All Your IFCException Are Belong To Us

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Robust exception handling mechanism for sound fine-grained dynamic information flow control

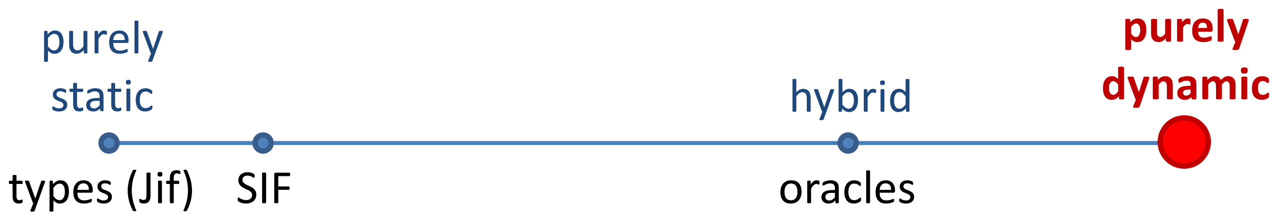
problem: exceptions can leak information

solution: public labels + delayed exceptions

Information flow control

Protect secrecy and integrity
by assigning security levels (labels) to data
and preventing information leaks

Information flow control



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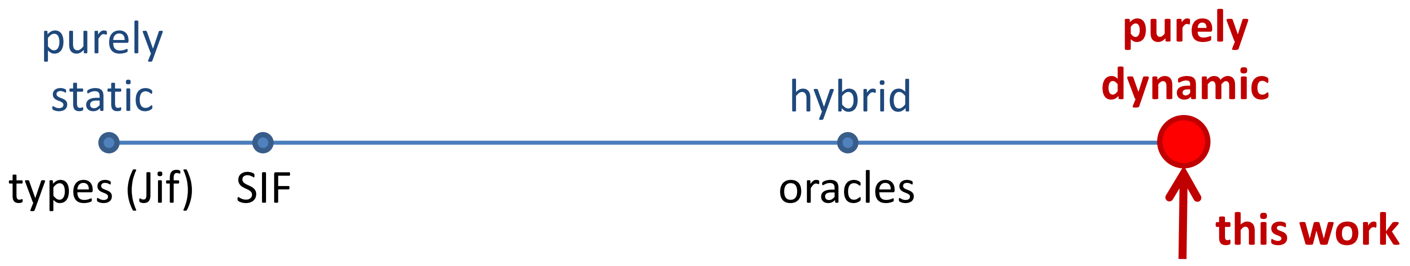

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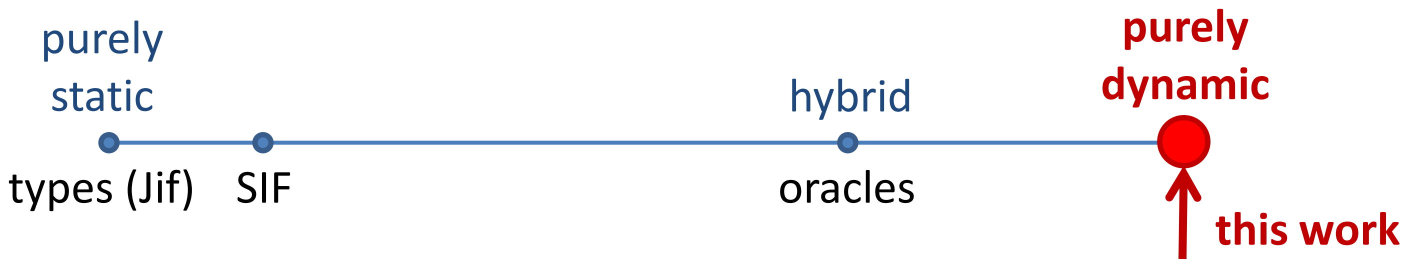

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1. security policy is often dynamic
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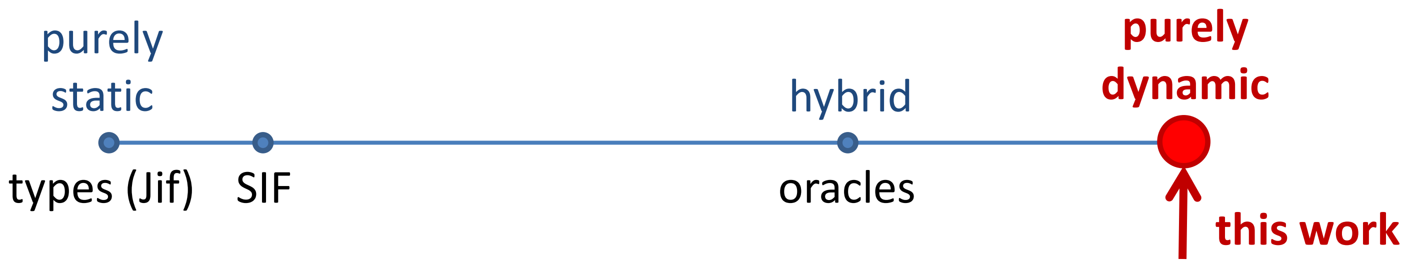

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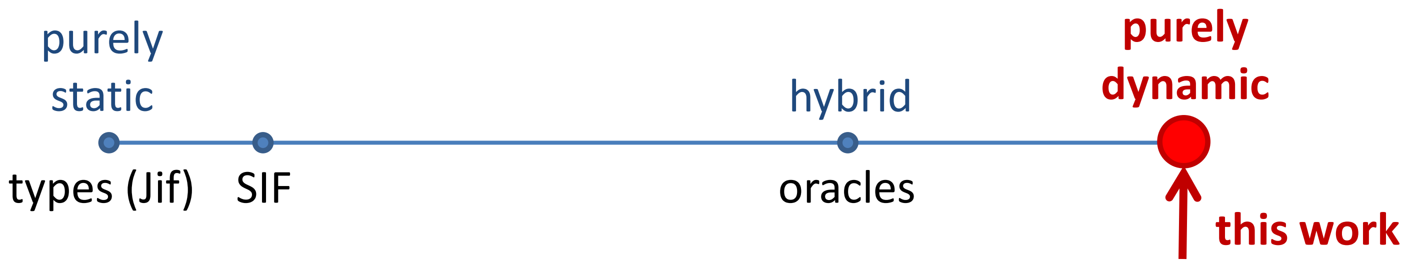

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     - **this talk**: Breeze, new language (no legacy constraints)
   - low-level machine code
     - CRASH/SAFE project: OS+HW-supported IFC

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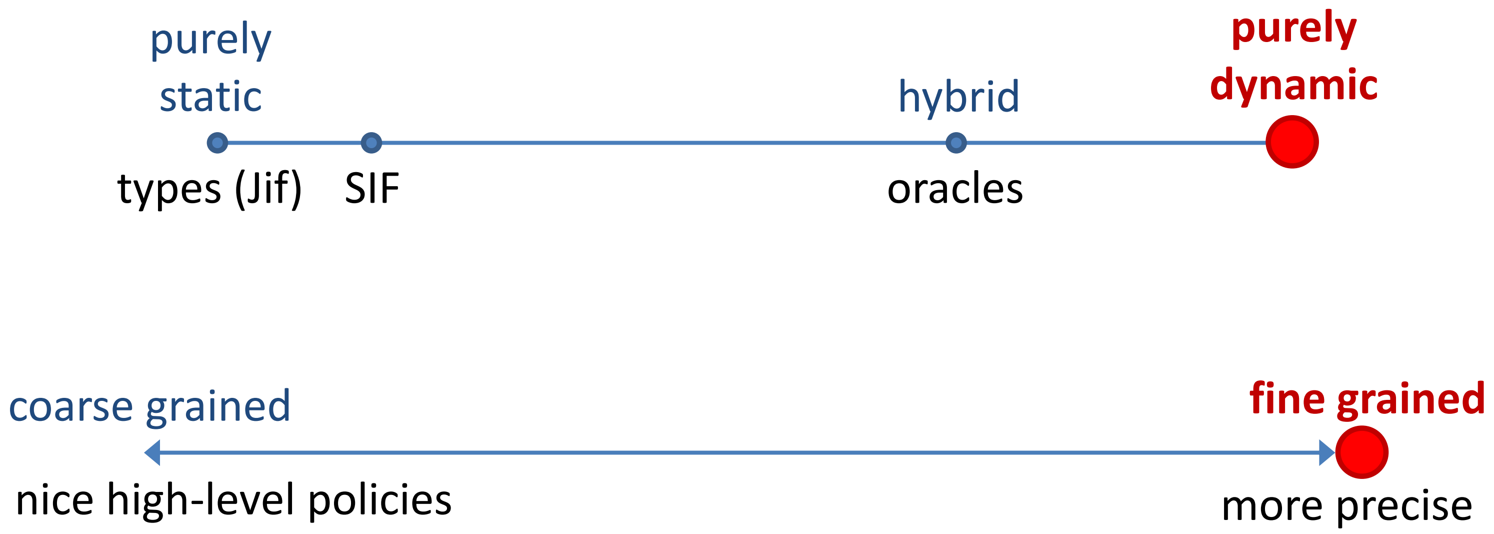

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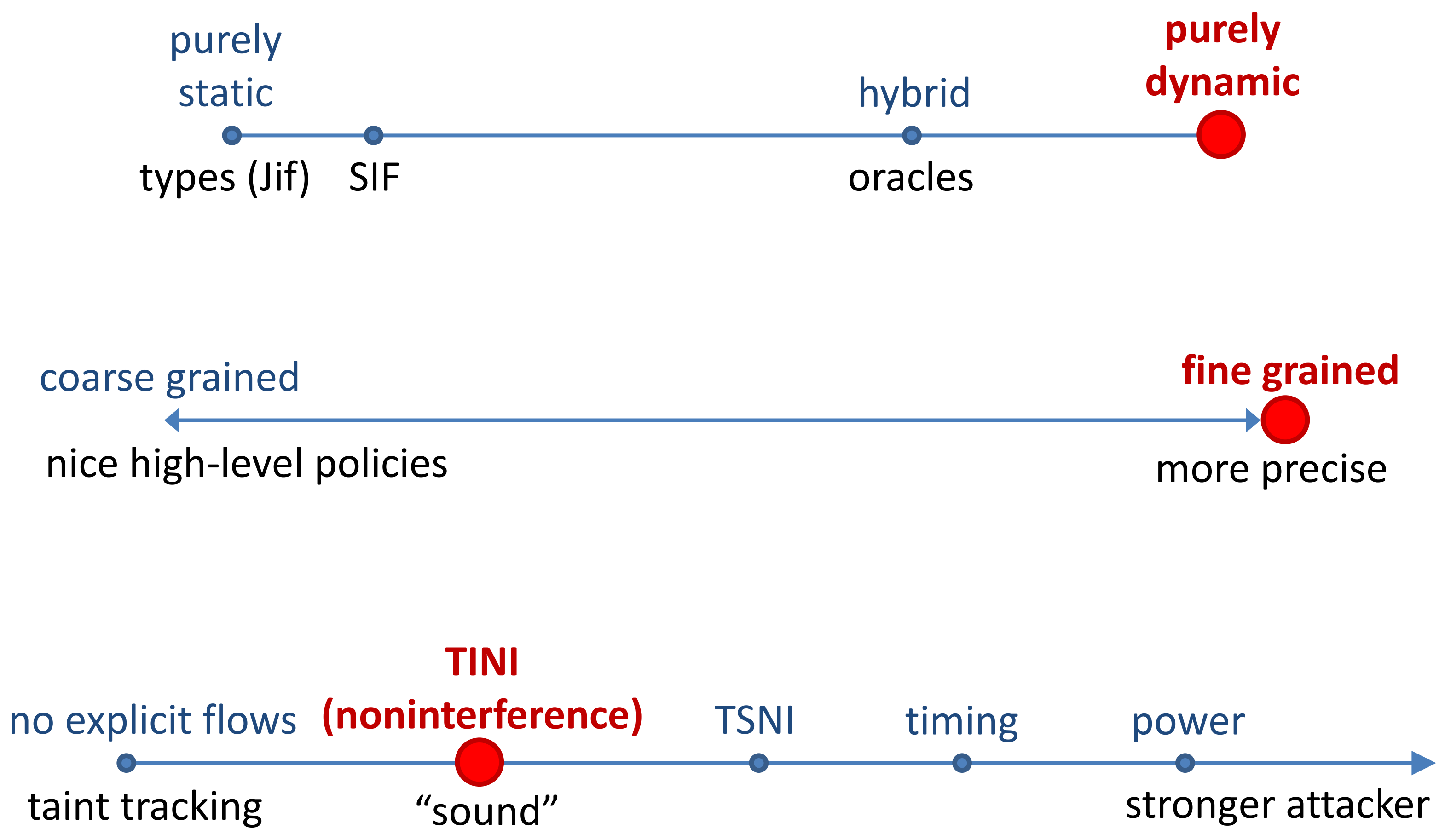
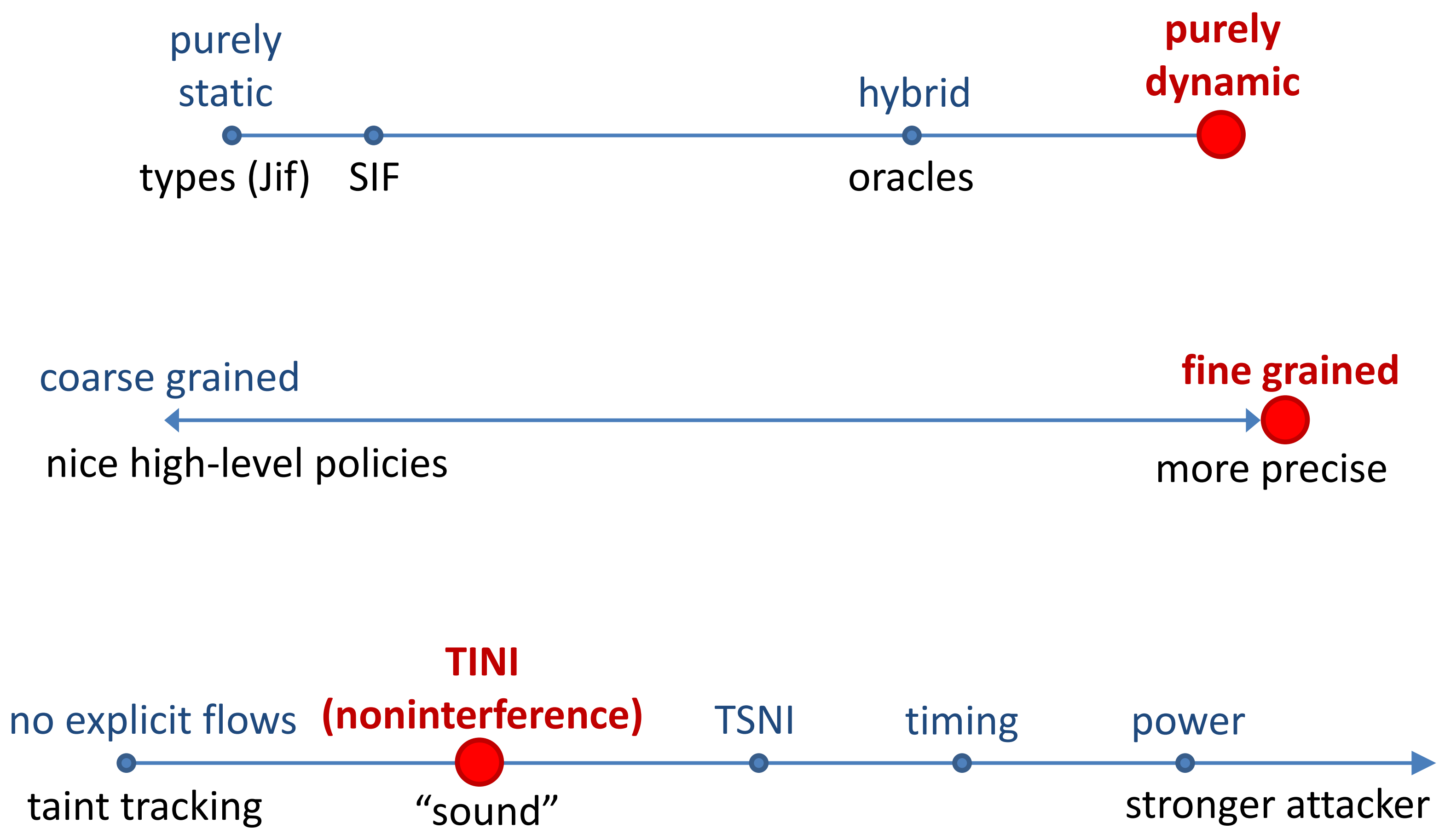


Is this even possible?



Yes, this is possible!

- TINI can be obtained purely dynamically!
  [Sabelfeld & Russo, 2009], [Austin & Flanagan, 2009]
- preventing implicit flows:
  - no low assignments in high contexts (branching on secrets)
  - `l:=false; if h {l:=true}; ...` is terminated

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  - `l:=false; if h {l:=true}; ...` is terminated
  - `l:=false; if h {l:=true}; l := false` has TINI
- TINI not a safety property [Fred Schneider, TISSEC ’00]
  - so we enforce a conservative approximation
  - incompleteness didn’t stop static enforcement either

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  - no low assignments in high contexts (branching on secrets)
  - `l:=false; if h {l:=true}; ...` is terminated

- “stopping the world” not an option
  - can’t punt on availability / reliability to get secrecy / integrity

Contributions

- **showing that robust error handling is possible**
  - recovery from all errors, including IFC violations
  - without sacrificing soundness (TINI) or precision
- **identifying the 2 necessary ingredients**

  = solutions to 2 general problems:

  1. IFC exceptions can leak via labels → **public labels**
  2. all exceptions can leak via control → **delayed exceptions**
- **exploring the entire design space**
- **experimentally evaluating most radical design**

Contributions

rest of this talk focused on this part

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IFC exceptions can leak via labels

- labels are themselves information channels
- get soundness by preventing secrets from leaking either ***into*** or ***out of*** label channel

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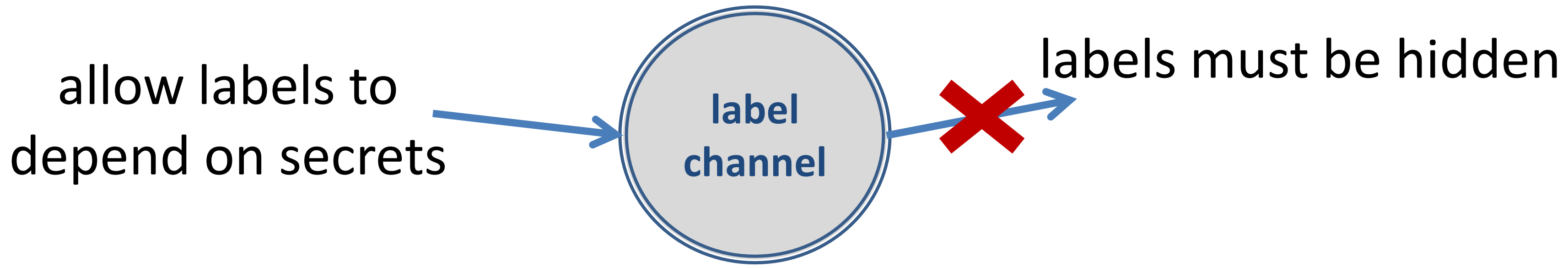

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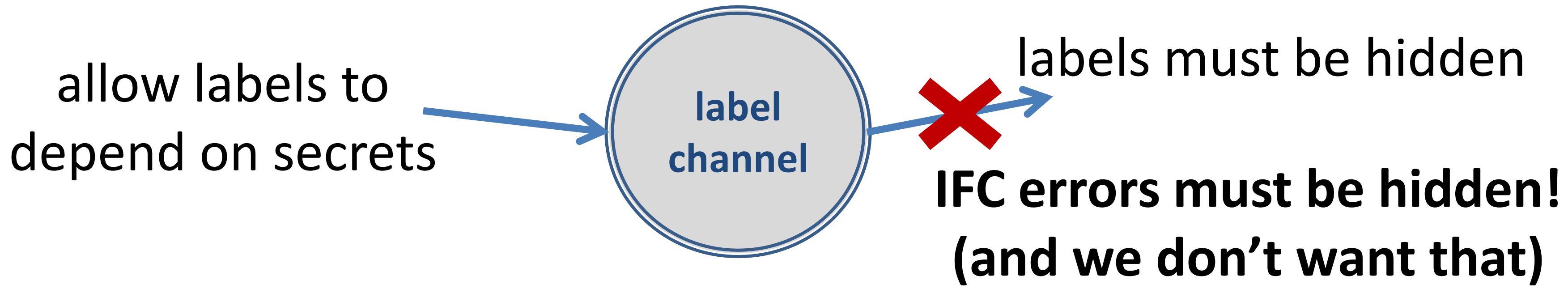

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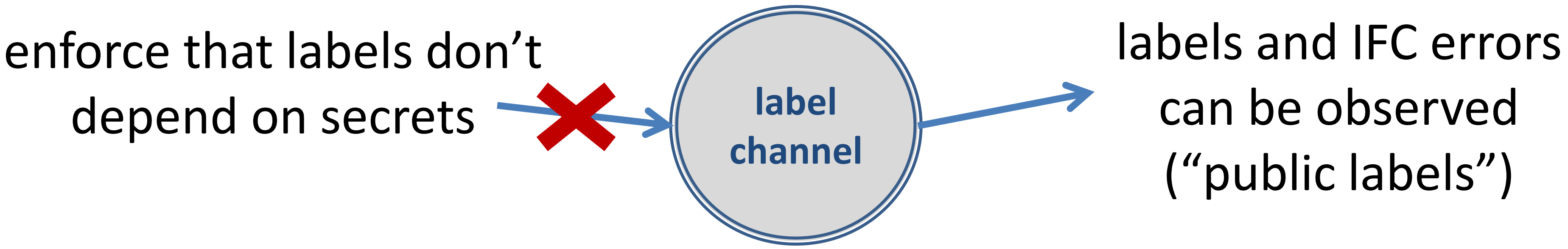
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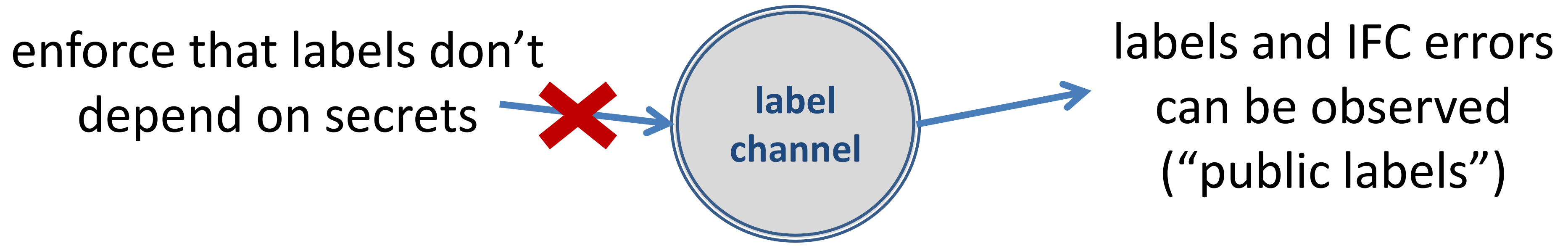
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```
if s then ()@secret else ()@top-secret
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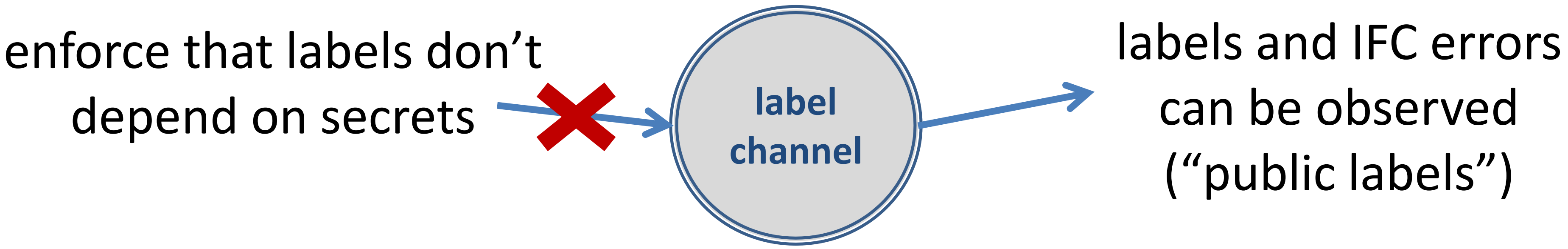
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Solution #1: sound public labels via brackets

```
top-secret[if s then ()@secret else ()@top-secret]
```

[Deian Stefan et al., IFCP 2011]

Problem #2: Exceptions can leak via control

- ending brackets need to be control flow join points, otherwise...

  -
    ```
    try
      let _ = secret[if h then throw Ex] in
      false
    catch Ex => true
    ```

Problem #2:
Exceptions can leak via control

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    try
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- brackets need to **delay** all exceptions!
  - `secret[if true@secret then throw Ex] => "(Error Ex)@secret"`
  - `secret [if false@secret then throw Ex] => "(Success ())@secret"`

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    try
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- brackets need to **delay** all exceptions!
  - `secret[if true@secret then throw Ex] => “(Error Ex)@secret”`
  - `secret [if false@secret then throw Ex] => “(Success ())@secret”`
- similarly for failed brackets
  - `secret[42@top-secret] => “(Error EBracket)@secret”`

Solution #2: Delayed exceptions

- **delayed exceptions unavoidable**
  - still have a choice how to propagate them
- we studied **two main alternatives**:
  1. **mix active and delayed exceptions** ($\lambda^{[\,]}{}_{\mathit{throw}}$)

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- **delayed exceptions unavoidable**
  - still have a choice how to propagate them
- we studied **two main alternatives**:
  1. **mix active and delayed exceptions** ($\lambda^{[\,]}_{throw}$)
  2. **only delayed exceptions** ($\lambda^{[\,]}_{NaV}$)
     - delayed exception = not-a-value (NaV)
     - NaVs are first-class replacement for values
     - NaVs propagated solely via data flow
     - NaVs are labeled and pervasive
     - simpler and more radical solution; implemented in Breeze

What’s in a NaV? Debugging aids!

- error message
  - `EDivisionByZero (“can’t divide %1 by 0”, 42)
- stack trace
  - pinpoints error **origin**
    - very different than for NullPointerException (the billion-dollar mistake)
- propagation trace
  - how did the error make it here?

Formal results

- proved TINI in Coq for $\lambda^{[\,]}$, $\lambda^{[\,]}_{NaV}$, and $\lambda^{[\,]}_{throw}$
  - for $\lambda^{[\,]}_{NaV}$ even with all debugging aids; **error-sensitive**
- some evidence that NaVs and catchable exceptions have **equivalent expressive power** (in theory)
  - translations validated by QuickChecking extracted code

$$\begin{tikzcd}
& \boxed{\lambda^{[\,]}} & \\
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New work:
Testing Noninterference, Quickly

Conclusion

- reliable error handling **possible** even for sound fine-grained dynamic IFC systems
- two mechanisms ($\lambda^{[\,]}_{NaV}$ and $\lambda^{[\,]}_{throw}$) and variants
  - **all errors recoverable**, even IFC violations
  - **necessary** ingredients: **sound public labels** (brackets)
    + **delayed exceptions**
  - quite **radical design** (not backwards compatible!)
  - **delayed exceptions applicable to static IFC**