Basic advances in CMACS technology: Abstract Interpretation

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CMU, Pittsburgh November 3, 2011

Advances in abstract interpretation

Significant advances on

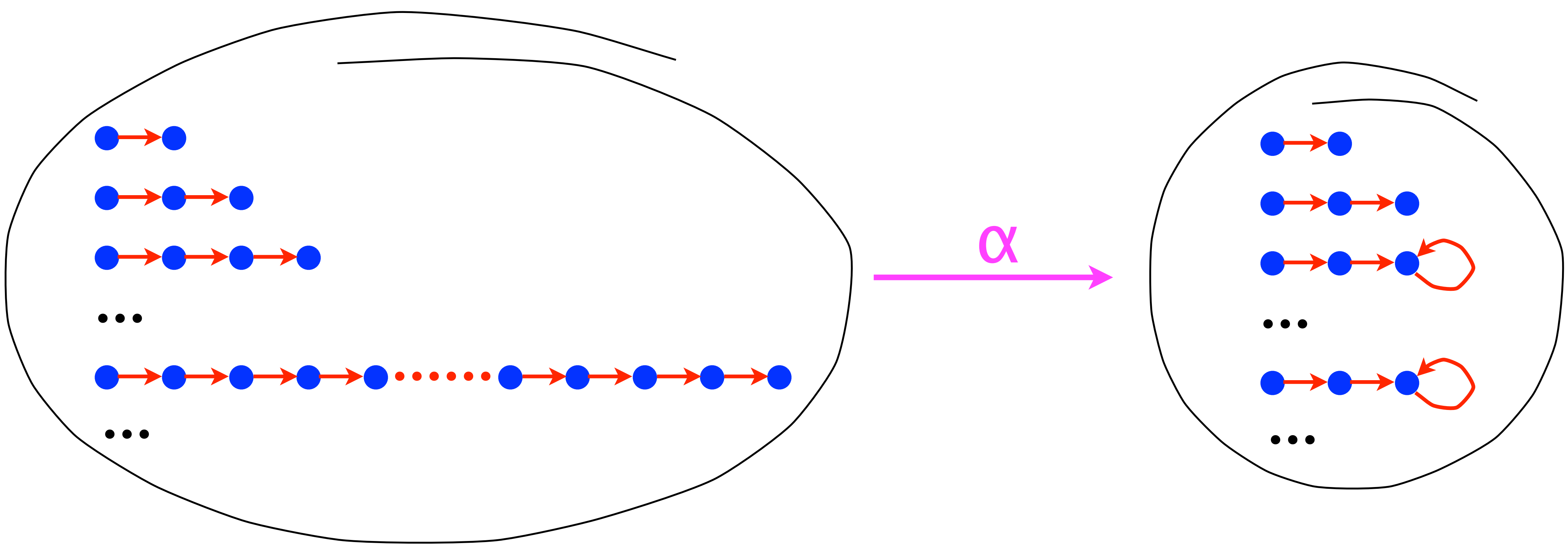
- Under-approximation
- Abstraction of unbounded array content
- Combination of algebraic and logical abstractions
- Probabilistic abstraction
- Termination/eventuality

have been done for infinite state systems.

Difficulty of the problems

- Abstraction to finite / bounded executions is impossible (unsound, ineffective, ...)

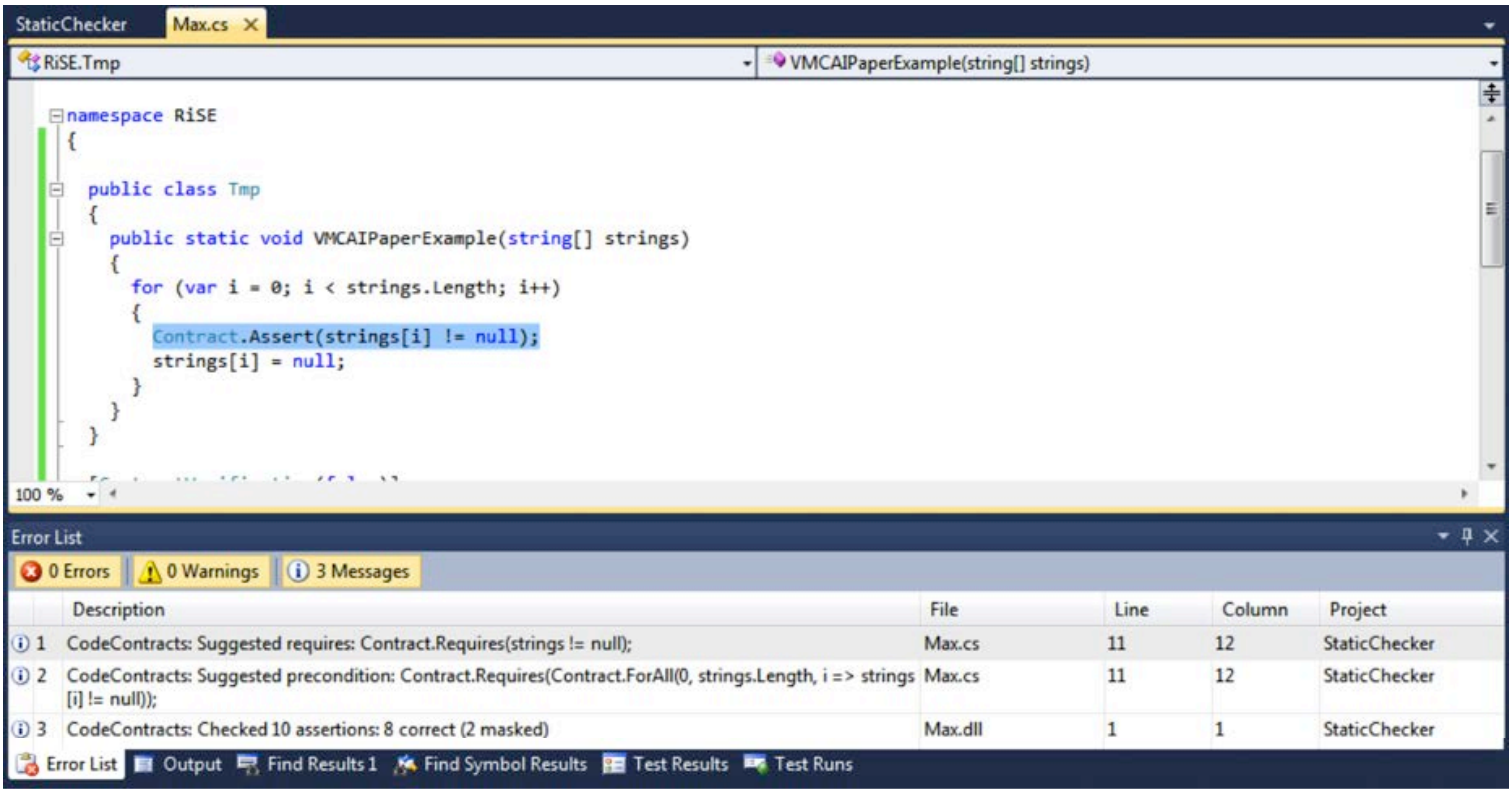
  Example: [non]-termination of *unbounded* programs



- Abstraction must be infinite, which is extremely difficult

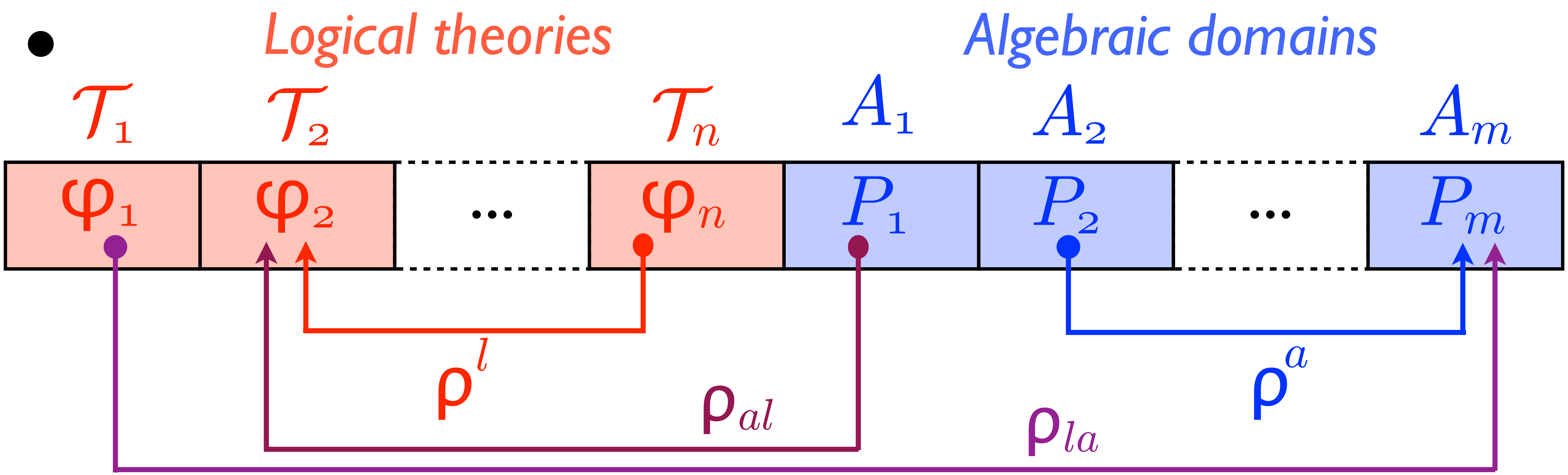
Under-approximation & arrays

- Previously: explore finite parts of a finite subset of executions
- New: algebraic approach to handle infinitely many infinite executions
- Example: pre-conditions ensuring the *presence* of errors



Combining algebraic & logical abstractions

- A *new understanding* of the Nelson-Oppen procedure to combine logical theories in SMT solvers/provers as an algebraic reduced product

- 

- When checking satisfiability of $\varphi_1 \wedge \varphi_2 \wedge \ldots \wedge \varphi_n$, the Nelson-Oppen procedure generates (dis)-equalities that can be propagated by ρ_{la} to reduce the P_i, $i=1,\ldots,m$
- $\alpha_i(\varphi_1 \wedge \varphi_2 \wedge \ldots \wedge \varphi_n)$ can be propagated by ρ_{la} to reduce the P_i, $i=1,\ldots,m$
- The purification to theory $\mathcal{T}_i$ of $\gamma_i(P_i)$ can be propagated to φ_i by ρ_{al} in order to reduce it to $\varphi_i \wedge \gamma_i(P_i)$ (in $\mathcal{T}_i$)

Termination

- Previously: recent progress on automatic proof of termination for *small, simple and pure programs* (no abstraction needed)
- Challenge: scale automatic program termination methods to large, *complex, and realistic programs* by integrating *abstraction*
- New advances:
  - Trace segments as a new basis for inductively formulating program properties
  - Fixpoint definition of a collecting semantics for termination/eventuality
  - Systematic ways for constructing termination proofs, by construction of abstract fixpoints (e.g. variant functions)

Probabilistic abstraction

- Fixpoint concrete collecting semantics parameterized by probabilistic scenarios:
  - $\langle \Omega, \ \mathcal{E}, \ \mu \rangle$ probabilistic space (scenarios, observable events, probability measure)
  - $\langle \mathcal{D}, \ \preceq \rangle$ conventional semantic domain
  - $S_p[\![\mathrm{P}]\!] \in \Omega \rightarrowtail \mathcal{D}$ probabilistic semantics
  - $\wp(\Omega \rightarrowtail \mathcal{D})$. concrete domain of probabilistic properties
- Several possible abstractions:
  - in the semantic domain
  - non-deterministic abstraction of the scenario domain
  - probabilistic abstraction in the scenario domain

  for conditionals and loops
- Recover classical probabilistic calculi and analyzes by abstraction

Advances in aerospace applications

- The paper

  Julien Bertrane, Patrick Cousot, Radhia Cousot, Jérôme Feret, Laurent Mauborgne, Antoine Miné, & Xavier Rival.
  Static Analysis and Verification of Aerospace Software by Abstract Interpretation. In *AIAA Infotech@Aerospace 2010*, Atlanta, Georgia. American Institute of Aeronautics and Astronautics, 20—22 April 2010. © AIAA.

  received the AIAA intelligent systems best paper award 2010

- All control/command software of a European aircraft manufacturer now mandatorily verified by abstract-interpretation based static analysis (in conformance with DO-178-C)

- Progress on the static verification of parallel processes

The End