Countering Trusting Trust through Diverse Double-Compiling

David A. Wheeler

February 28, 2006
(Minor update from December 2, 2005)

http://www.dwheeler.com/trusting-trust

This presentation contains the views of the author and does not necessarily indicate endorsement by IDA, the U.S. government, or the U.S. DoD.

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Outline

- Trusting trust attack
  - What it is
  - Attacker motivations
  - Triggers & payloads
- Inadequate solutions & related work
- Solution: Diverse double-compiling (DDC)
  - What it is
  - Why it works (assumptions, justification)
  - How to increase diversity
  - Practical challenges
- Demo: tcc
- Limitations & broader implications

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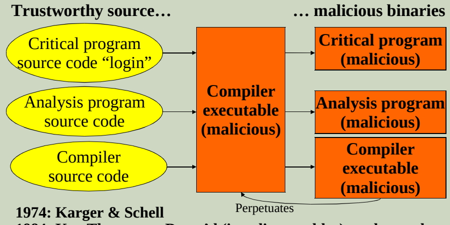
Trusting trust attack

Trustworthy source… **… malicious binaries**



1974: Karger & Schell
1984: Ken Thompson. Demo'd (inc. disassembler), undetected

Fundamental security problem

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Attacker motivations

- Huge benefits – Controlling a compiler controls everything it compiles
  - Controlling 2-3 compilers would control almost every computer worldwide
- Risks low – no viable detection technique
- Costs low...medium
  - Requires one-time write of trusted binary
    - Not necessarily easy, but *someone* can, one-time, & not designed to withstand determined attack
  - Even if costs were high, the power to control every computer would be worth it to some

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Triggers & payloads

- Attack depends on triggers & payloads
  - Trigger: code detects condition for performing malicious event (in compilation)
  - Payload: code performs malicious event (i.e., inserts malicious code)
- Triggers or payloads can fail
  - Change in source can disable trigger/payload
- Attackers can easily counter
  - Insert multiple attacks, each narrowly scoped
  - Refresh periodically via existing compromises

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Inadequate solutions & Related work

- Manual binary review: Size, subverted tools
- Automated review / proof of binaries: Hard
- Recompile compiler yourself: Fails if orig. compiler malicious, massive diligence
- Interpreters just move attack location
- Draper/McDermott: Compile paraphrased source or with 2nd compiler, then recompile
  - Any who care must recompile their compilers
  - Can't accumulate trust – can still get subverted
  - Helps; another way to use 2nd compiler?

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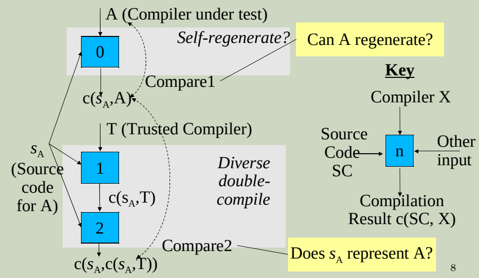
Solution: Diverse double-compiling

- **Developed by Henry Spencer in 1998**
  - Check if compiler can self-regenerate
  - Compile source code twice: once with a second "trusted" compiler, then again using result
  - If result bit-for-bit identical to original, then source and binary correspond
- **Never described/examined/justified in detail**
- **Never tried**

Diverse double-compiling in pictures



Why does it work?

Assuming:

1. Have trusted: compiler T, DDC environment, comparer, process to get s_A & A

   Trusted = triggers/payloads, if any, are different
2. T has same semantics as A for what's in s_A
3. Flags etc. affecting output identical
4. Compiler s_A deterministic (control seed if random)

Then:

1. c(s_A,T) functionally same as A – same source code!
2. If A malicious, doesn't matter – never run in DDC!
3. Final result bit-for-bit equal iff s_A represents A – only an untainted compiler, with identical functionality, creates the final result!

How to increase diversity

- Trusted Compiler T must not have triggers/payloads for compiler A
- Could prove T's binary – hard
- Alternative: increase diversity
  - Compiler implementation (maximally different)
  - Time (esp. old compiler as trusted compiler)
  - Environment
  - Source code mutation/paraphrasing

Practical challenges

- Uncontrolled nondeterminism
- May be no alternative compiler that can handle *s*
  - Can create, or hand-preprocess
- "Pop-up" attack
  - Attacker includes self-perpetuating attack in only some versions (once succeeds, it disappears)
  - Defenders must thoroughly examine every version they accept, not just begin/end points
- Multiple compiler components
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- Inexact comparison (e.g., date/time stamp)

Demo: tcc

- Performed on small C compiler, tcc
  - Separate runtime library, handle in pieces
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  - x86: Constants -127..128 can be 1 byte (vs. 4)
  - tcc detects this with a cast (prefers short form)
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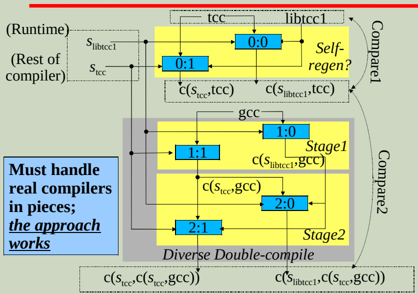
Diverse double-compilation of tcc



Limitations

- Not absolute proof (unless T & environment proved)
  - But you can make as strong as you wish
  - Hard to overcome & can use more tests/diversity
- Only shows source & binary correspond
  - Could still have malicious code in source
  - But we have techniques to address that!
- A's source code must be available (easier for FLOSS)
- Source/binary correspondence primarily useful if you can see compiler source
- Not yet demonstrated on larger scale – doing that now
- Easier if language standard & no software patents
  - Visual Basic patent app for "isNot" operator

Broader implications

- Practical counter for trusting trust attack
- Can expand to TCB, whole OS, & prob. hardware
- Governments could require info for evals
  - Receive all source code, inc. build instructions:
    - Of compilers: so can check them this way
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  - Could establish groups to check major compiler releases for subversion
- Insist languages have public unpatented specifications (anyone can implement, any license)
- Source code examination now justifiable

In the News...

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Recent Work: Relaxing Constraint: Compiler Need not be Self-compiled

- Instead of self-compiling, can use parent compiler P
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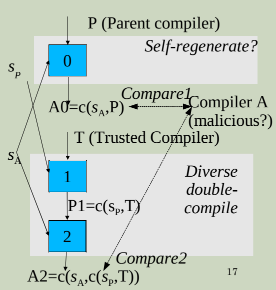

Backup

Can DDC be used with hardware?

- Probably; not as easy for pure hardware
- Requires 2nd implementation T
  - Alternative hardware compiler, simulated chip
- Requires "equality" test
  - Scanning electron microscope, focused ion beam
- Requires knowing exact correct result
  - Often cell libraries provided to engineer are *not* the same as what is used in the chip
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Can this scale up?

- Believe so; best proved by demonstration
- Working with"real" compiler: gcc
- Step 1: Real compiler, less diversity
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- Publicized by Ken Thompson, 1984
  - Back door in "login" source code would be obvious
  - Could insert back door in compiler source; login's source is clean, compiler source code is not
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Fundamental security problem

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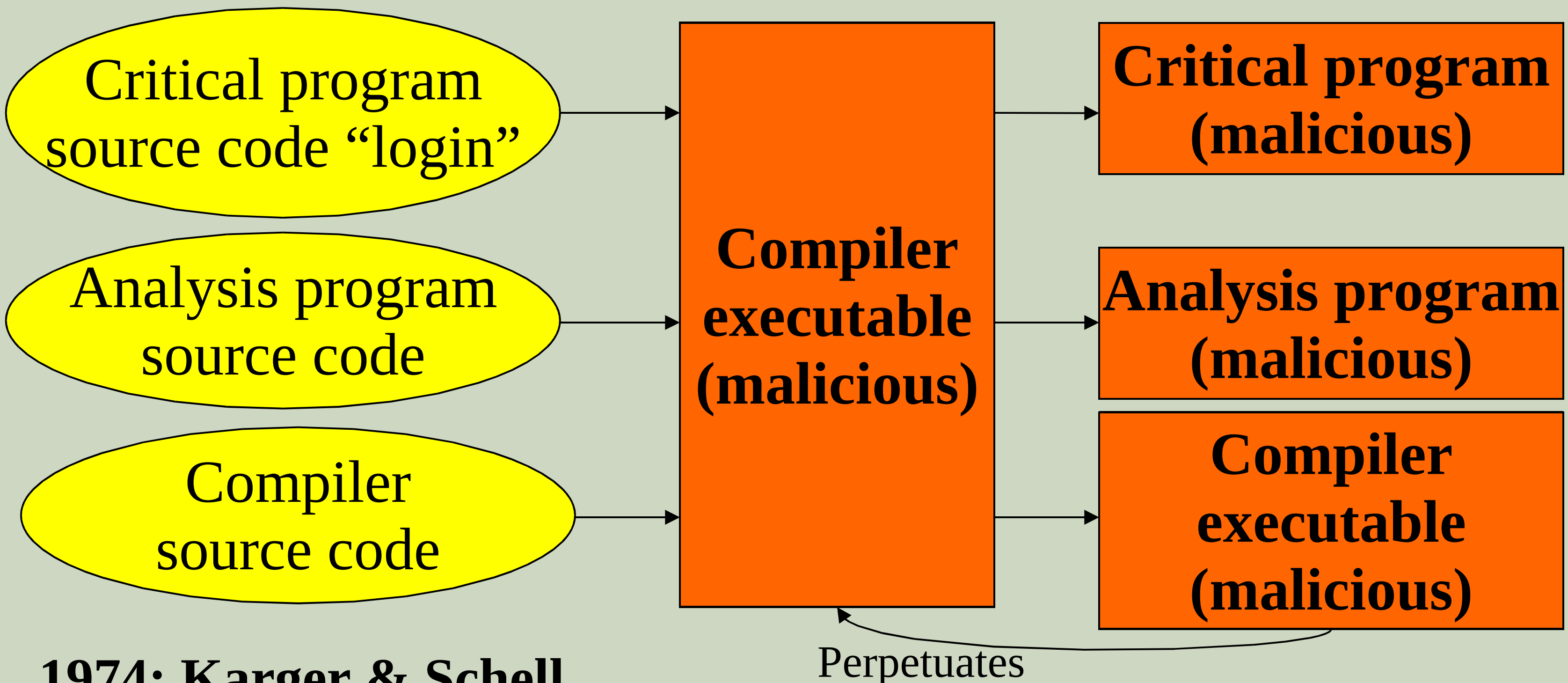

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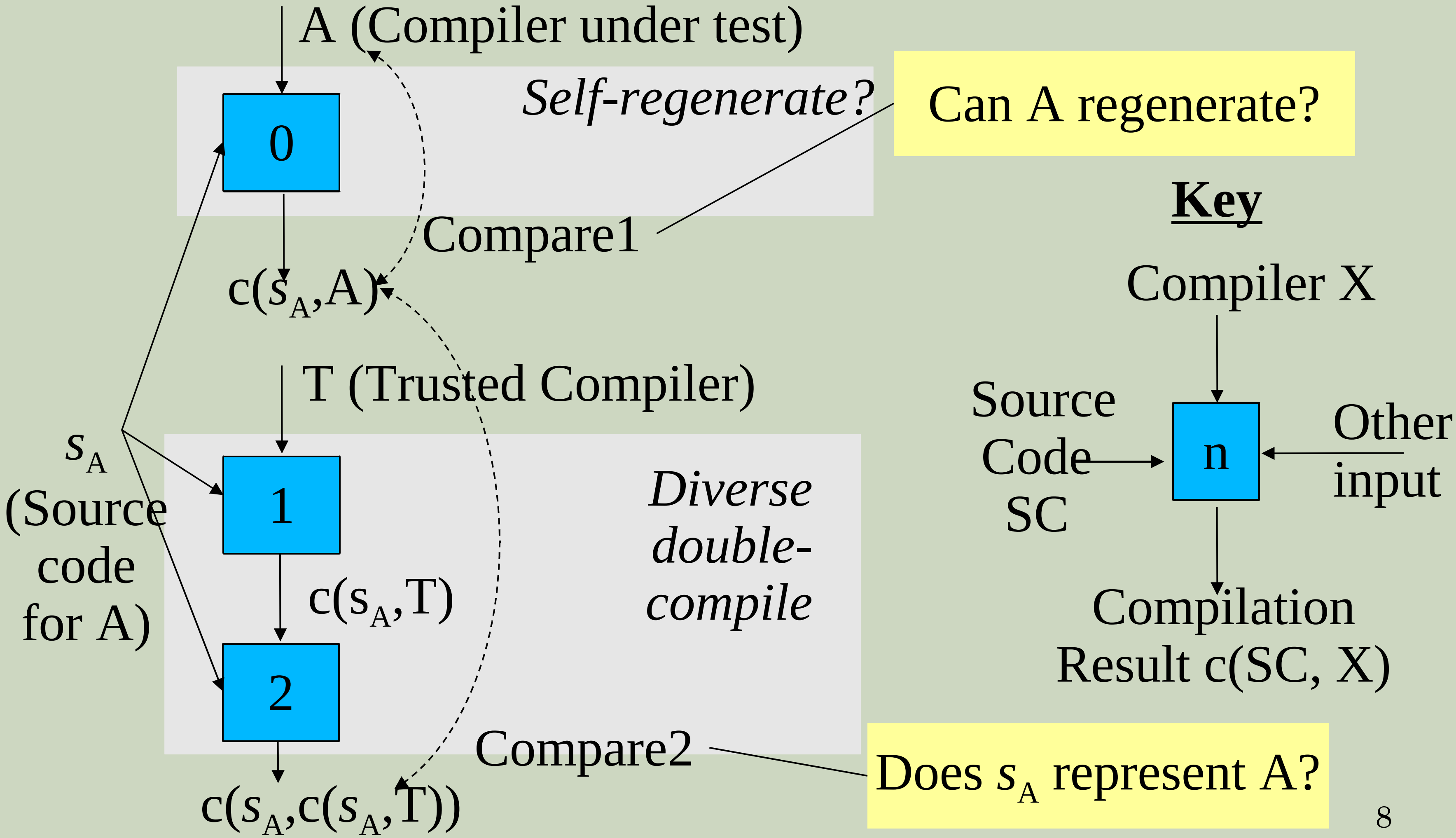

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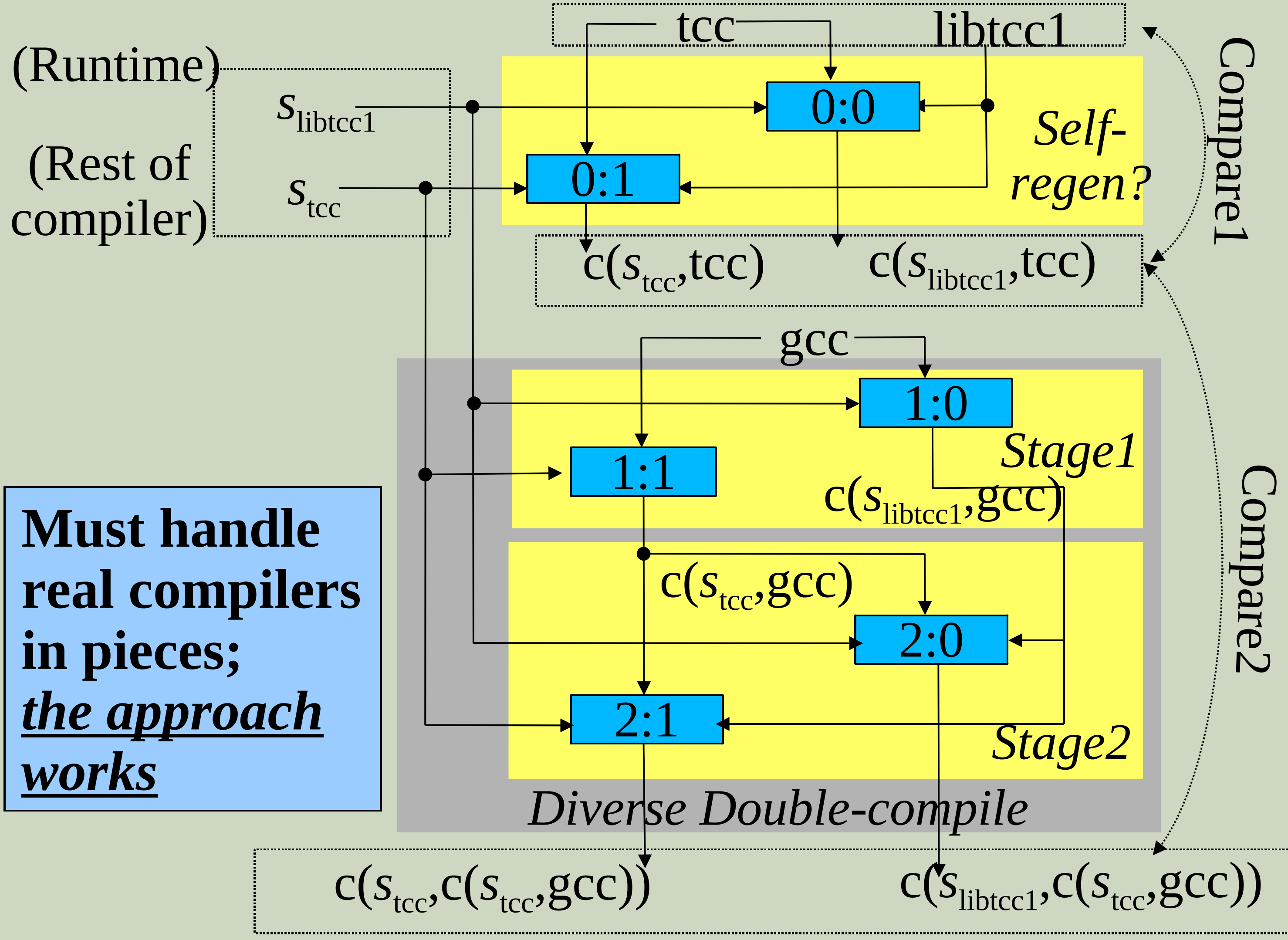

Must handle real compilers in pieces; *<u>the approach works</u>*

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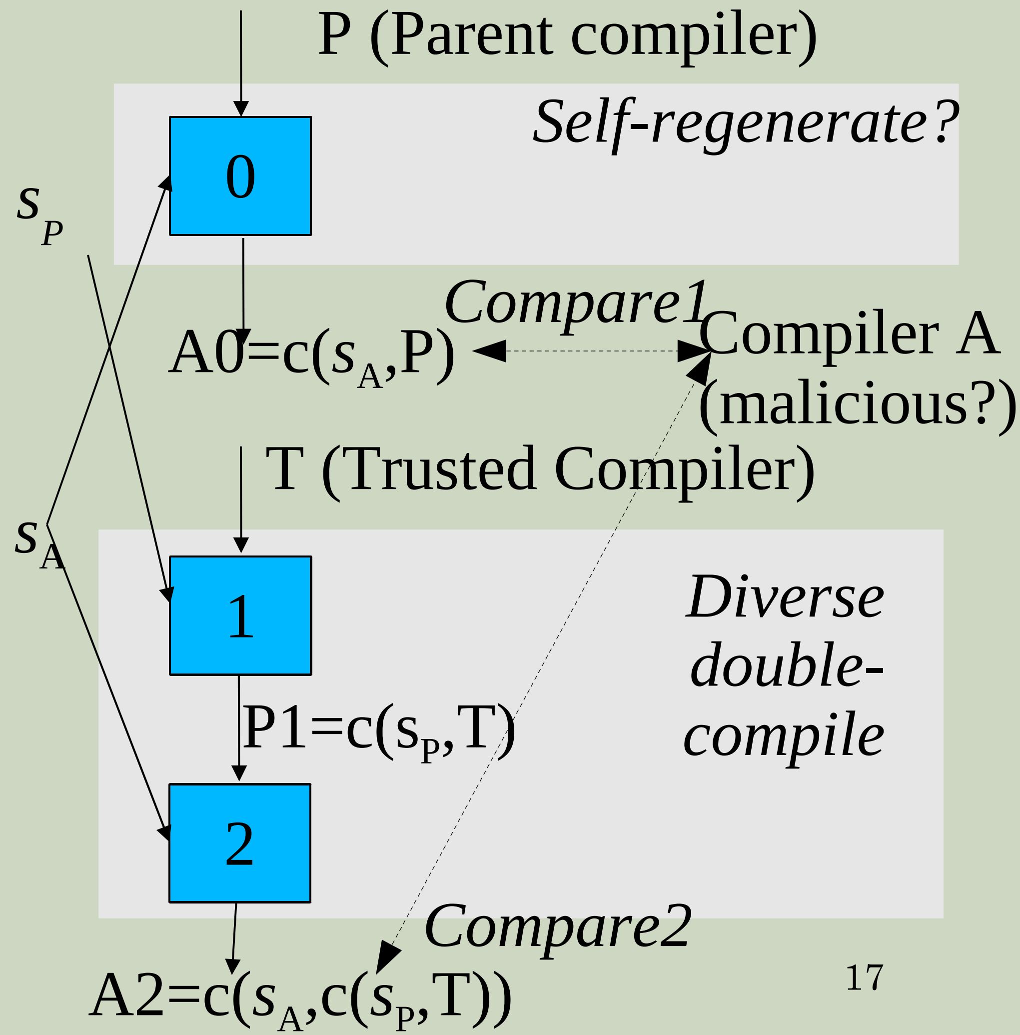

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