Model-based development for embedded control systems

Paul Caspi

Retiring from Laboratoire **Verimag** *(CNRS-UJF-INPG)*

28th September 2007

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Many thanks to

- the organisers, speakers, attendants

for this wonderful and memorable day

Joint work with. . .

Jacques Richalet
Catherine Bellon
Eric Pilaud
Paul Amblard
Albert Benveniste
Benoît Caillaud
René David
Oded Maler
Thierry Le Sergent
Norman Scaife
Alberto Sangiovanni-Vincentelli
Gabriele Saucier
Nicolas Halbwachs
Daniel Pilaud
Joseph Sifakis
Pascal Raymond
Christine Bodennec
Moez Yeddes
Florence Maraninchi
Stavros Tripakis
Chiheb Kossentini
Anne Guérin-Dugué
Jacques Pulou
John Plaice
Jean-Louis Bergerand
Gérard Berry
Alain Girault
Jean-Louis Camus
Marc Pouzet
Cécile Dumas
Adrian Curic
Christos Sofronis
Thao Dang

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. . . and all those who will hate me for omitting to cite their name

Which Embedded Control Systems?

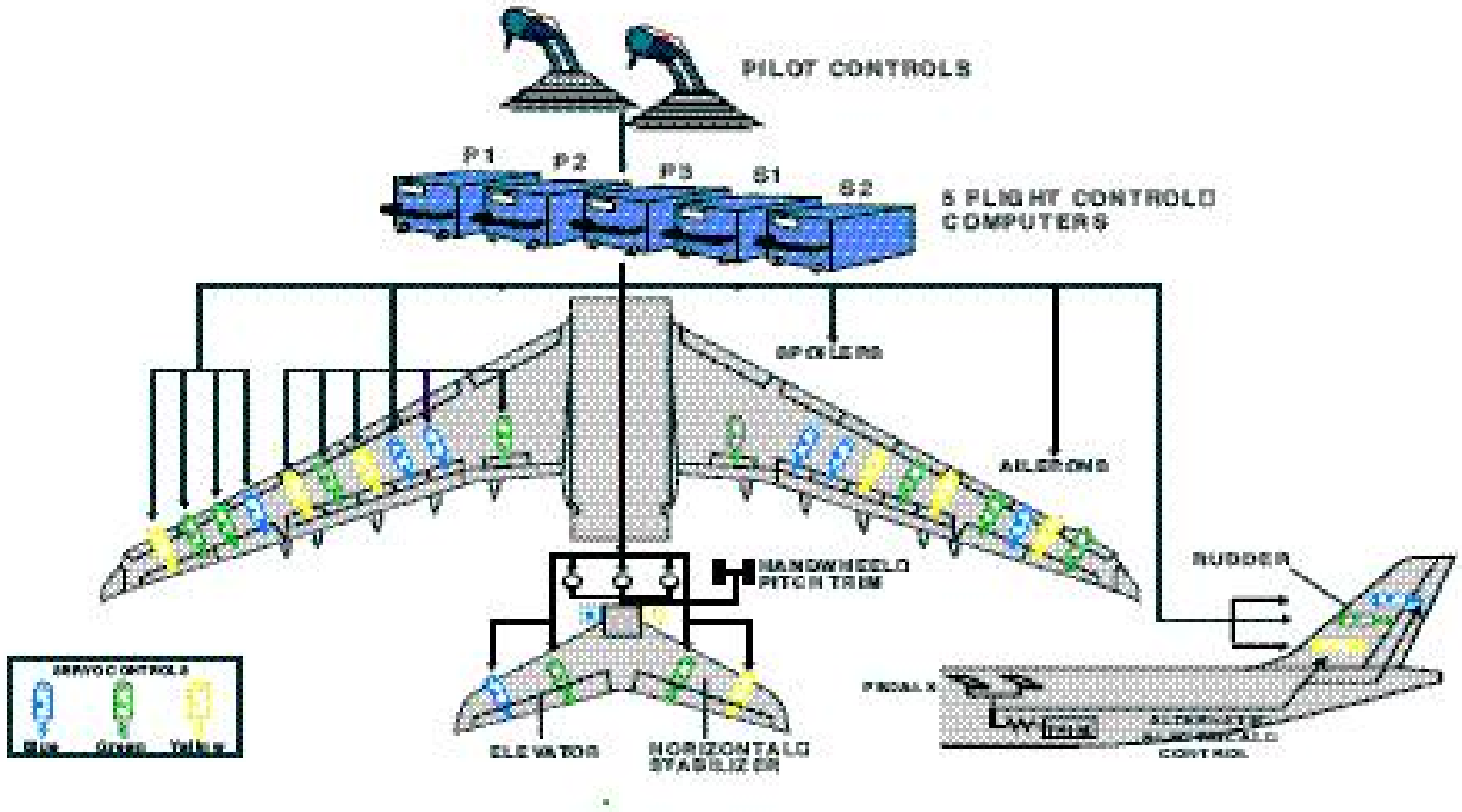
flight control

emergency shutdown

speed control, signalling

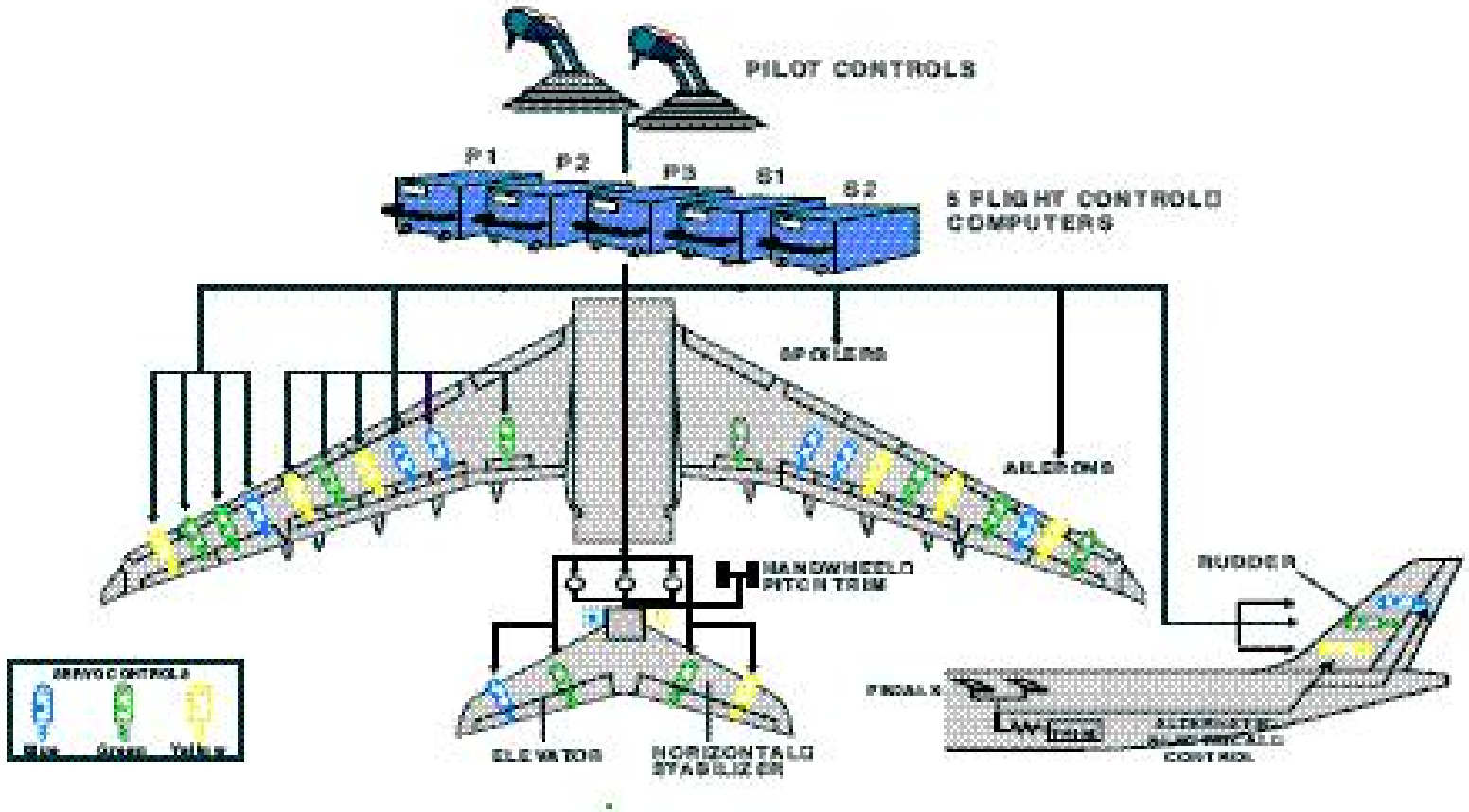
full automation

Looking inside



Fly-by-wire ? Drive-by-wire ? Electronic Control Units ?

Looking inside



Fly-by-wire ? Drive-by-wire ? Electronic Control Units ?

Fly-by-computers ! Fly-by-software !

Two Questions

Knowing the low reliability of computing technology

- thousands of car “recalled” for computing bugs
- Ariane V accident
- your personal computer . . .

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1. *Is it wise to use this poor technology in safety critical systems?*

Two Questions

Knowing the low reliability of computing technology

- thousands of car “recalled” for computing bugs
- Ariane V accident
- your personal computer . . .

1. *Is it wise to use this poor technology in safety critical systems?*

2. *Why, nevertheless, things are not as bad as could be expected?*

A Tentative Answer

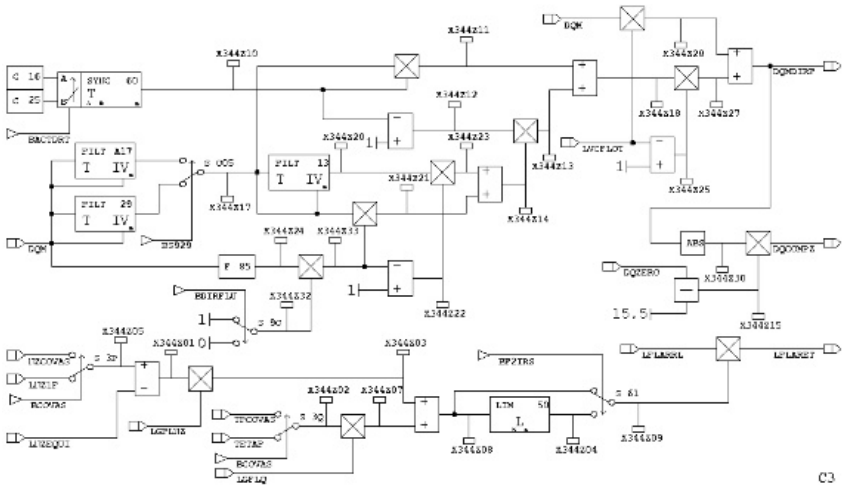
The safety-critical control industry has designed a very strong model-based development method
A short story of this method:

- **Aérospatiale** pioneering role
- How things evolved since then
- State of the Art and perspectives

Are academic people really aware of this story?

Aérospatiale pioneering steps in the early eighties

control models (block-diagrams)



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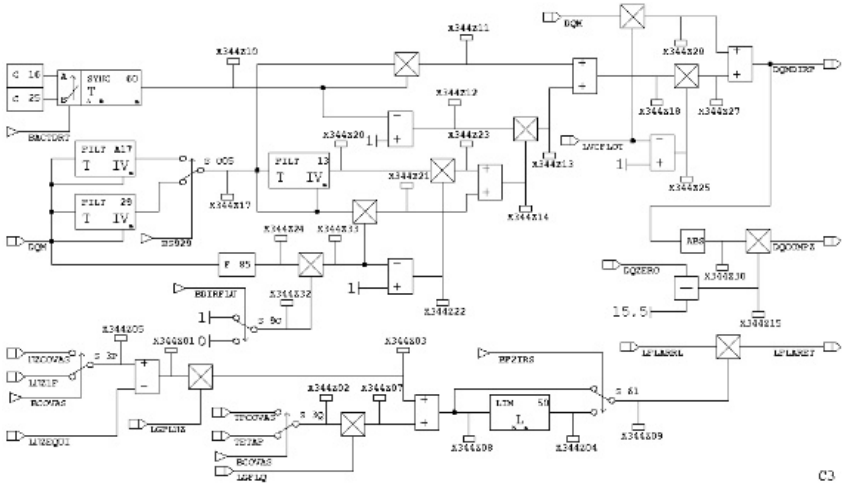

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formal software specification

Aérospatiale pioneering steps in the early eighties

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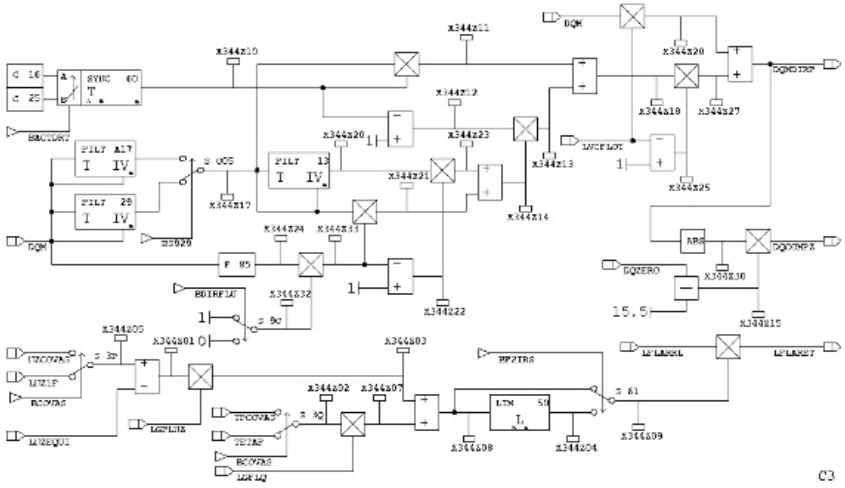

↓

automatic code generation

↓

Software

=

formal software specification

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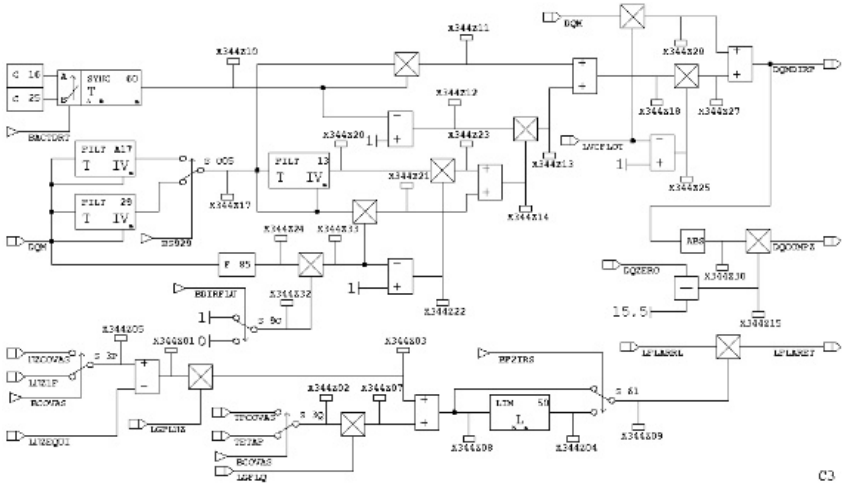


↓

automatic code generation

↓

Software

=

formal software specification

“Spécification Assistée par Ordinateur”(SAO)
“Computer Aided Specification”

Interest of **SAO**

Twofold :

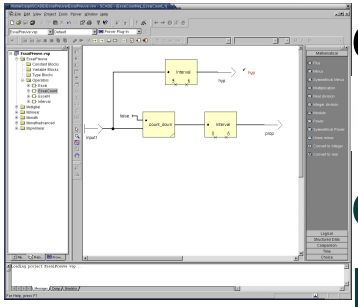
- Automatic code generation from high-level control models:
  easier and earlier debugging
- Graphic language close to the cultural background of avionic engineers, test pilots, suppliers, certification authorities, . . . :
  allows easier communication within the entreprise
  preserves the know-how and makes easier the technology transfer

SAO participates to the success of A320

From then on. . .

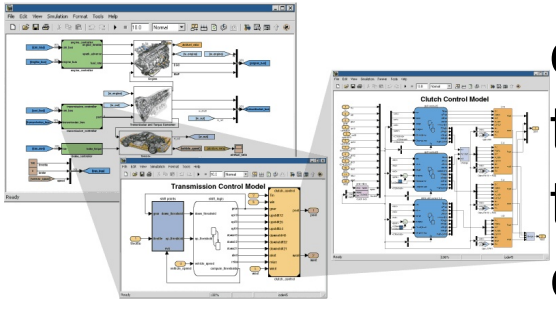
Powerful model-based development tools:

- **SAO** replaced by **SCADE**



commercial product partially based on synchronous technology
qualified code generator for safety-critical applications

- Simulink/Stateflow



continuous/discrete time simulation toolbox
the defacto standard in control modelling

- Formal methods: automatic mathematical proofs for dynamic systems

PROVER TECHNOLOGY

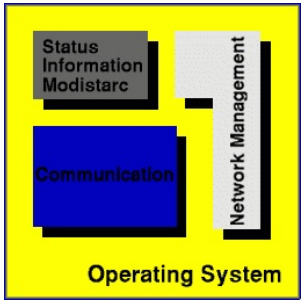
PolySpace TECHNOLOGIES
Delivering safe code · faster

. . .

From then on. . .

More powerful execution platforms:

- multi-tasking



WIND RIVER

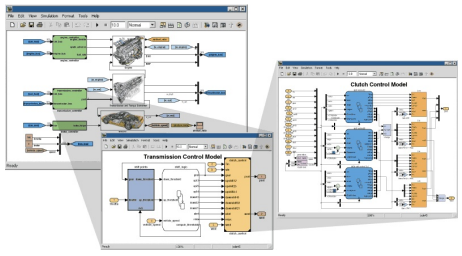
- distributed and multi-processor

TTTech

FlexRay™

State of the Art

modelling



State of the Art

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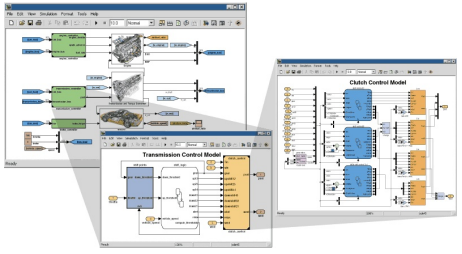
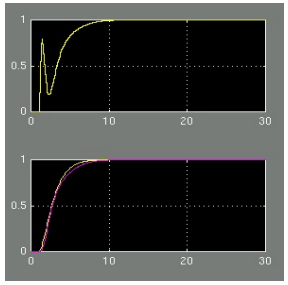


simulation
debugging



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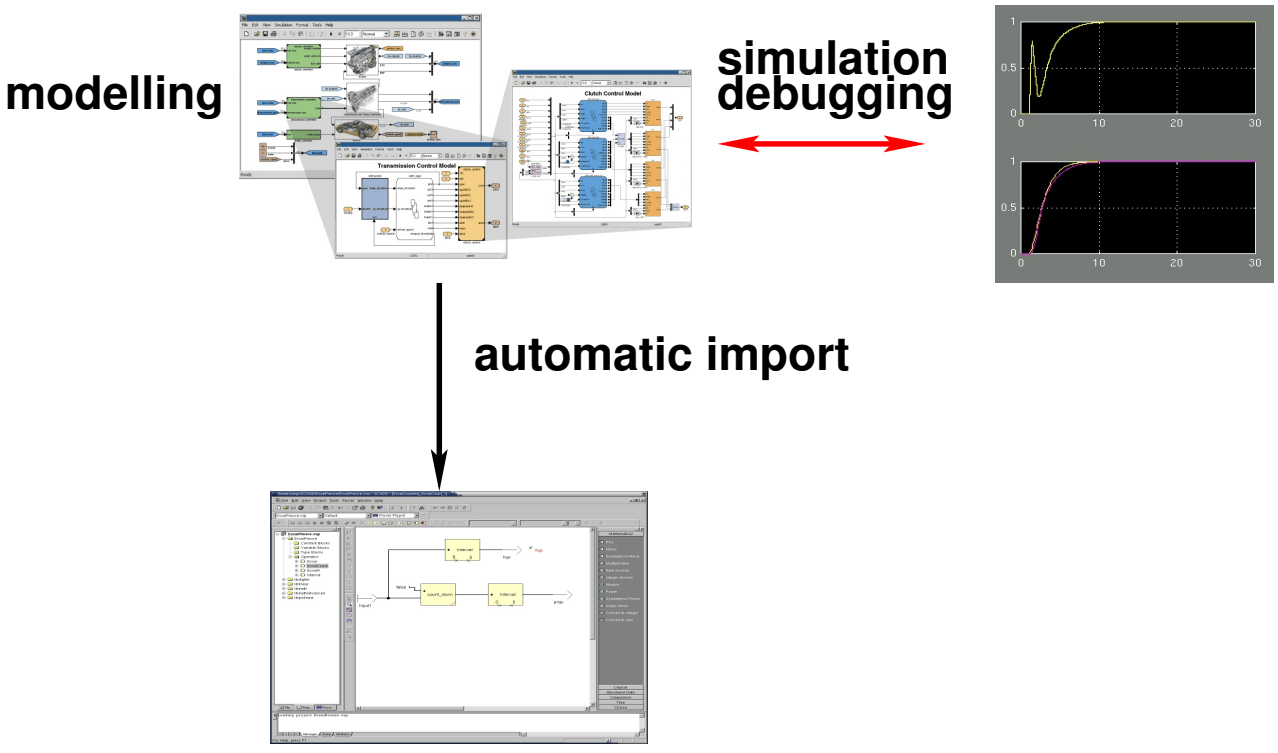

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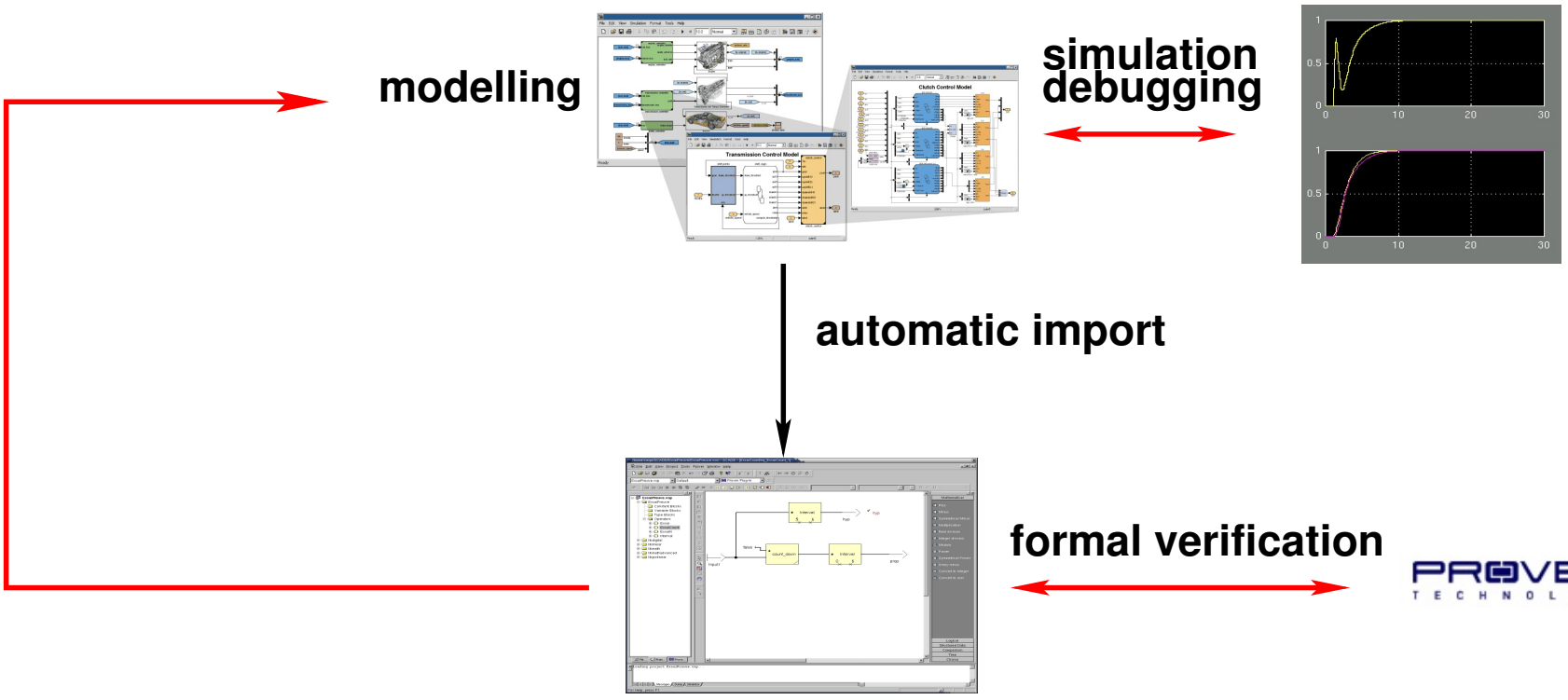

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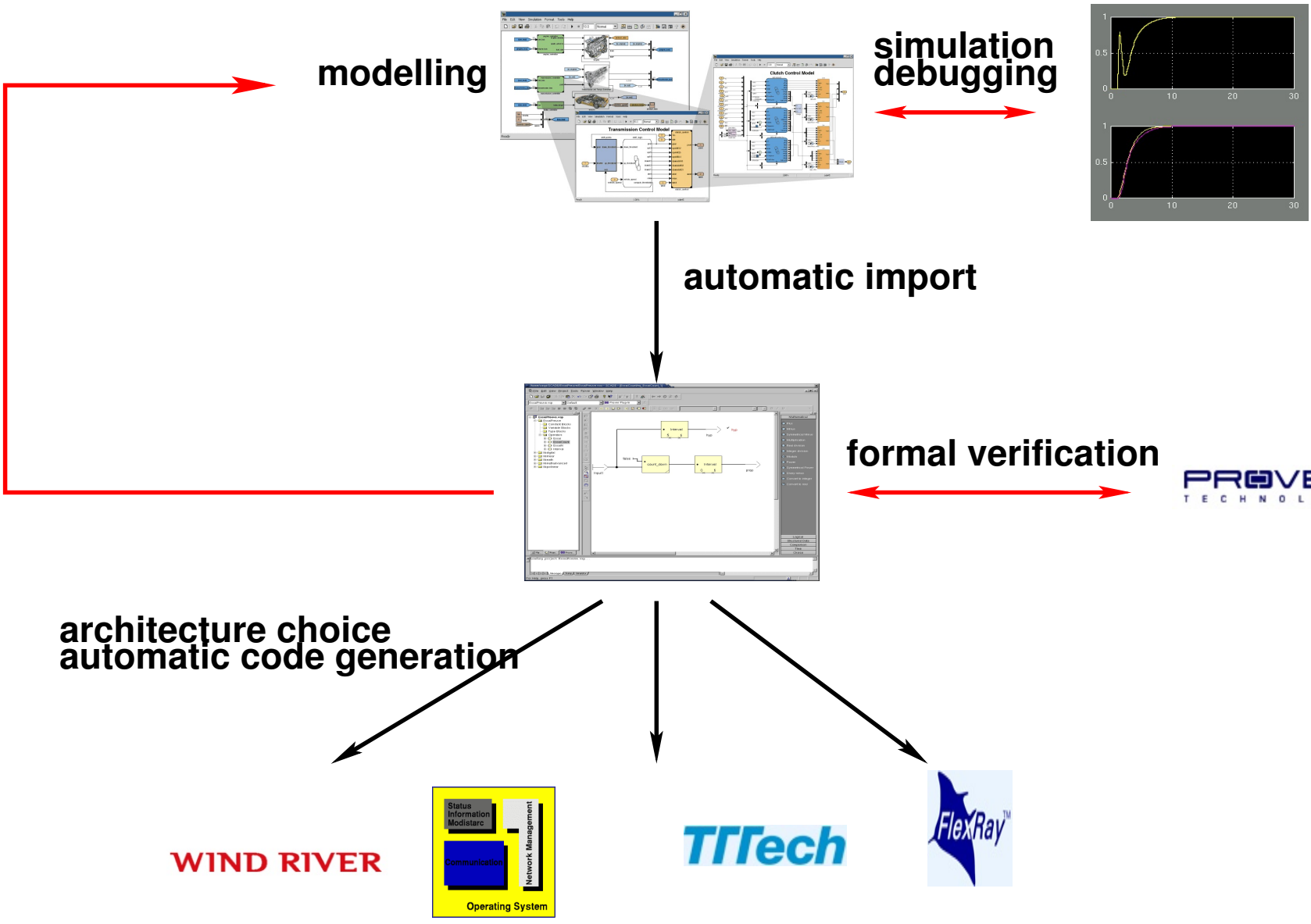

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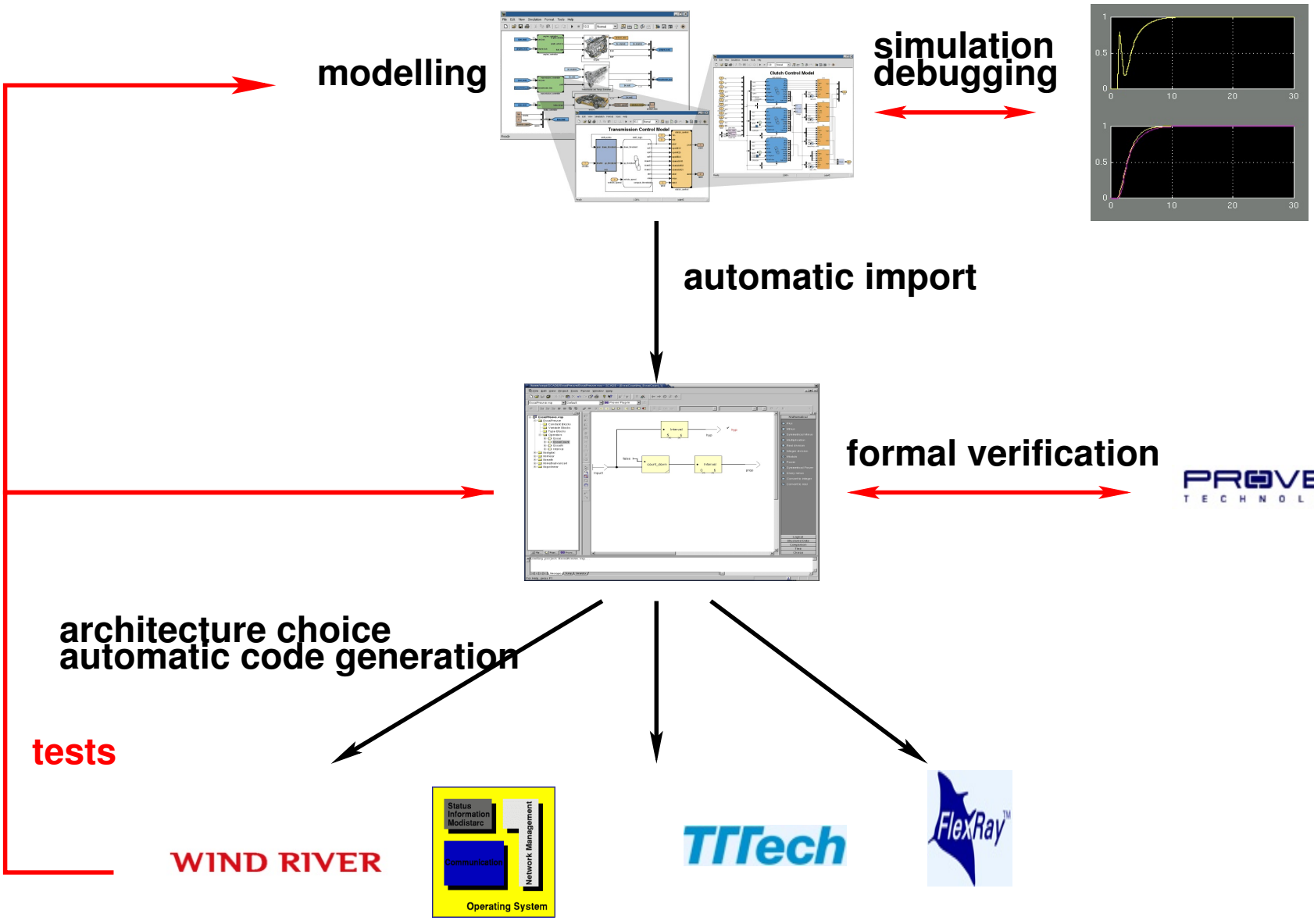

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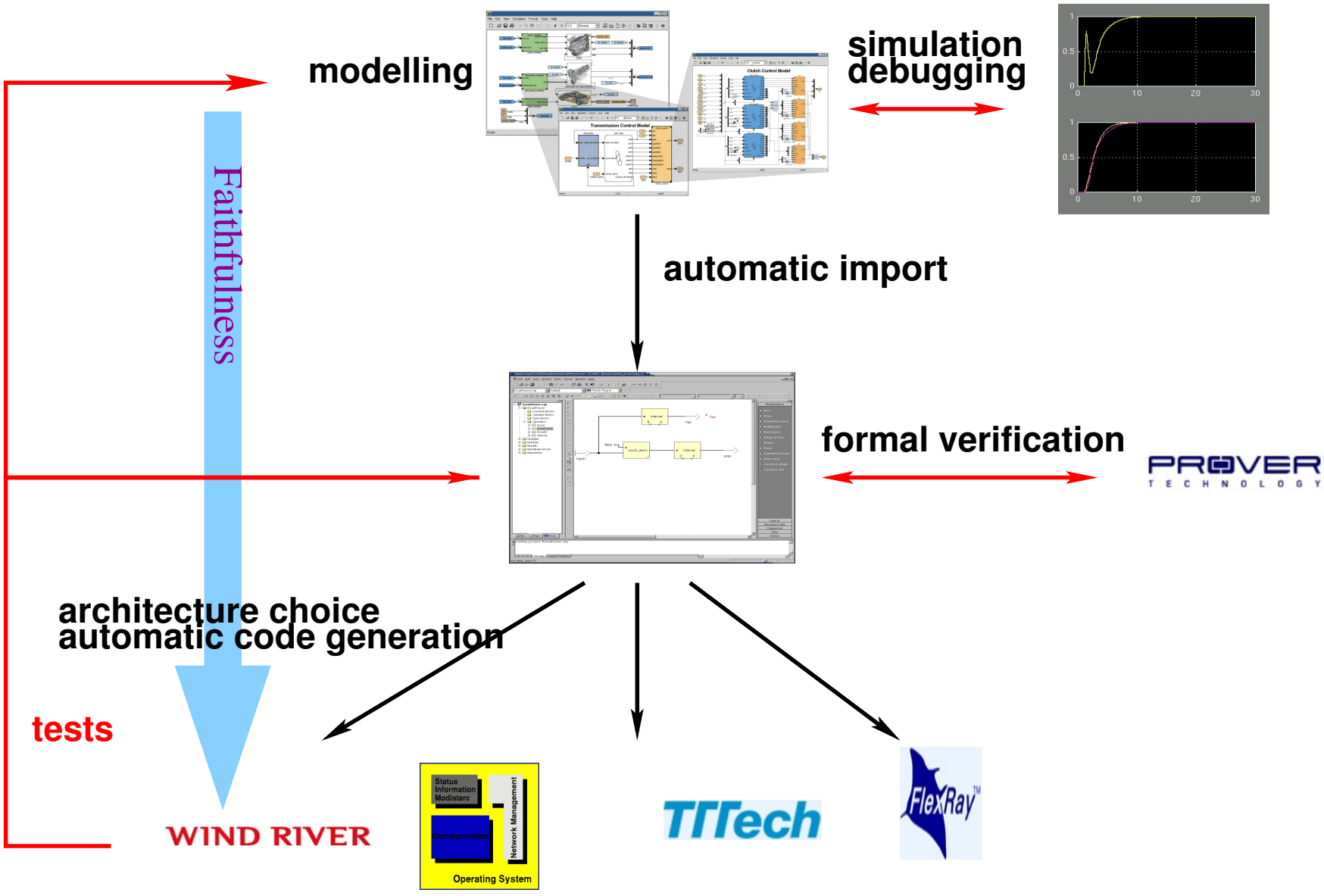


A Key Issue: Faithfulness

What you { *model* / *simulate* / *prove* } is what you { *implement* / *execute* }

(Gérard Berry 1984)

From Handicraft to Industry

In twenty years, the industry of critical control moved from

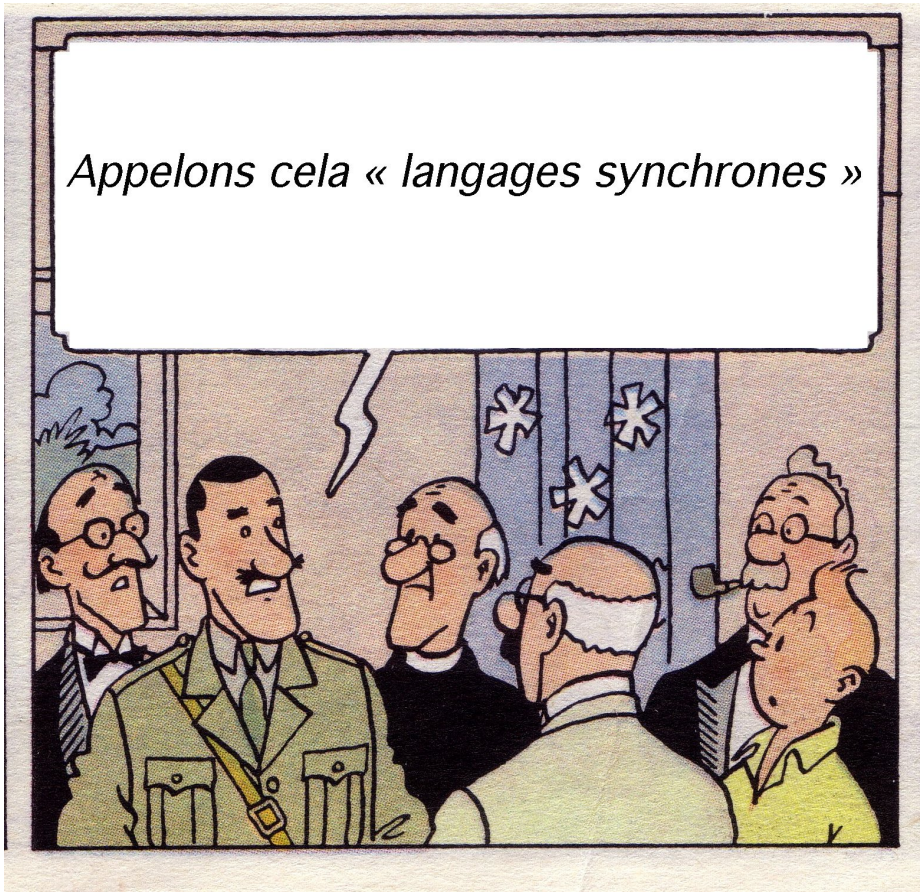
- handicraft :
  - paper design, human coding, validation on hardware
- to industry:
  - functional and architectural design and validation based on formal models that can be simulated and checked,
  - automatic code generation ensuring faithfulness between models and implementations

This is a notable advance that has to be pursued, strengthened and extended

In twenty years, we moved from this. . .

to this. . .

What was our role in this story?



Strengthen

Formalise

Generalise

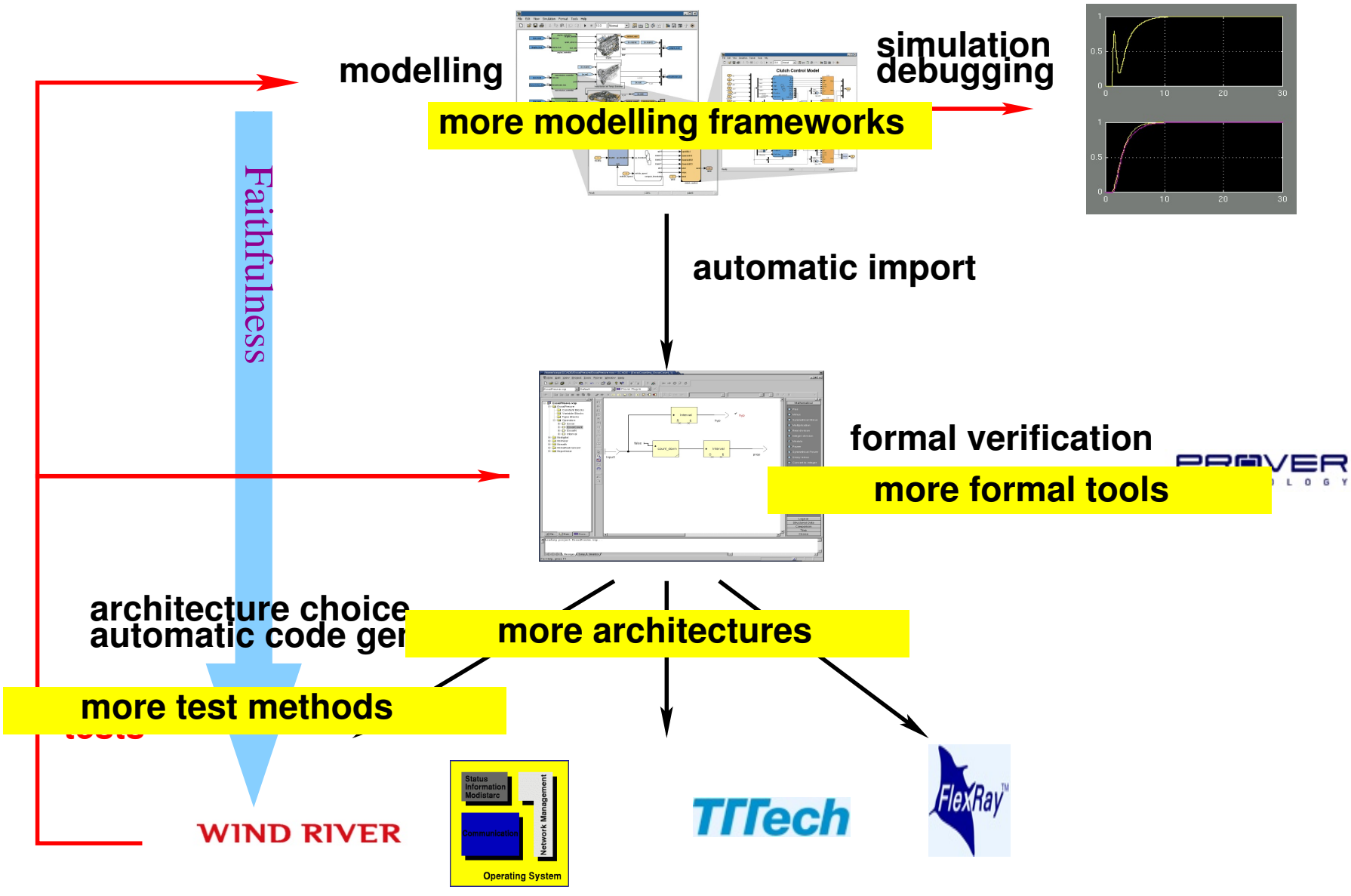
Optimise

Help building tools

Some Regrets

- We were ahead of Mathworks in the eighties and we missed continuous time
- I was a bad supervisor: as I didn't care of my career, I couldn't as well care for my students ones.

Perspectives



Thanks again to all of you and good luck

The True Story of SCADE/Lustre