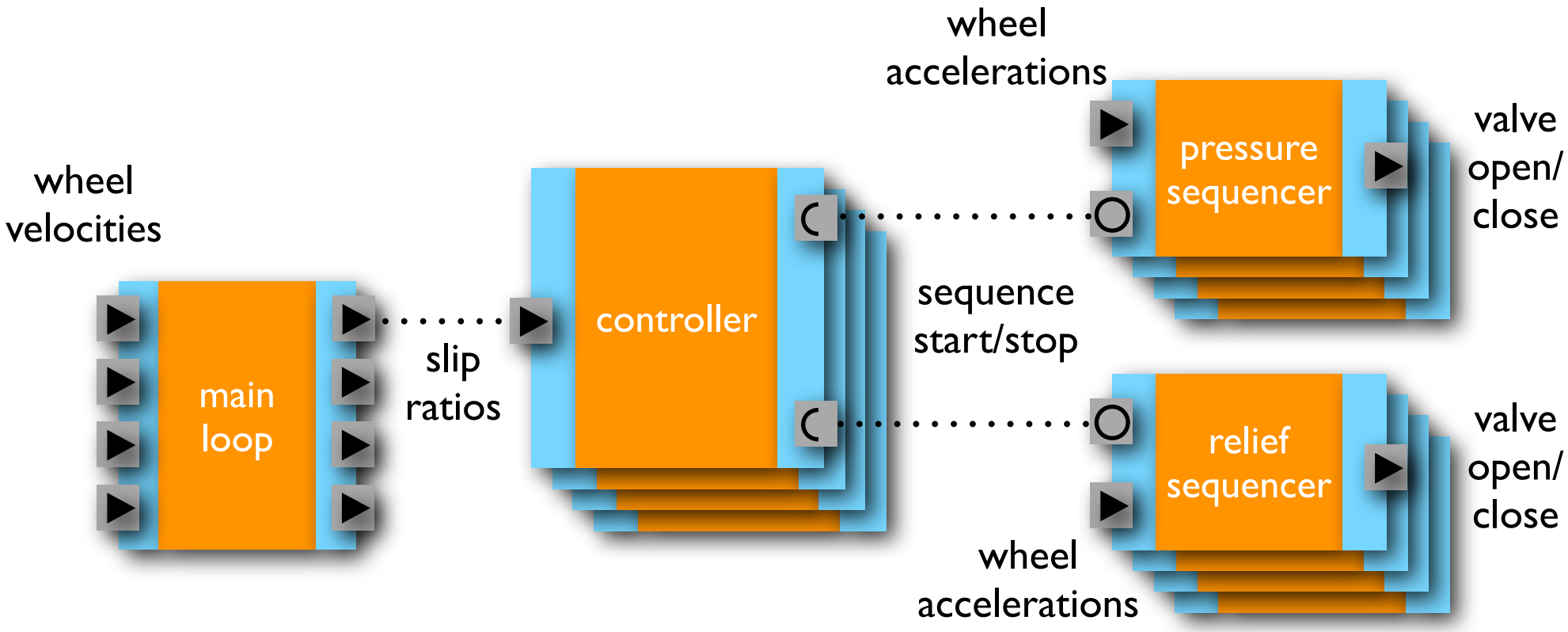
The *RAWFP* AUTOSAR DSEL

- Combines
  1. The structure of AUTOSAR software components
  2. The API of AUTOSAR's run-time environment (RTE)
  3. The functional behavior of its host language Haskell
- Formalizes
  a) The RTE semantics (concurrency, interaction & timing)
  b) Component scoping and encapsulation
  c) The potential meaning of AUTOSAR system constraints

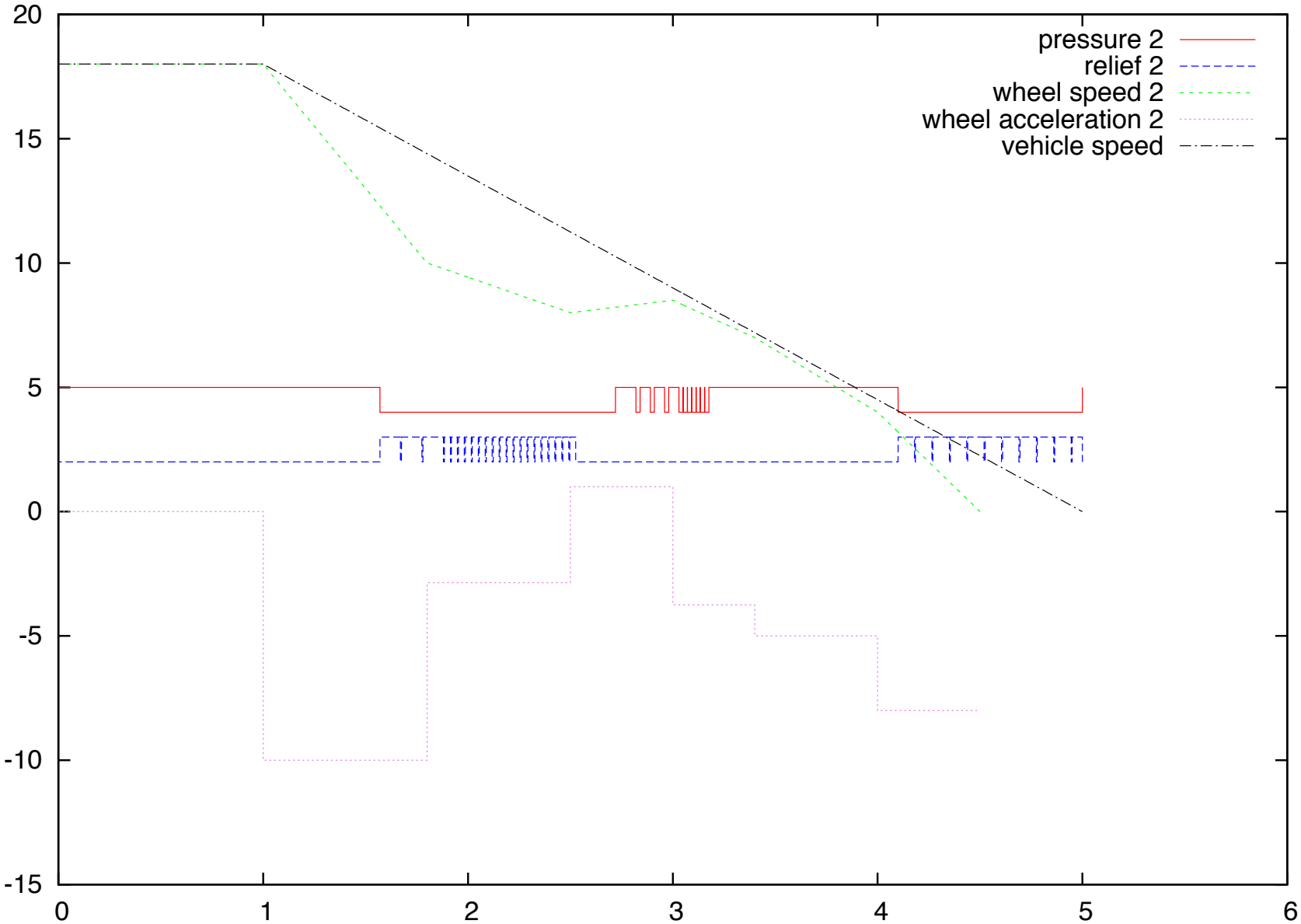
The *RAWFP* AUTOSAR DSEL

- Current achievements:
  - A simulator executing AUTOSAR systems defined entirely on the software component level
  - A modular scheduling architecture, including a fully randomized scheduler option
  - Integration with *QuickCheck* (with trace shrinking)
  - Prototype C code generation
- *Caveat: work is very much in progress!*

Demo: An ABS system



Demo: simulation output



Outlook

- Next steps:
  - Extending the AUTOSAR standard coverage
  - Improving simulator efficiency
  - Integrating code generation with industrial tools
  - Assembling and reporting semantic ambiguities found
- Long-term goals:
  - To provide a tool for truly high-level modeling and simulation of automotive software systems
  - To fully automate the translation of models to executable AUTOSAR code