Inria PROSECCO

More Secure Software Systems

by Formal Verification, Property-Based Testing, Secure Compilation, and Dynamic Monitoring

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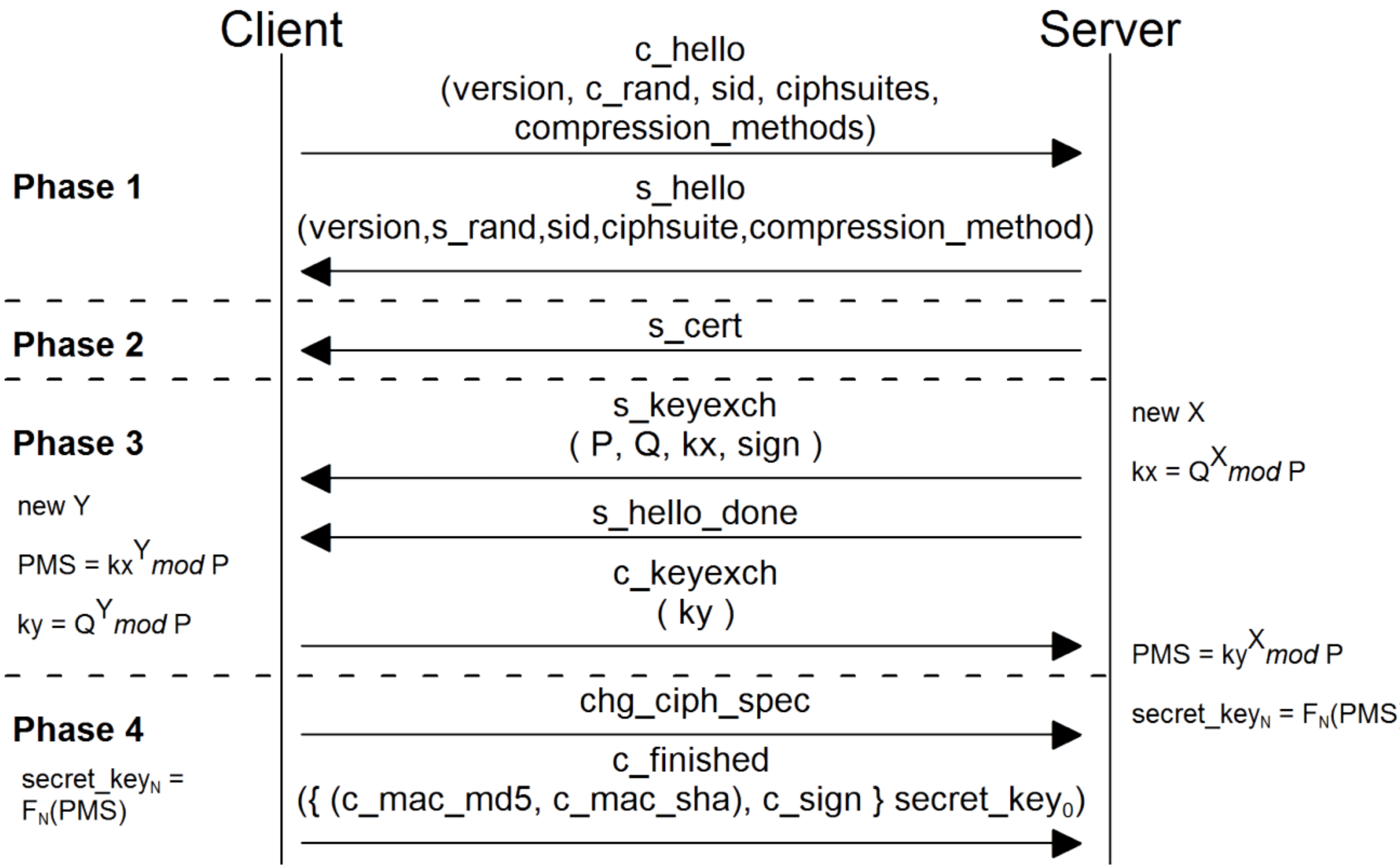
Software [in]security is a big problem

e.g. vulnerabilities in TLS (Prosecco)

Formal verification can help

- … find bugs & prove security
- ProVerif & CryptoVerif
  - Prosecco tools for *automatically* analyzing the security of crypto protocol *models*
  - successful for finding logical flaws early in protocol design phase

Formal verification can help



Formal verification can help

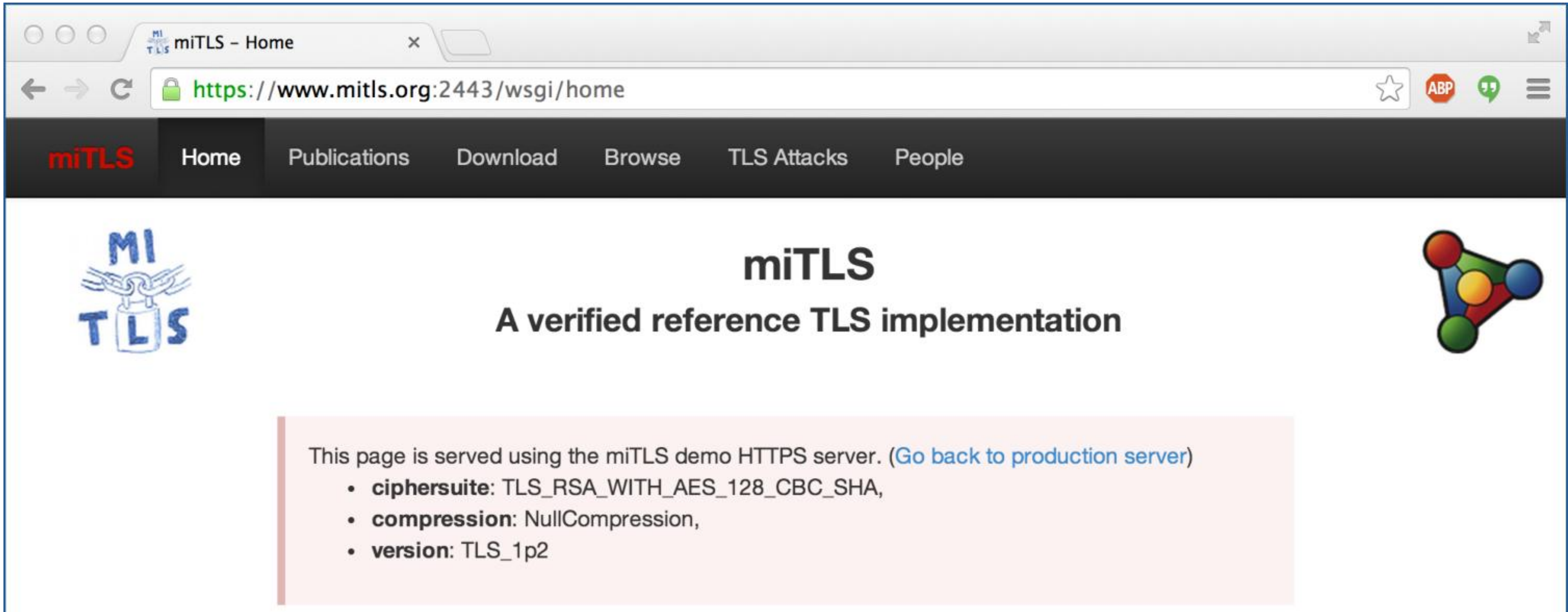
- … find bugs & prove security
- ProVerif & CryptoVerif
  - Prosecco tools for *automatically* analyzing the security of crypto protocol *models*
  - successful for finding logical flaws early in protocol design phase
- Just that **models are very abstract**
  - previous proofs of TLS models **missed** implementation attacks
- Verified models are cool
  - **but verified implementations are much coolear**

Verifying implementations with F*

- **F* is a new programming language**
- … putting together:
  - **impure functional programming** in ML
    - extracts to OCaml and F#, interoperates
  - the **automation** of SMT-based verification systems
    - like in Why3, Frama-C, Boogie, VCC, Dafny
  - the **expressive power** of interactive proof assistants based on dependent types
    - like in Coq, Agda, or Lean

miTLS*

- Formally verified reference implementation of TLS 1.2 in F* (working towards TLS 1.3)
- Written from scratch focusing on verification



The limits of formal verification

- **scalability**
  - state of the art for verifying correctness and security of systems is 10.000-20.000 LOC (and 500.000 LOP)
- **legacy code** (e.g. OpenSSL)
  - vs nice fresh reference implementations (e.g. miTLS*)
- **effort of failed proofs** (automatic or interactive)
  - finding bugs by failed proof attempts very costly
  - **can find very interesting bugs by testing**

SMACKTest: testing TLS state machine

Live state machine attack testing.

Run tests against your browser

SmackTest can connect your browser to a FlexTLS instance and model various SMACKTLS traces that will try to trick your TLS instance into adopting an insecure state. Start

Run tests against your server

SmackTest can create a FlexTLS instance that can evaluate SMACKTLS tests against a server and return detailed trace results. Server (eg. myserver.com Start

Downloads

- USENIX paper (WOOT 2015): PDF
- USENIX slides (WOOT 2015): PDF
- FlexTLS source code: TAR

SMACKTest: testing TLS state machine

Live state machine attack testing.

ClientHello
ServerHello
ServerCertificate
ServerKeyExchange
Authenticate Client
ServerCertificateRequest
ServerHelloDone
ClientCertificate
ClientKeyExchange
ClientCertificateVerify
ClientCCS
ClientFinished
ServerNewSessionTicket

If the test does not begin, click here to launch it manually, then return to this tab to inspect results.

298: Test incomplete. Click for detailed log.

297: Test incomplete. Click for detailed log.

296: Test failed. Click for detailed log.

295: Test succeeded. Click for detailed log.

294: Test incomplete. Click for detailed log.

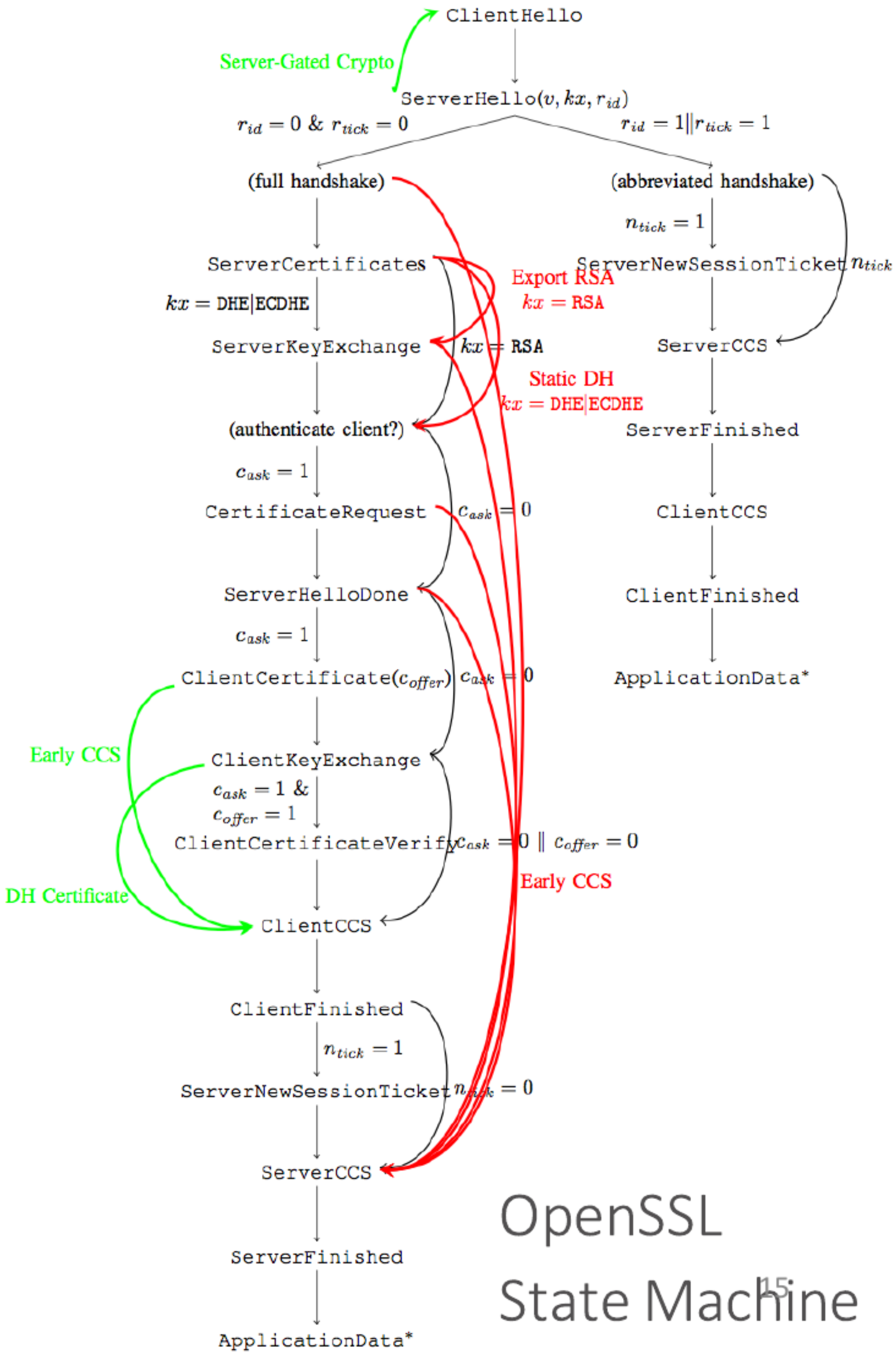
293: Test incomplete. Click for detailed log.

292: Test incomplete. Click for detailed log.

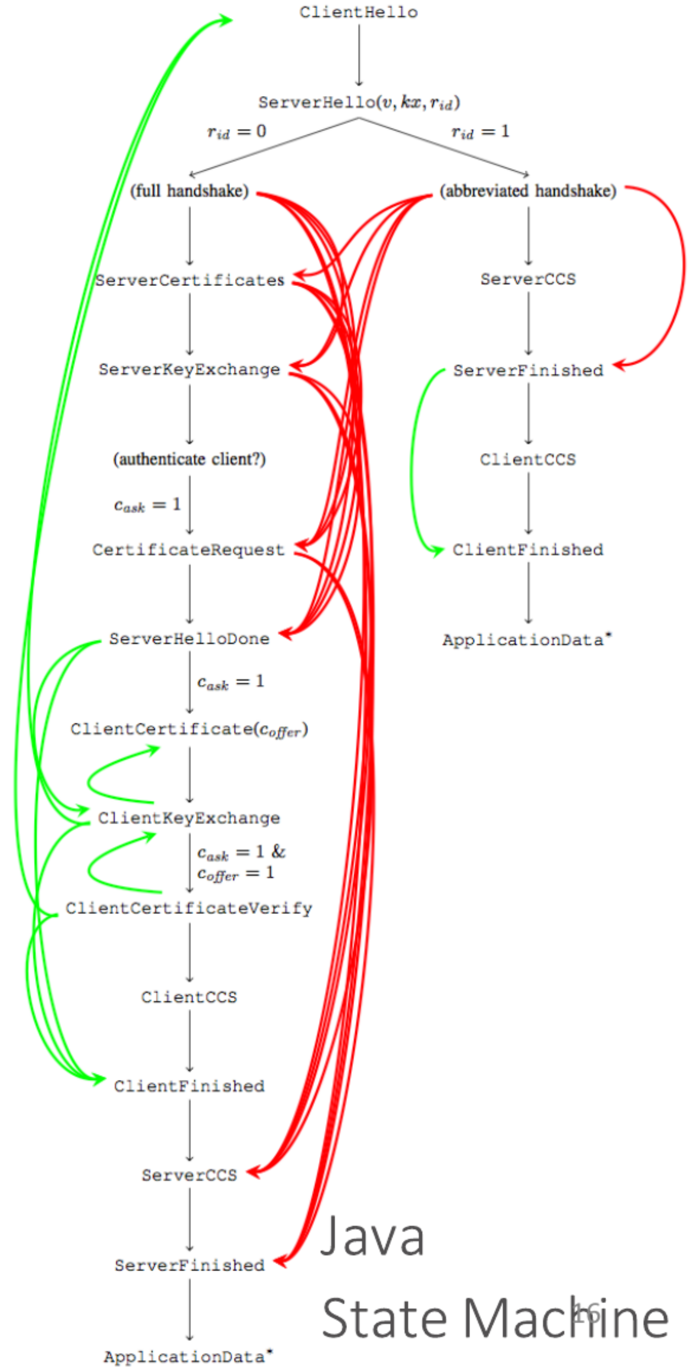
291: Test incomplete. Click for detailed log.

290: Test incomplete. Click for detailed log.

289: Test succeeded. Click for detailed log.



OpenSSL State Machine

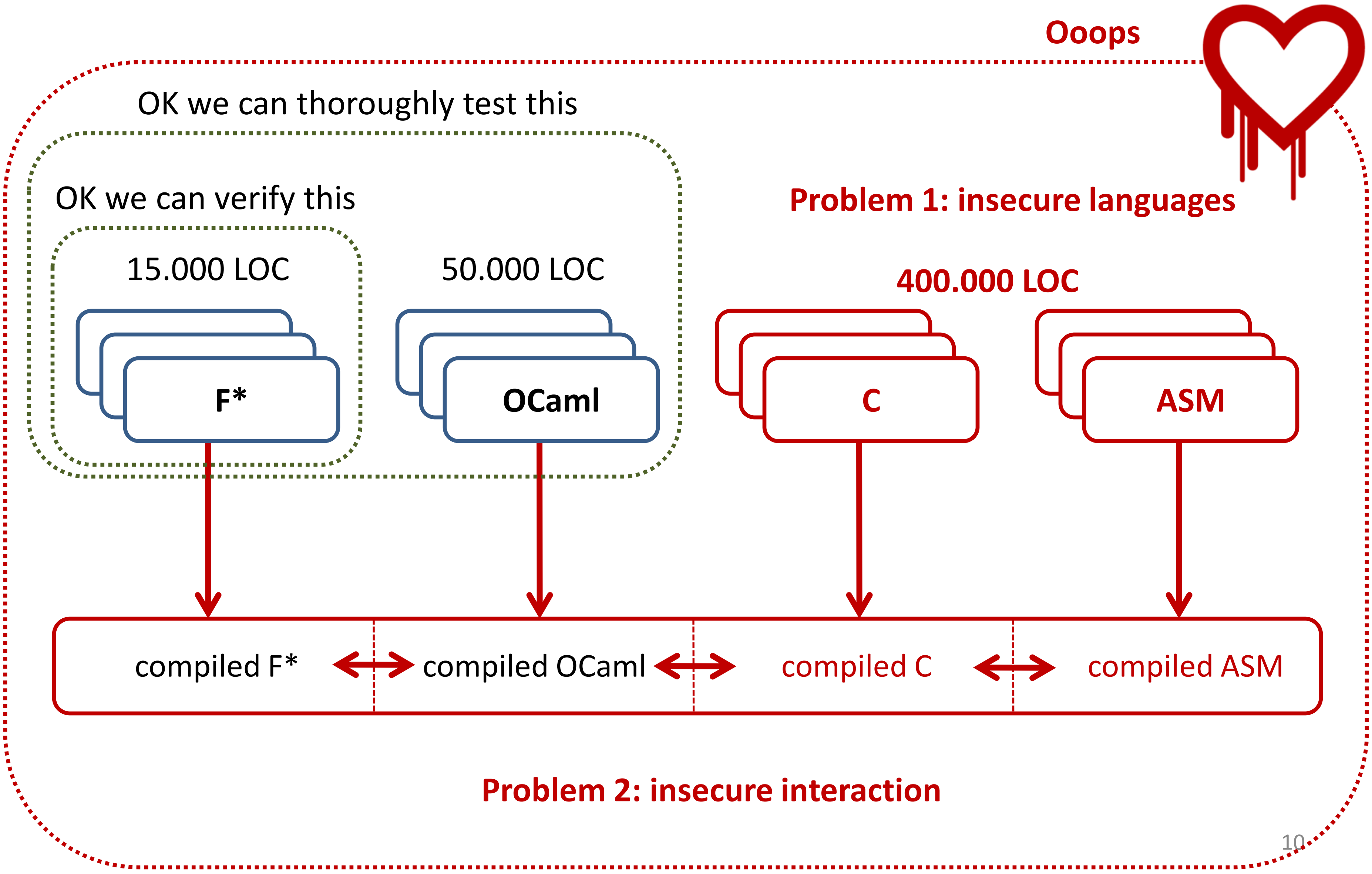


Java State Machine

Dependable property-based testing

- Beyond just finding bugs, confidence by testing
- Integrating testing and formal verification
  - **QuickChick**: property-based testing for Coq (soon F* too)
    - i.e. putting the "property" back in property-based testing
- Systematically measuring testing quality
  - **Polarized mutation testing**
    - i.e. property-based mutation
- Making testing more thorough and cost-effective
  - **Luck**: a domain-specific language for data generators
    - i.e. property-based generation

Back to miTLS*



Secure compilation

- 1. Secure language semantics (e.g. memory safe C)
- 2. Secure language interaction (dynamic isolation, call discipline, type checking, immutability, uniqueness, …)
- **But, at what cost? In software, 10x? 100x? 1000x?**
- **Micro-policies**

  - **new tagged hardware architecture**
  - associates **large metadata tag to each word**
  - efficiently propagates and checks tags; **hw caching**
  - dynamic monitoring: **software defined**, **very flexible, fine-grained** (words, instructions), **fast …**
  - **… average 10% runtime overhead** for complex policies!

More Secure Software Systems

- Formal Verification
- Property-Based Testing
- Secure Compilation
- Dynamic Monitoring
- **… they can all play a role!**

Thank you!