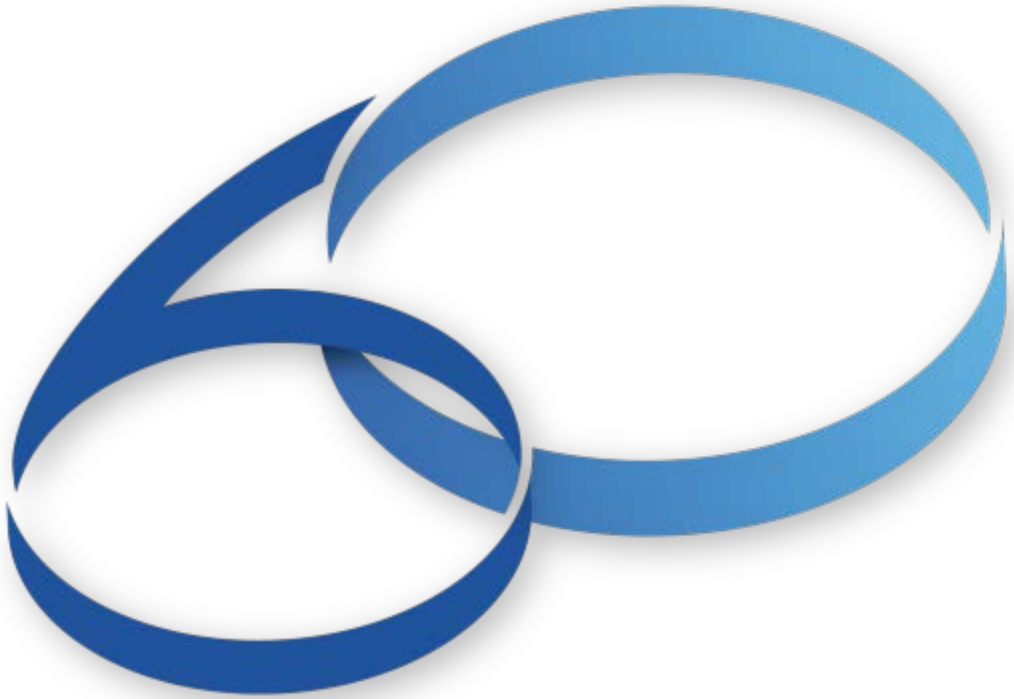

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Formal verification of industrial control systems at CERN

VTSA 2014 Student Session

30/10/2014

Contains joint work of B. Fernández, E. Blanco, S. Bliudze, J.O. Blech, J-C. Tournier, T. Bartha, A. Vörös, I. Majzik

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Context – CERN

- European Organization for Nuclear Research
- laboratory and accelerator complex for **particle physics research**
- PLCs for controlling **vacuum**, **cryogenics, HVAC**, etc. systems

Context – PLCs at CERN

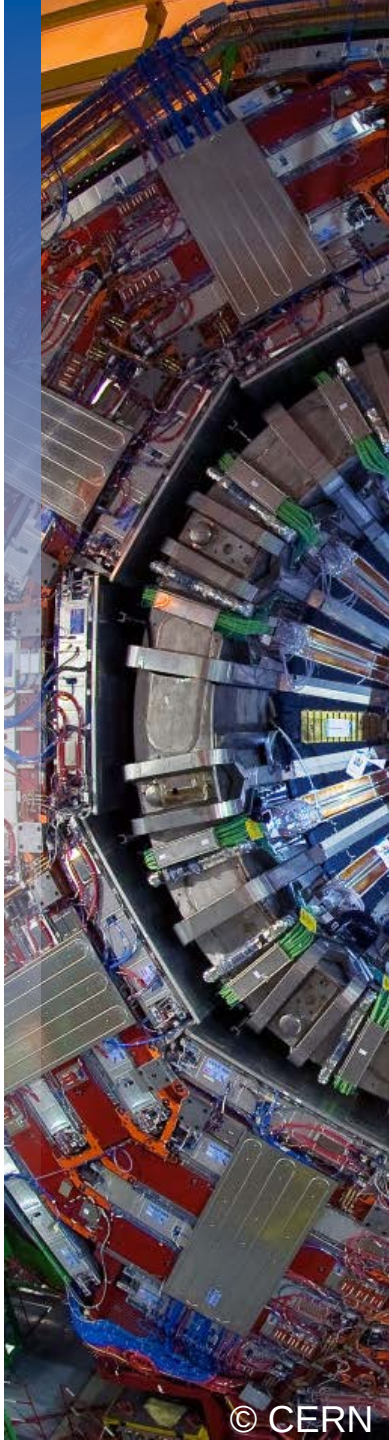
- Programmable Logic Controllers
  robust industrial computers
- 1000+ PLCs at CERN
- Common framework (UNICOS)
  → Common library of base modules

Motivation for formal verification

- Human lives are not depending on PLCs

but

- **expensive equipment**
- **long-term consequences**
- **common library**
- **update** is difficult
- **long life-time** of PLC programs



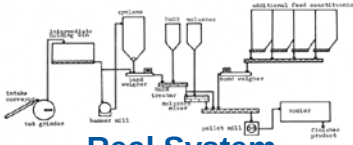
Goal

- To **improve the quality** by eliminating bugs
  - Complementing automated and manual testing
- Applying **model checking** to find **“high quality” bugs**

but

- CERN is not a CS research institute
- Building on **off-the-shelf solutions**

Challenges and answers



Real System
(hardware, software)

Specifications

How to get models?

Formal Model

Automated generation

Formal Requirement

How to formalize requirements?

Requirement patterns

Which model checker should be used?

Model checker

satisfied

not satisfied

How to proceed with a counterexample?

Multiple (general meth., intermediate model)

✓

Counter-example

Analysis and demonstration

How to make it efficient?

Reductions

And it should be integrated to the development process.

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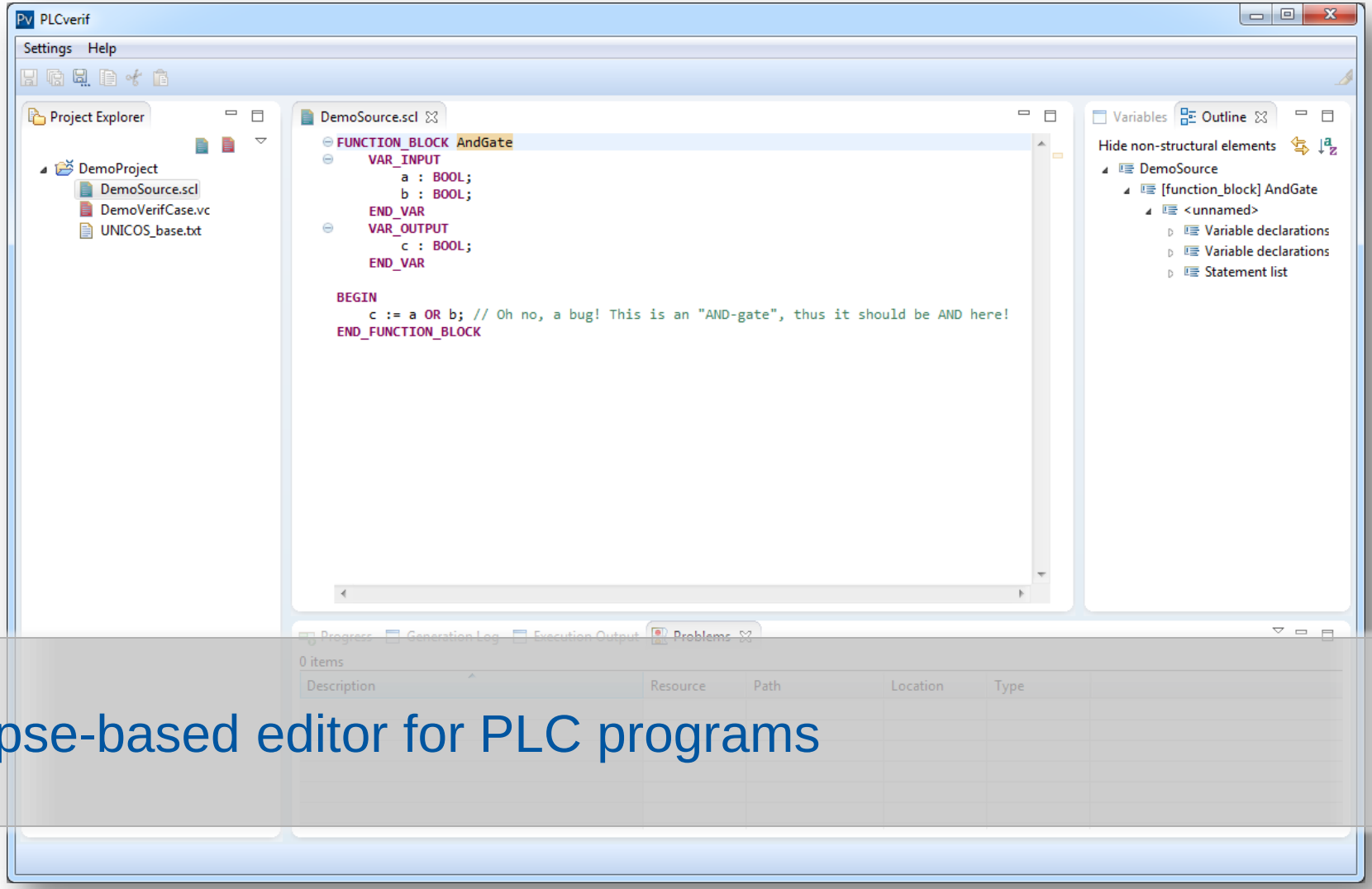
The PLCverif tool



Eclipse-based editor for PLC programs

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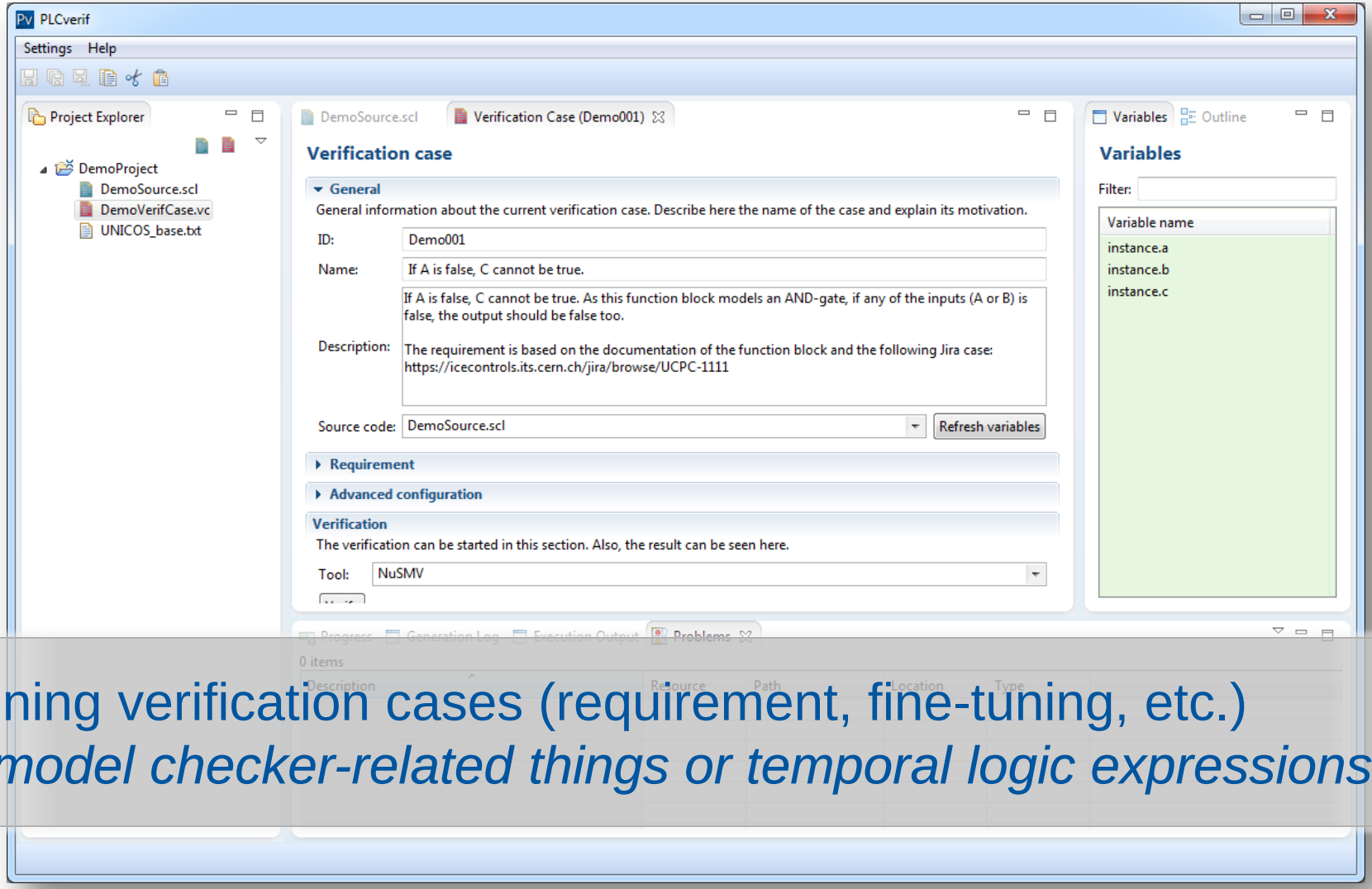
The PLCverif tool



Defining verification cases (requirement, fine-tuning, etc.)

No model checker-related things or temporal logic expressions

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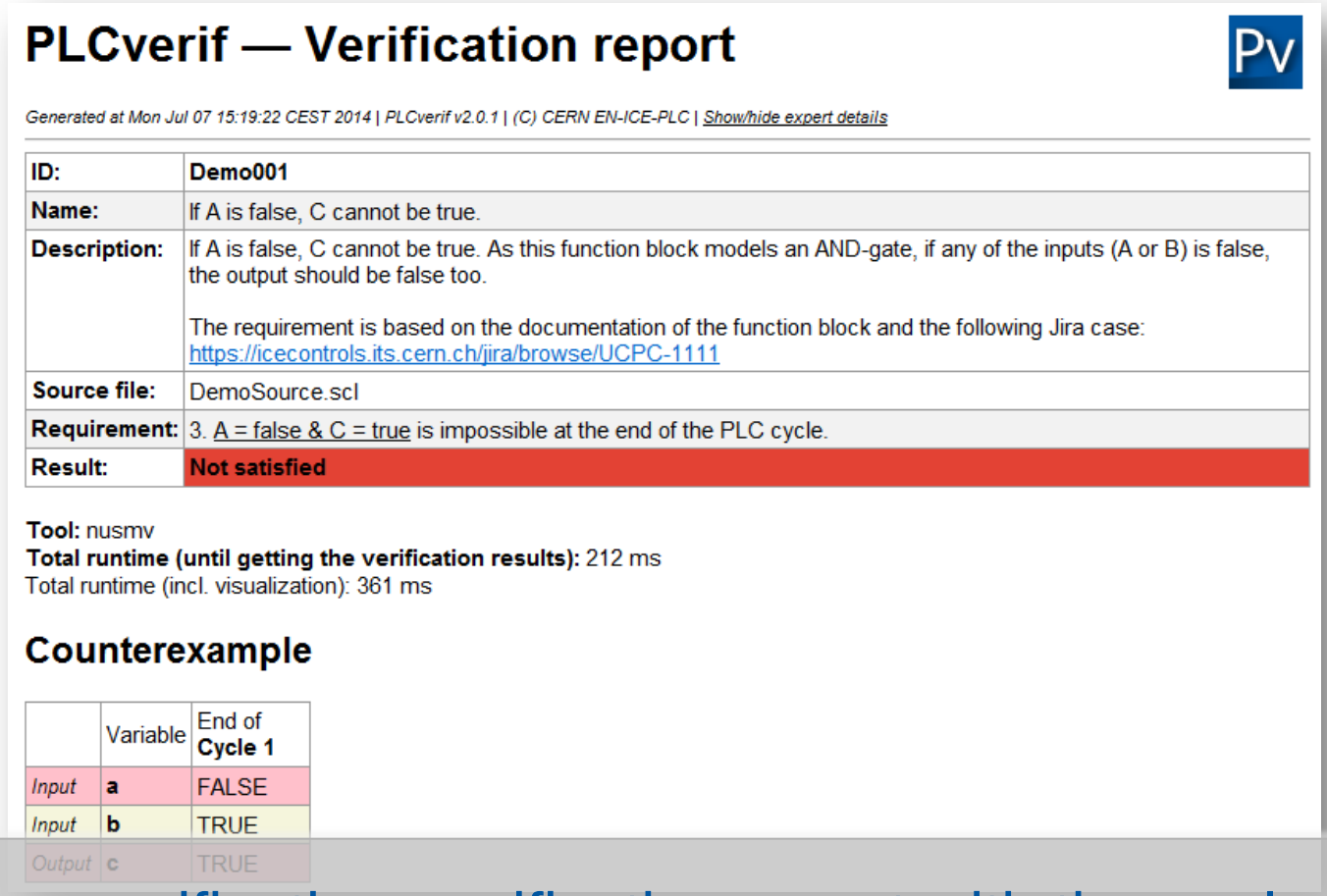
The PLCverif tool



PLCverif — Verification report

Generated at Mon Jul 07 15:19:22 CEST 2014 | PLCverif v2.0.1 | (C) CERN EN-ICE-PLC | Show/hide expert details

ID:	**Demo001**
Name:	If A is false, C cannot be true.
Description:	If A is false, C cannot be true. As this function block models an AND-gate, if any of the inputs (A or B) is false, the output should be false too. The requirement is based on the documentation of the function block and the following Jira case: https://icecontrols.its.cern.ch/jira/browse/UCPC-1111
Source file:	DemoSource.scl
Requirement:	3. A = false & C = true is impossible at the end of the PLC cycle.
Result:	**Not satisfied**

Tool: nusmv
Total runtime (until getting the verification results): 212 ms
Total runtime (incl. visualization): 361 ms

Counterexample

	Variable	End of **Cycle 1**
Input	**a**	FALSE
Input	**b**	TRUE
Output	**c**	TRUE

Click-button verification, verification report with the analysed counterexample

Still to improve

- **Big programs**
  - Works fine for **100-1000 LoC** (10^{200} states before reduction)
  - What about **100 kLoC** ($10^{100,000}$ states before reduction)? (many **reused modules** and a bit of code to connect them)

- **Integers and time**
  - Works **fine for mostly Boolean programs** (with few integers/timers)
  - What about having 10-100-1000-… integers?
  - BDD-based NuSMV fails. What about other model checkers?

- And a blocker problem…

The Blocker Problem

"We can check if the program behave as it is supposed to behave. **But how should it behave?**"

- **The code is the authoritative specification**
  - Already long evolution (10+ years)
  - Complex code
- Big need for a **specification** method that …
  - … is **unambiguous**, **formal**.
  - … has a **semantics** adjusted to the PLC domain.
  - … can be **easily used by automation engineers** and by the "internal customers" without long training.
  - Ongoing research: 2014 – 2017

Summary

- First steps are made to apply FV to industrial control systems of CERN
  - Many interesting bugs were found (*with joint effort of automation engineers and formal methods people*)

- Still long way to go
  - Improving the performance
  - **Formal specification**

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Visit https://cern.ch/enice/PLC+formal+verification for contacts and more information.

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