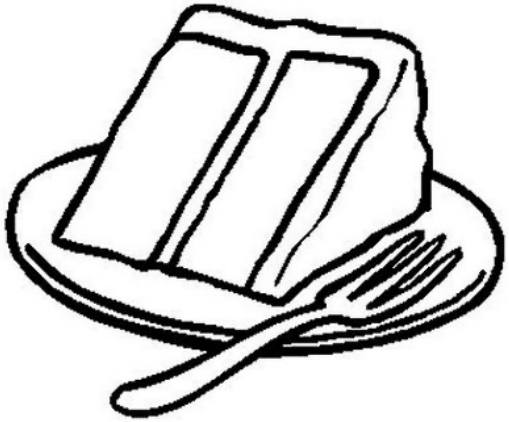
Have Your Verified Compiler And Extend It Too



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Sorin Lerner
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Compiler Correctness

Building robust compilers is difficult

complex interactions resist testing

Compiler bugs are contagious

invalidate source level guarantees

Few users extend their compiler

hand optimized, unreadable code

Verified Compilers

- Implement compiler in proof assistant
- Prove compiler correct interactively
- CompCert [Leroy], Lambda Tamer [Chlipala]

Strong Guarantee

Difficult to Extend

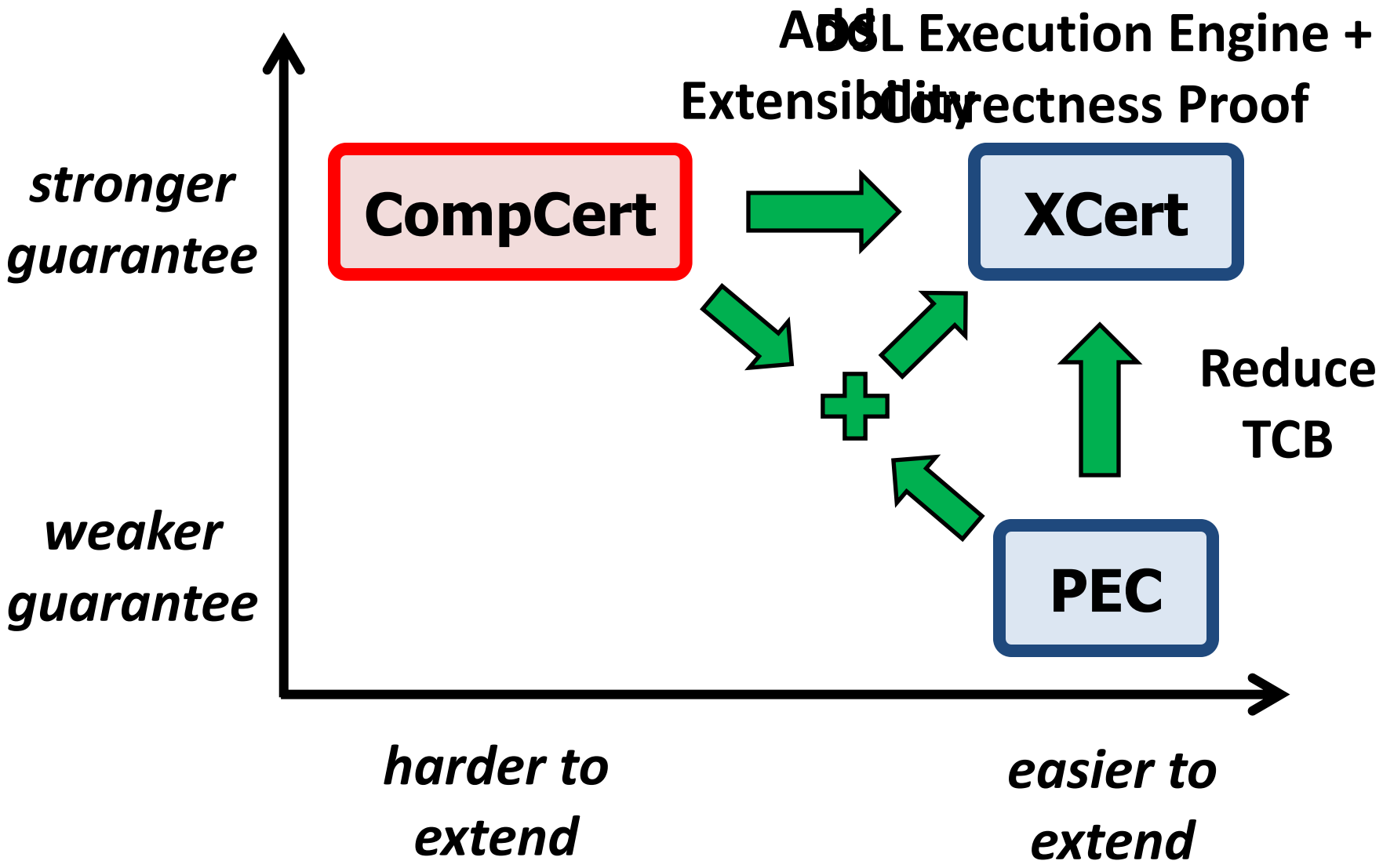
DSL-based Compilers

- Domain Specific Language for optimizations
- DSL opts proven correct automatically
- Rhodium [POPL 05], PEC [PLDI 09]

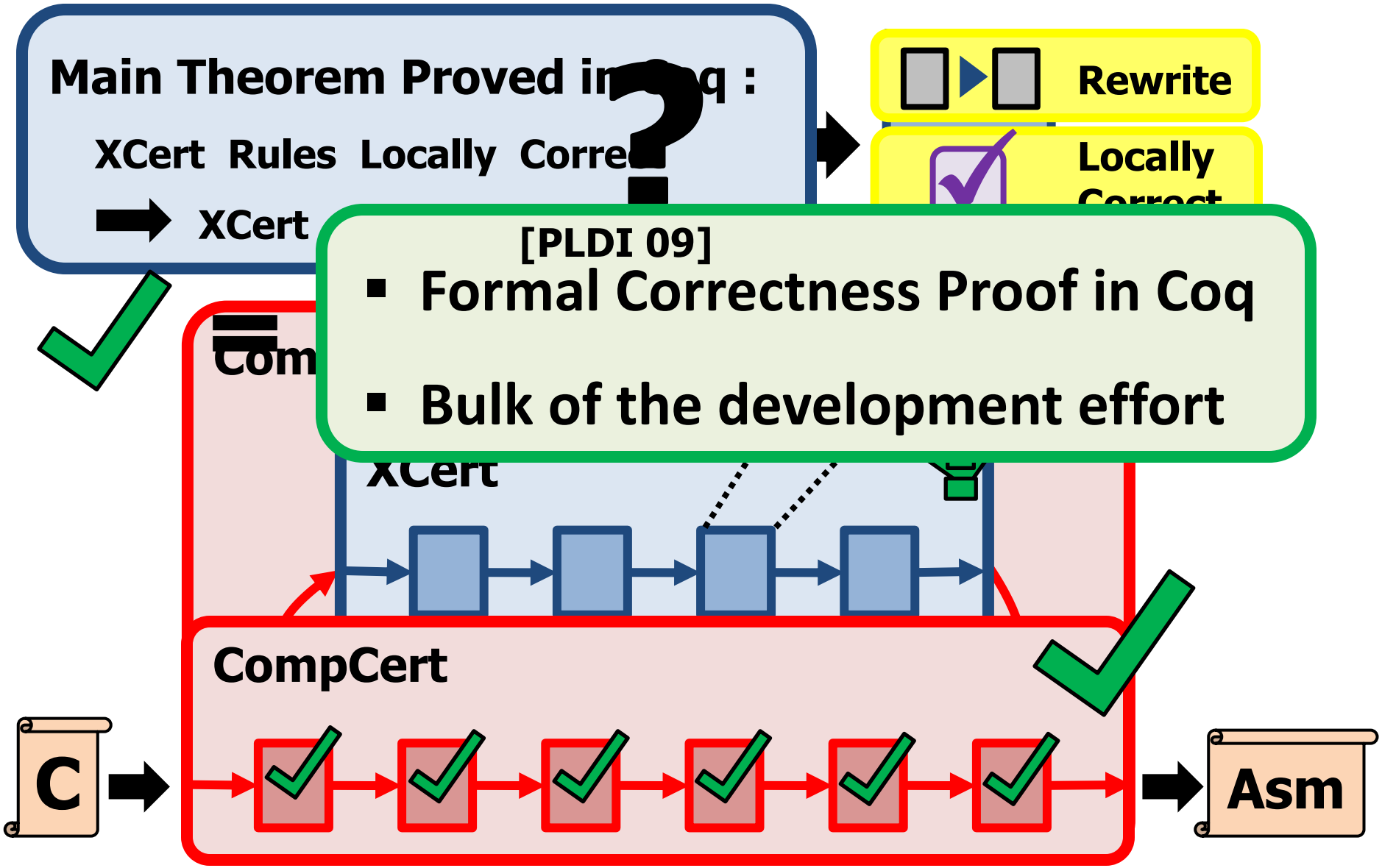
Easier to Extend

Weaker Guarantee

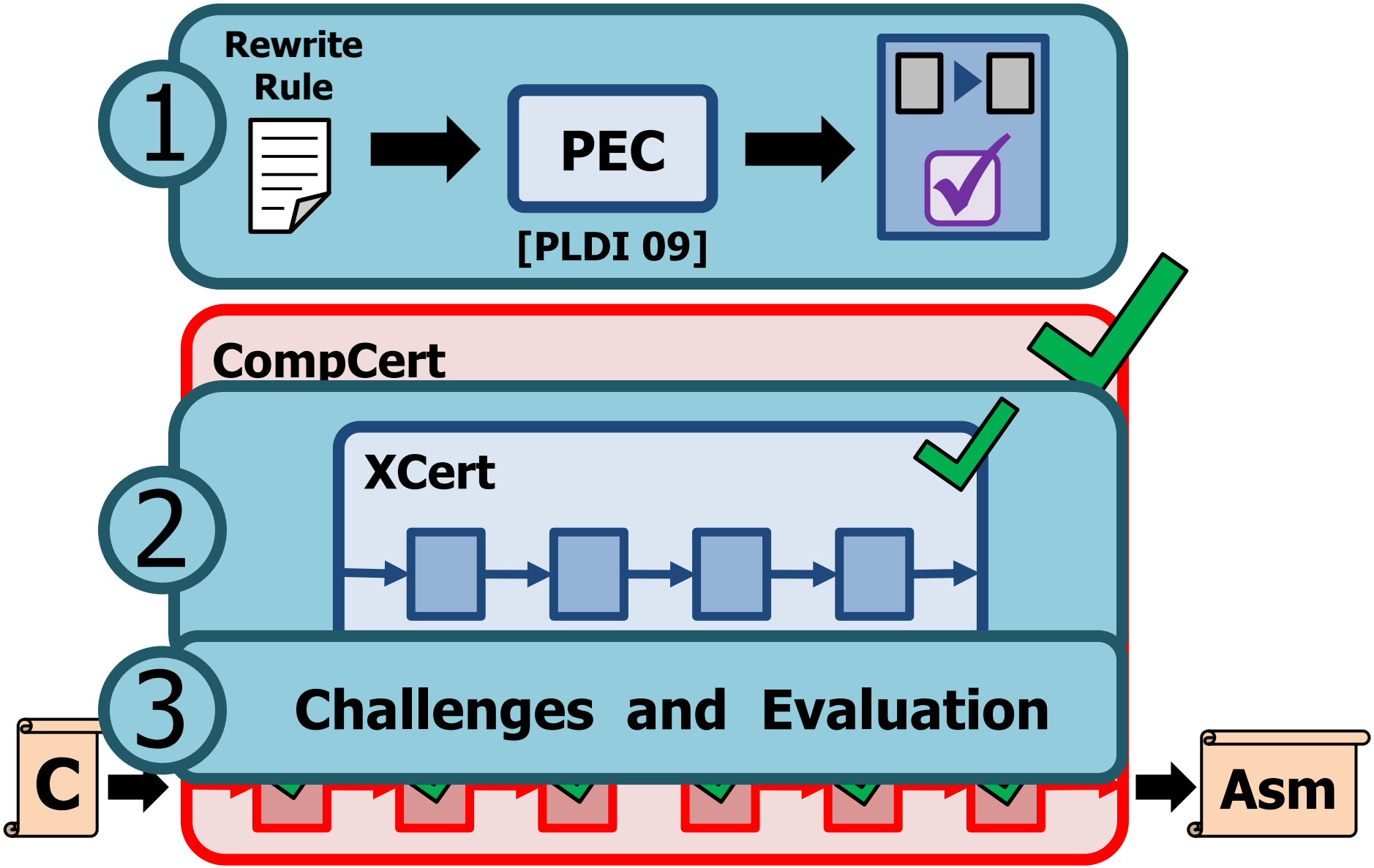
Contribution



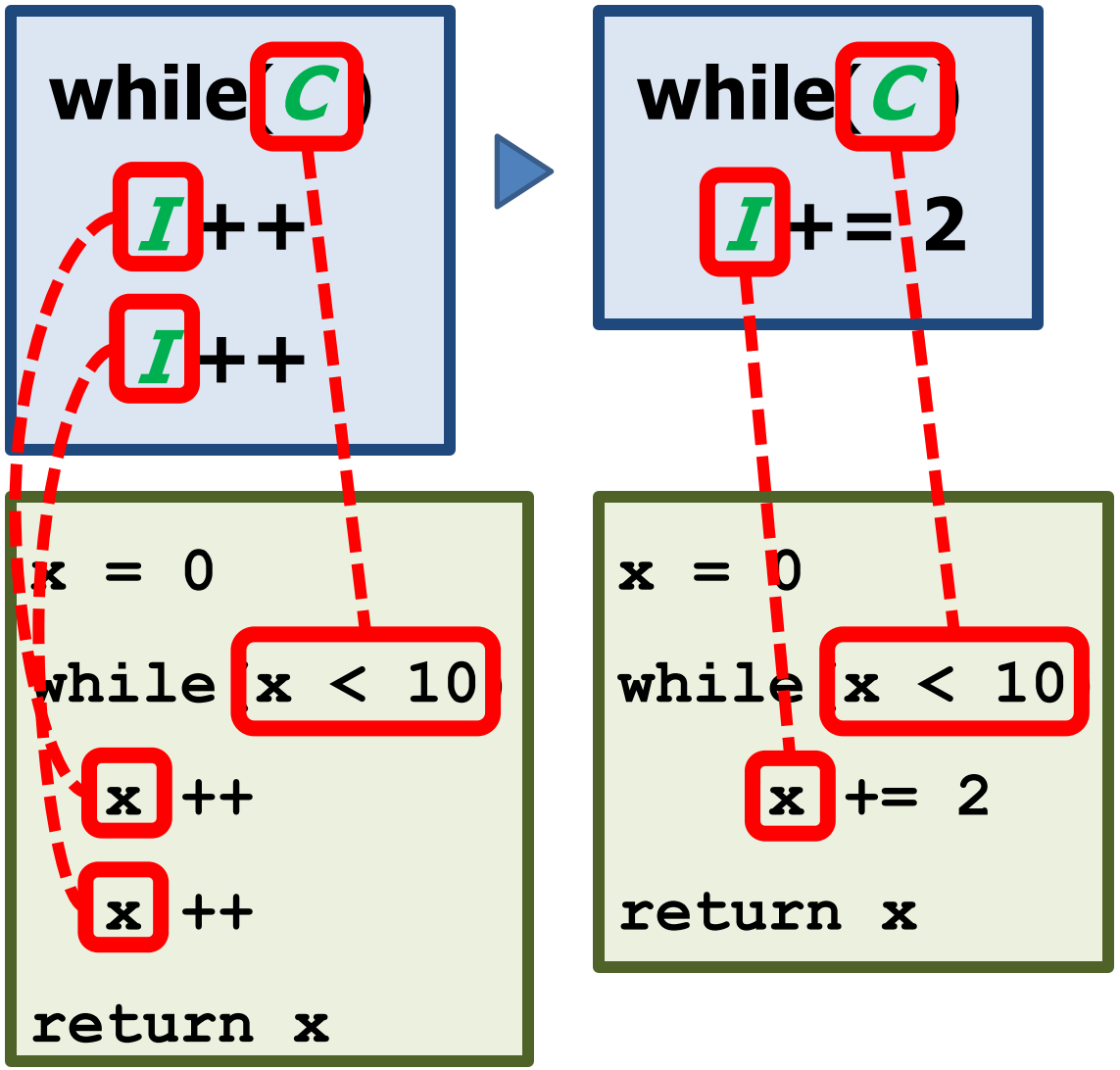
Extensible & Certified Compiler



Extensible & Correct Compiler



[PLDI 09]



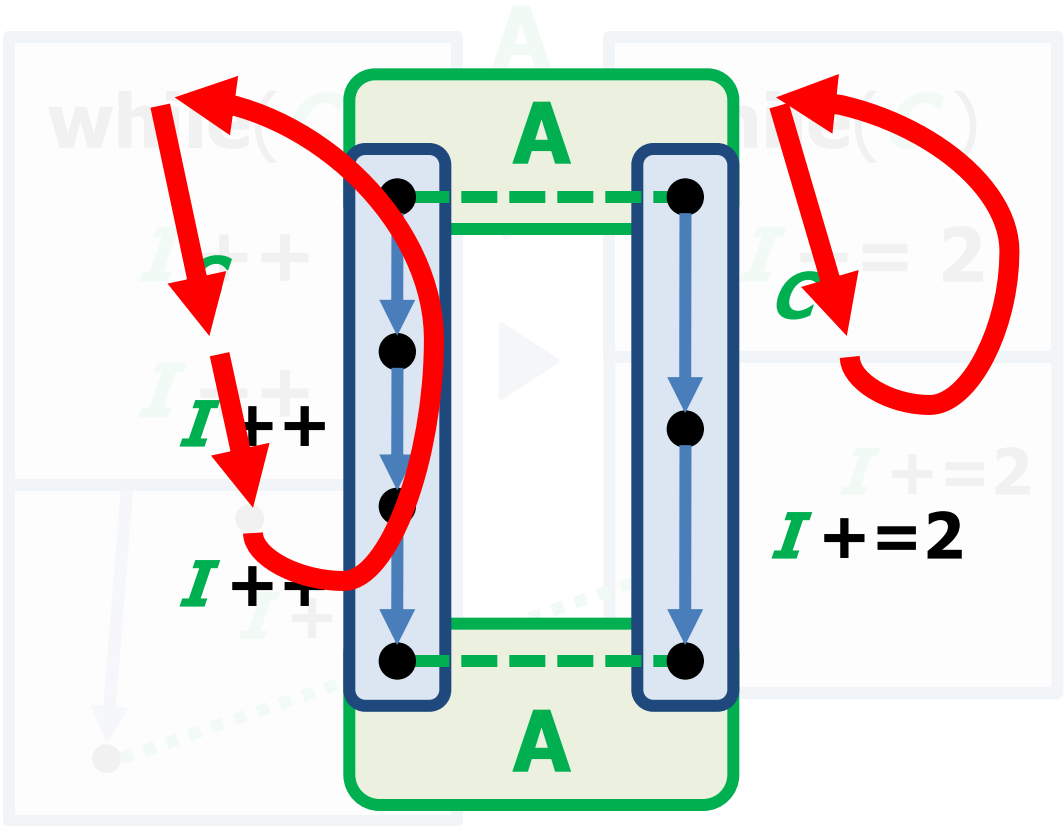
Rewrite Rule

- Find & Replace
- Match Pattern

  C → x < 10

  I → x
- Apply Subst

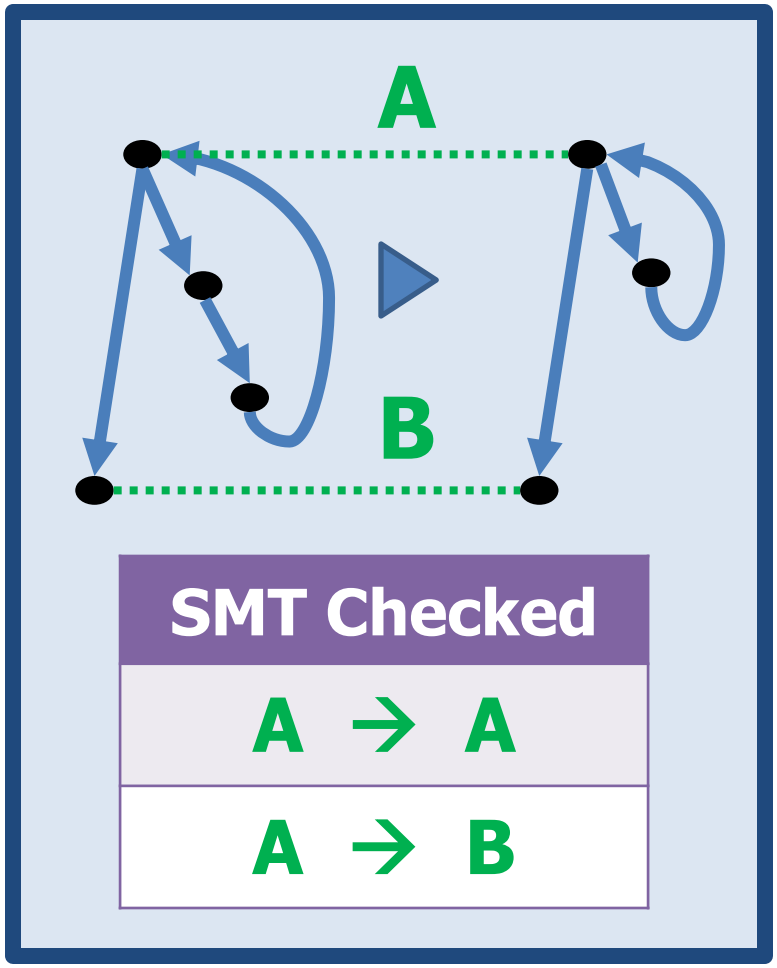
[PLDI 09]



PEC Checker

1. Convert to CFG
2. Guess Sync Points
3. Check w/ SMT

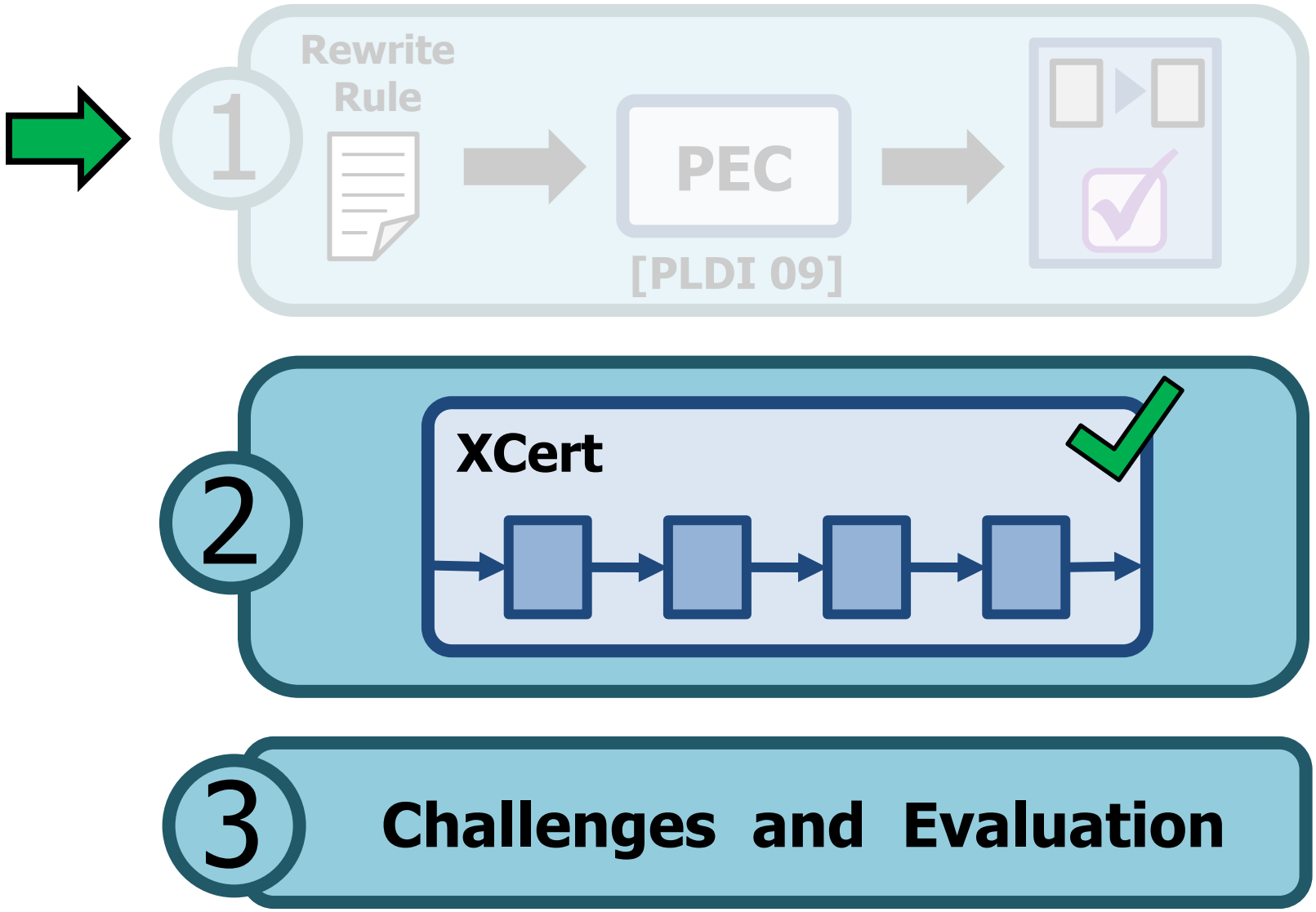
SMT Checked
A → A ✓
A → B ✓



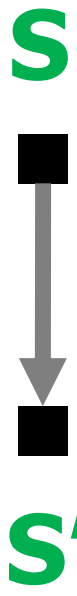
XCert Module

1. Rule in Coq
2. SMT Checks

Extensible & Correct Compiler



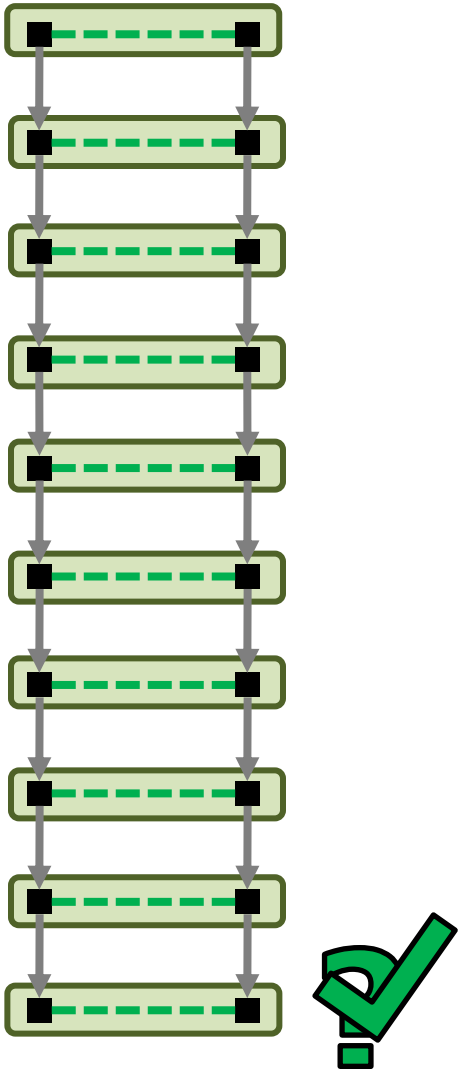
XCert Correctness Proof



Small Step

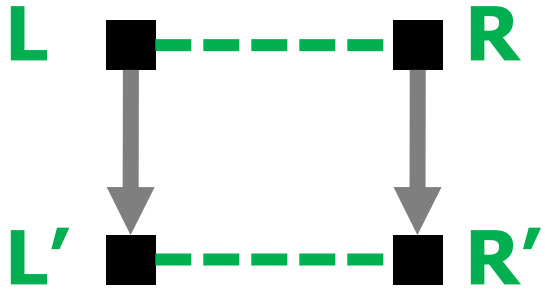
- Execute instruction
- Step state **S** to **S'**

XCert Correctness Proof



Equivalent Executions

- Initial Equiv ➡ Final Equiv
- Prove Simulation Diagram

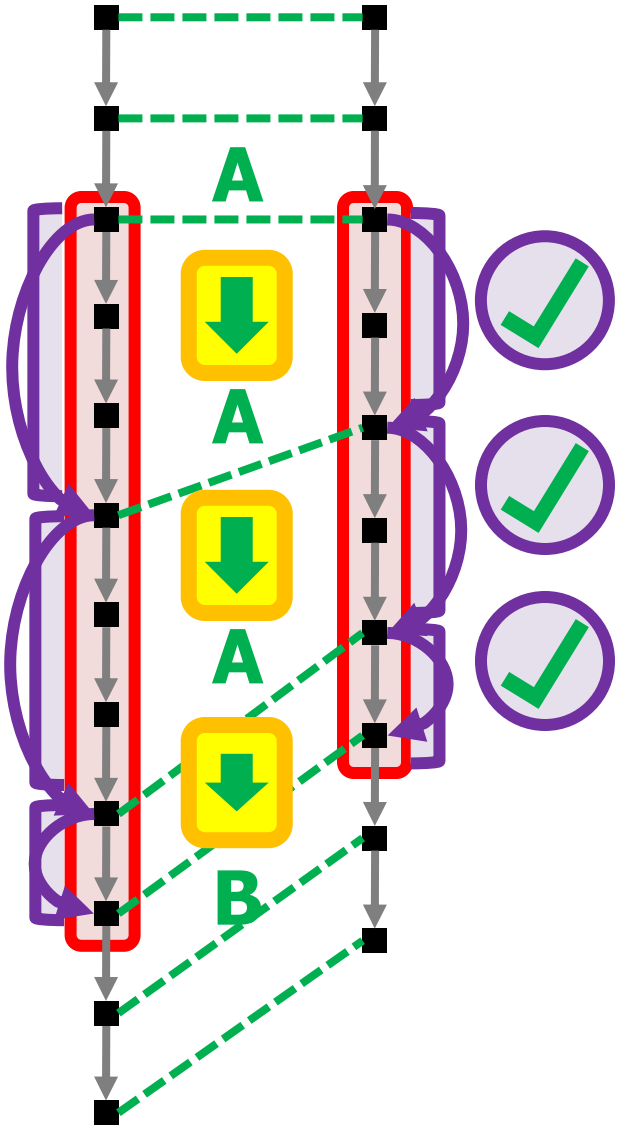


- CompCert Small Step Library:

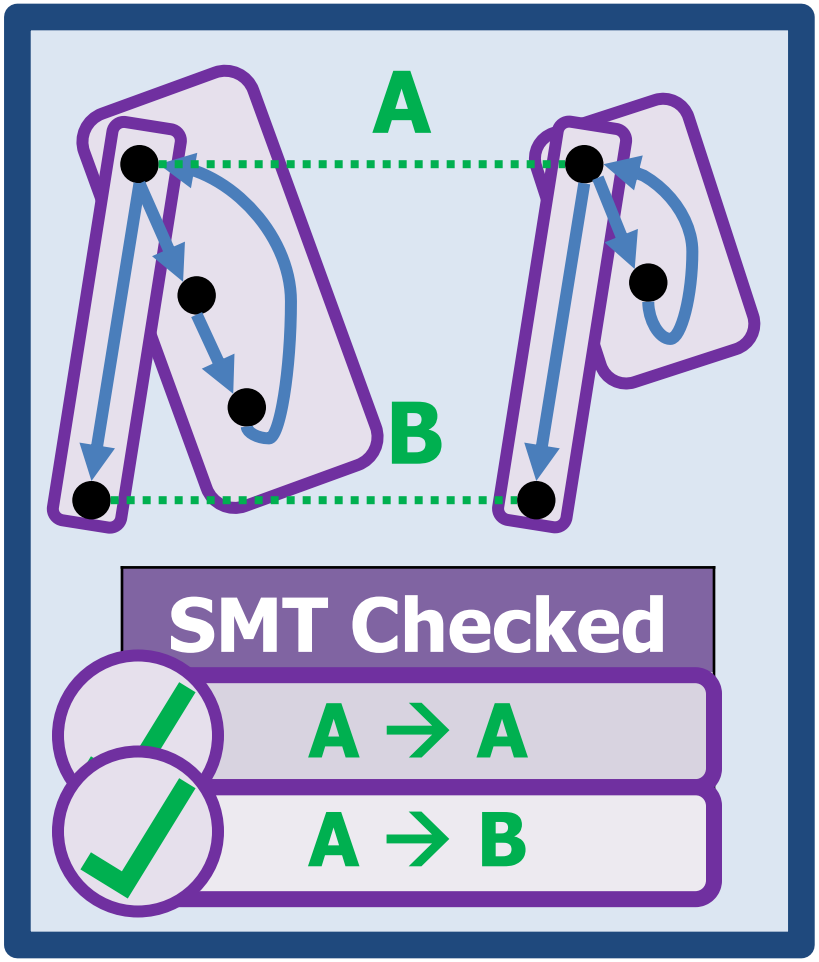
$$\frac{L \sim R \quad \wedge \quad L \Rightarrow L'}{\text{Sim Diagram} \quad \Rightarrow \quad \text{Progs Equiv}}$$

$$\exists R' : R \Rightarrow R' \quad \wedge \quad L' \sim R'$$

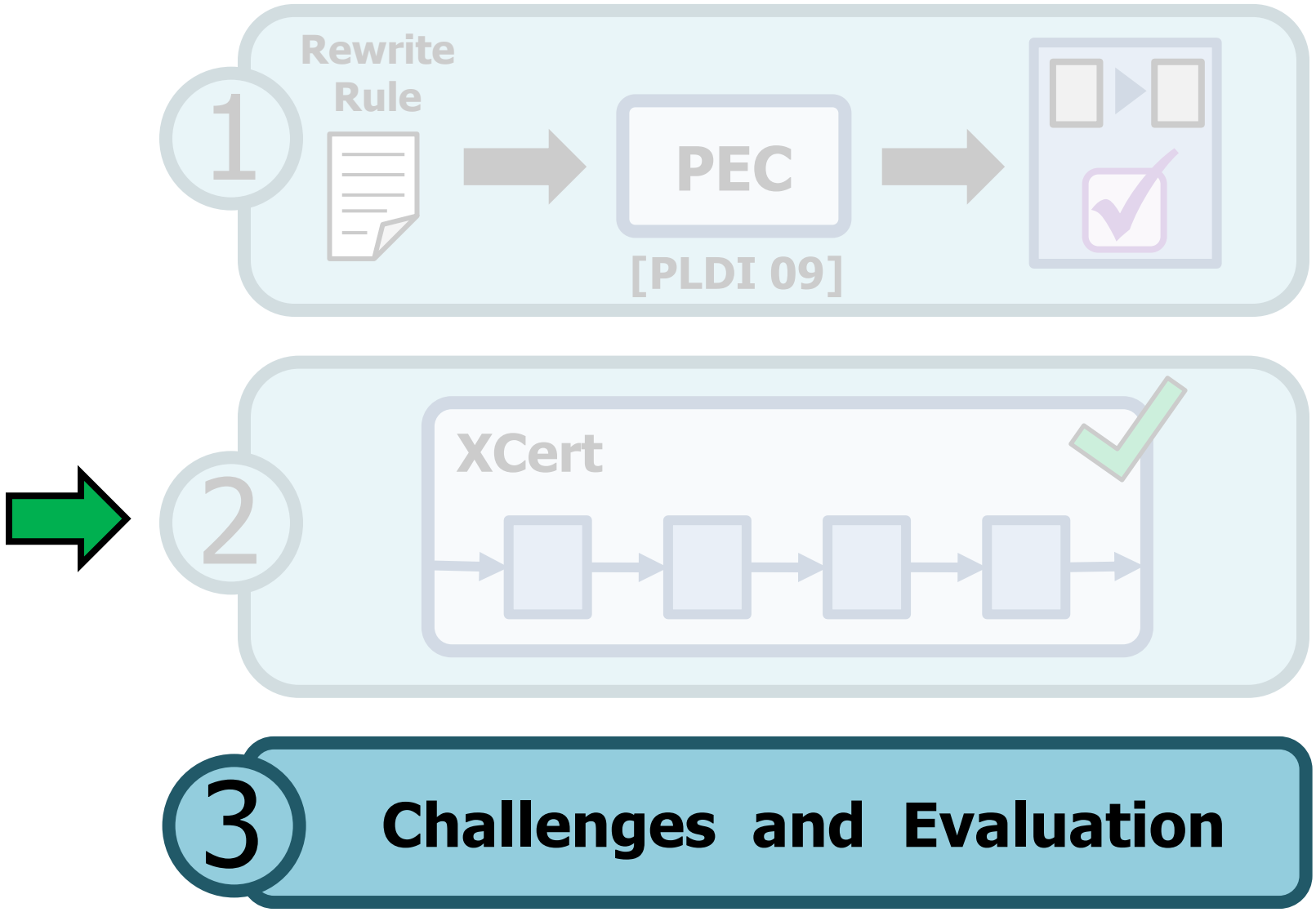
XCert Simulation Diagram



XCert Module



Extensible & Correct Compiler



Challenges (see paper)

XCert Execution Engine

- CFG pattern matching
- CFG splicing

XCert Correctness Proof

- Managing case explosion
- Verified validation **[Tristan and Leroy]**
- Preserving non-terminating behaviors

Evaluation

Engine : 1,000 lines of Coq functional code

Proof : 3,000 lines of Coq proof script

Trusted Computing Base (TCB)

- Compcert : Coq + Coq encoding of C sem
- XCert adds : SMT + SMT encoding of C sem

Evaluation

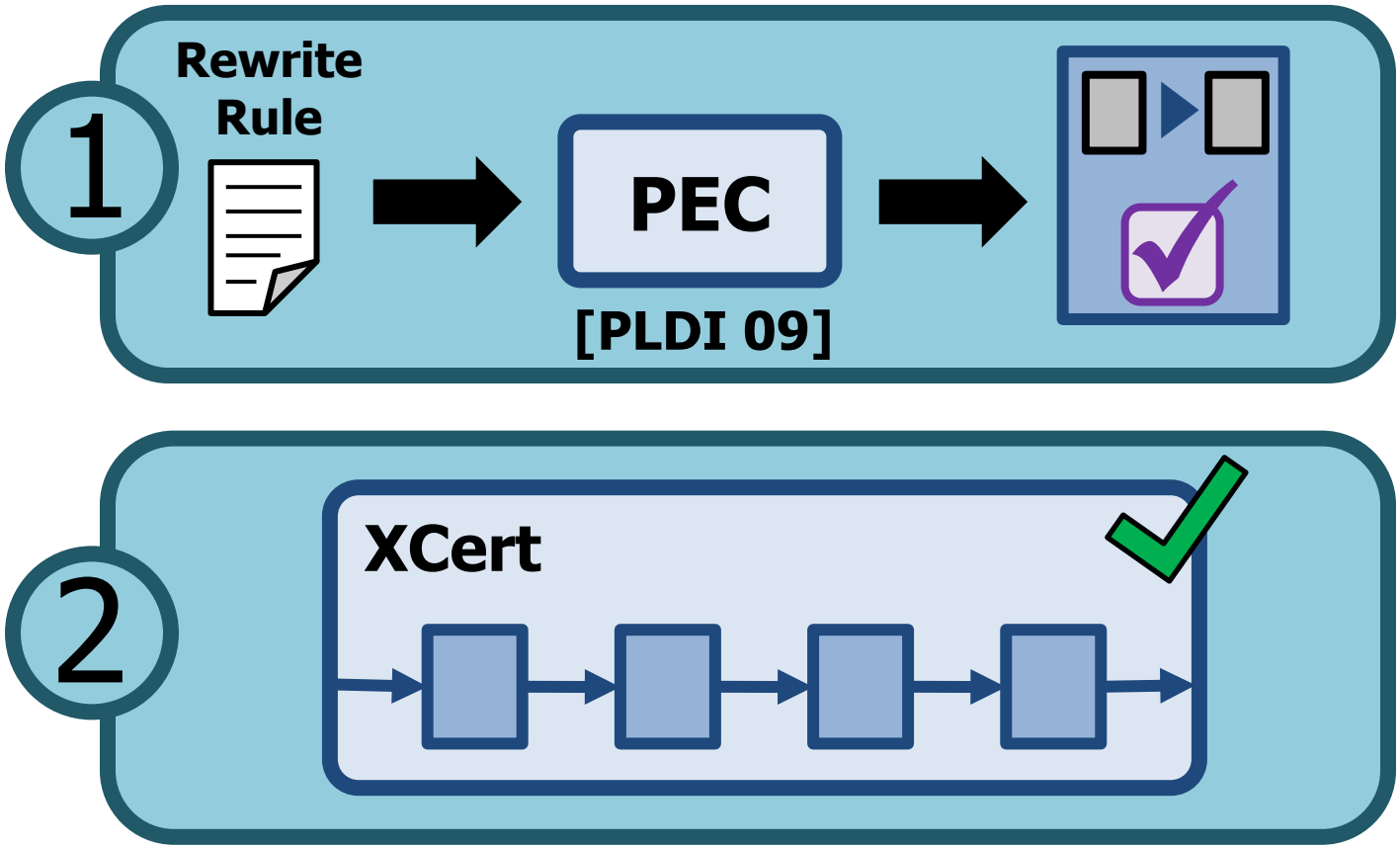
Extensibility: Support PEC Opts **[PLDI 09]**

- No manual proof effort or TCB increase
- Maintain Compcert end-to-end correctness

Sample of Optimizations Run:

Loop Invariant Code Hoist	**Loop Peeling**
Software Pipelining	**Conditional Speculation**
Loop Unswitching	**Partial Redundancy Elim**

Extensible & Correct Compiler



Thank You!