
All the Binaries Together

A Semantic Approach to ABIs

— Andrew Wagner, Amal Ahmed —



(Secure Interoperability, Languages, and Compilers)






“The standard is haunted ... by that **Three Letter Demon**. ... a contract was forged in blood.”
— JeanHeyd Meneide, WG14 C/C++ Compatibility Chair

What Is an ABI?

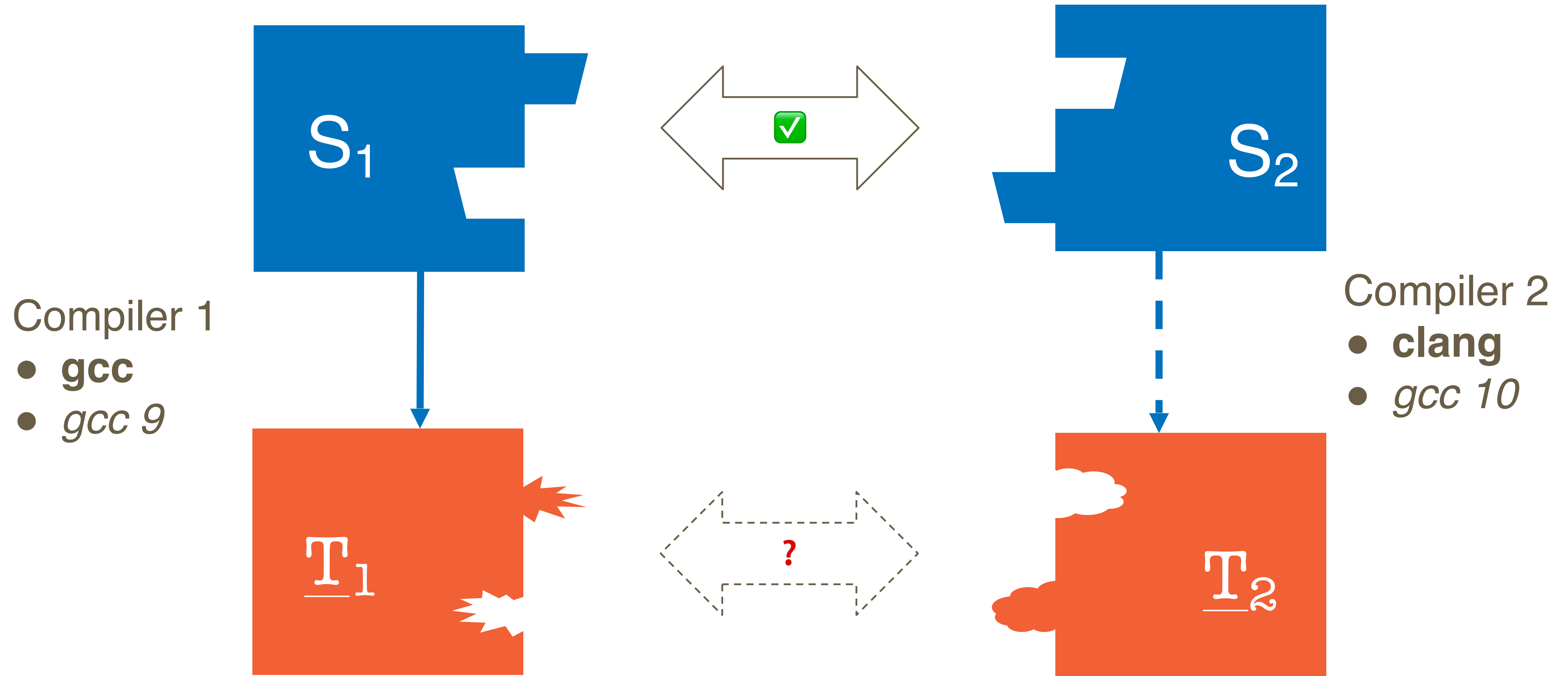
- Data layouts
- Calling conventions
- Name mangling
- + *Safety invariants*
- + *Ownership*
- ...



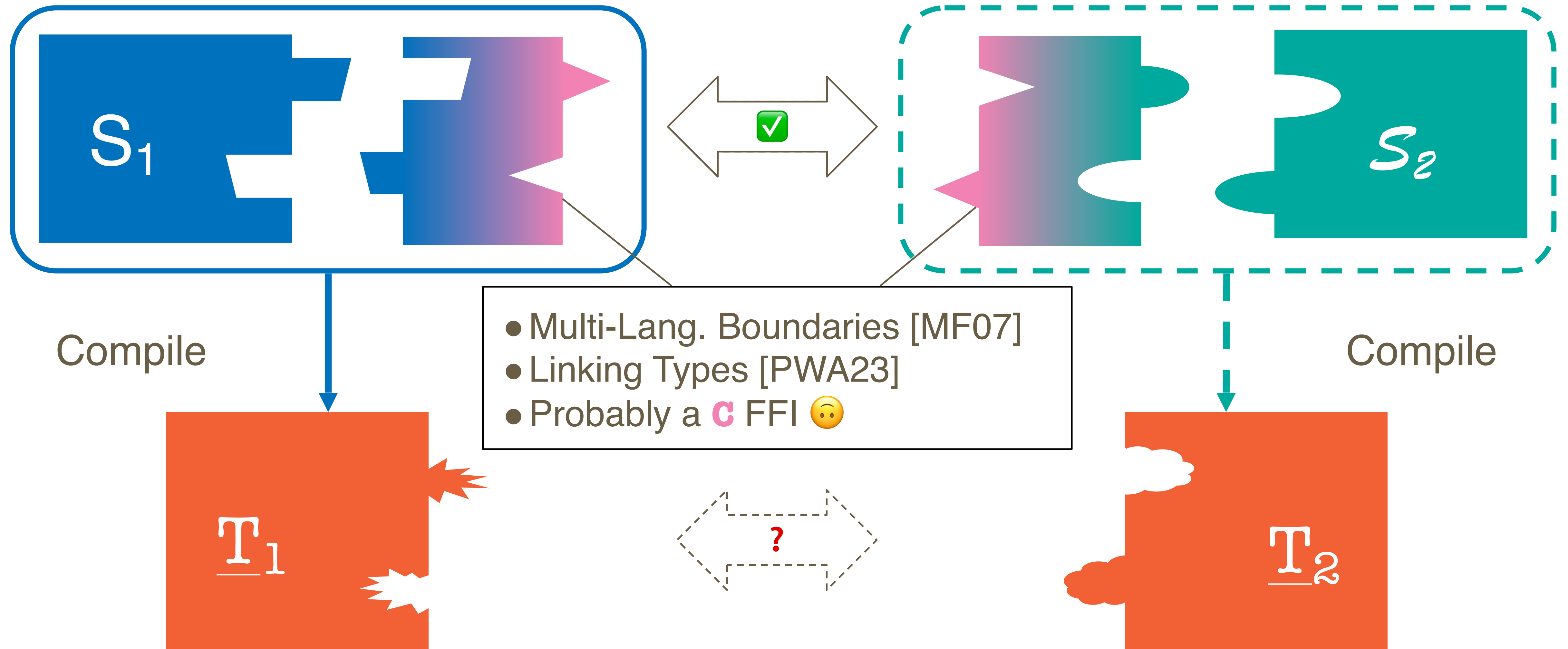
Who Cares?

- ★  **Swift:** *ABI Stability Manifesto*
- ★  **Rust:** *crABI*
- ★  **C++:** *WG21 ARG*
- ★  **WASM:** *Component Model*
- ★  **You!**

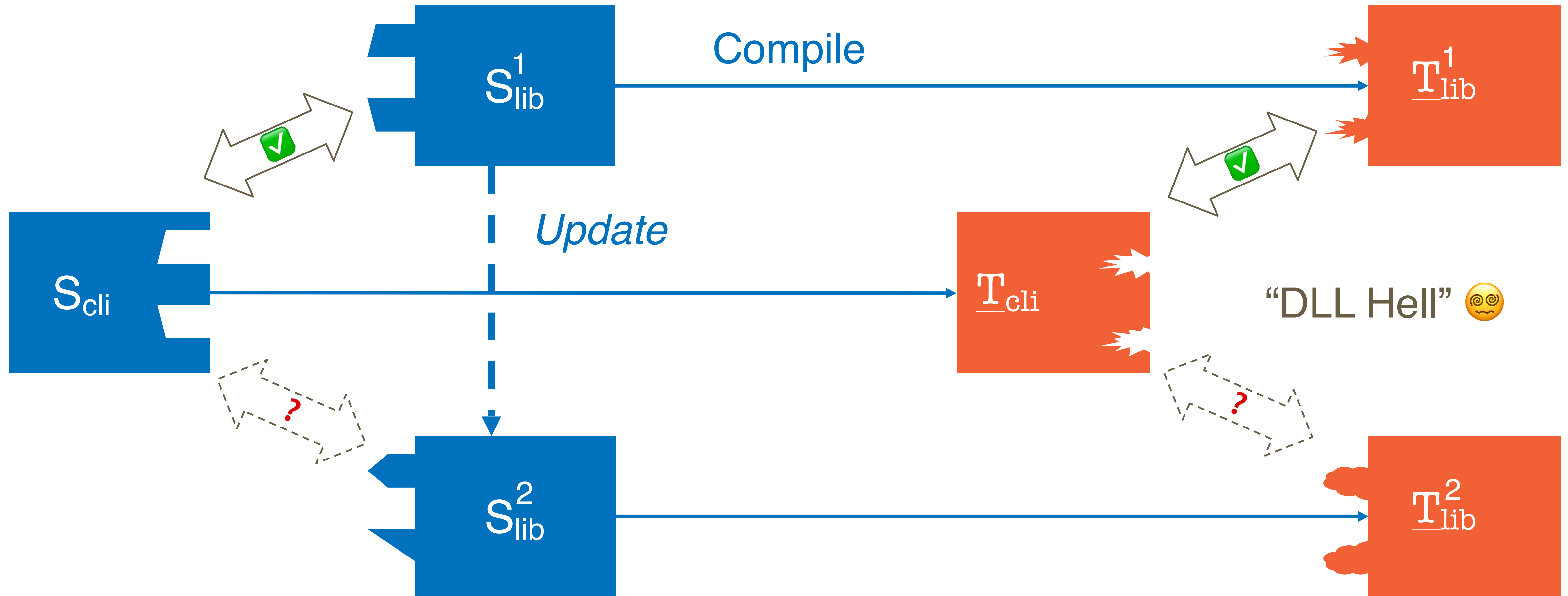
All the Compilers Together



All the Languages Together



All the Libraries Together

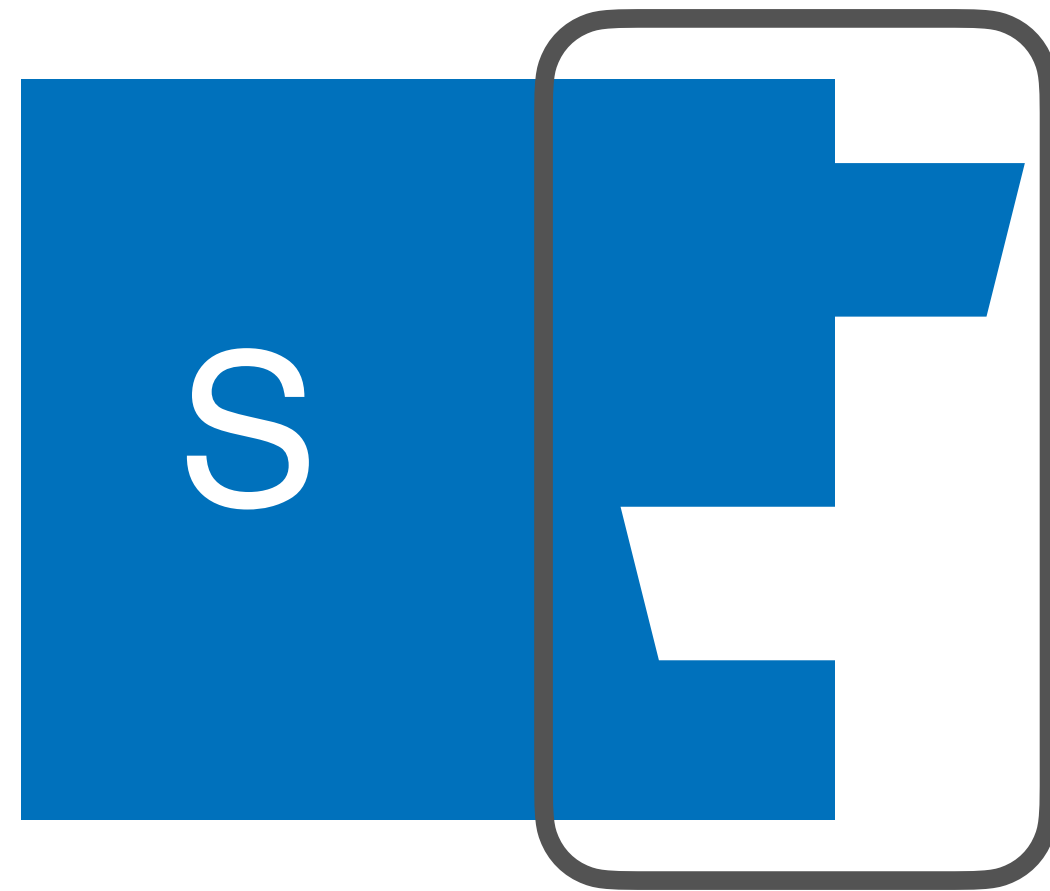


Towards a Formal ABI

- Languages are already grappling with these problems
- Growing dissatisfaction with status quo
- Demand for richer ABIs
- Design decisions, tradeoffs, uncharted territory

Can we provide a semantic foundation?

What Is an ABI, Formally?



“This source interface ...”

This Type τ

\underline{T} is **ABI compliant** with τ if

$$\underline{T} \in \llbracket \tau \rrbracket$$



“... describes target programs like this”

Denotes These Programs

$\llbracket \tau \rrbracket = \{ \underline{T} \mid \dots \}$ ————— Semantic Typing via Realizability

T is **ABI compliant** with τ if

$$\underline{T} \in \llbracket \tau \rrbracket$$

Is this a good spec?

1. **Formalization:** Can the spec capture all the pertinent details?
2. **Application:** Can the spec be used in all the relevant scenarios?

Case Study: Reference Counting

- PCF-ish Source
 - Records, variants, higher-order recursive functions
- C-ish Target
 - Block-based memory, pointer arithmetic
- Reference Counting ABI
 - All values are boxed and reference-counted
 - Separation logic specification

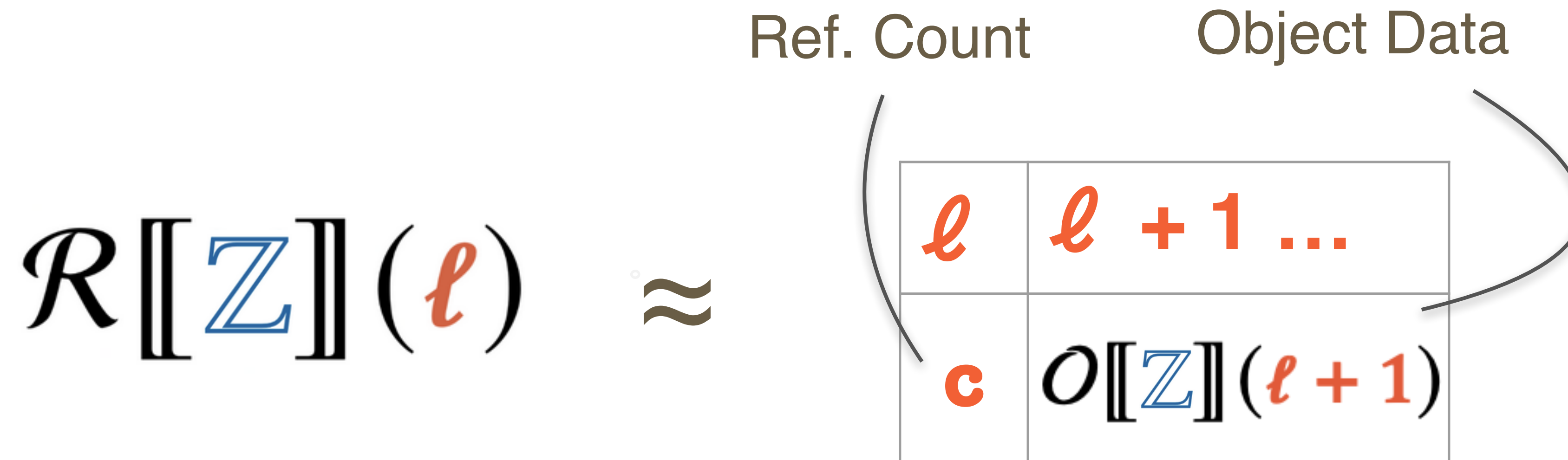
Formalization: Semantic Typing via Realizability

$$\Gamma \vdash e : T$$

$$\Gamma \models e : T$$

$$\begin{aligned} &\approx \left\{ \text{“Prestate like } \Gamma \text{”} \right\} e \left\{ v. \text{“} v \text{ like } T \text{”} \right\} \\ &\approx \left\{ \star \overline{\mathcal{R}[\![T_x]\!](x)} \right\} e \left\{ \ell. \mathcal{R}[\![T]\!](\ell) \right\} \end{aligned} \quad (\Gamma = \overline{x : T_x})$$

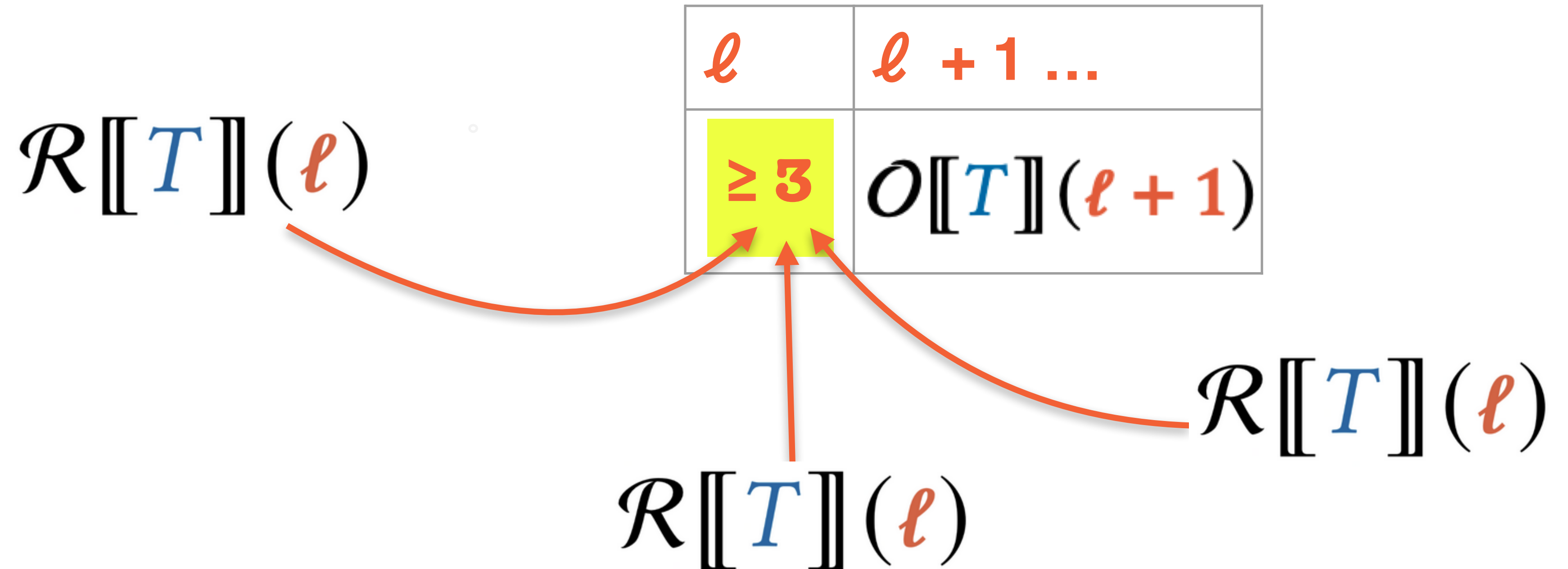
Formalization: Reference Layout



Also:
Unboxed data
via pointer
tagging

$$\mathcal{O}[\mathcal{Z}](\ell + 1) = \exists n. \ell + 1 \mapsto n$$

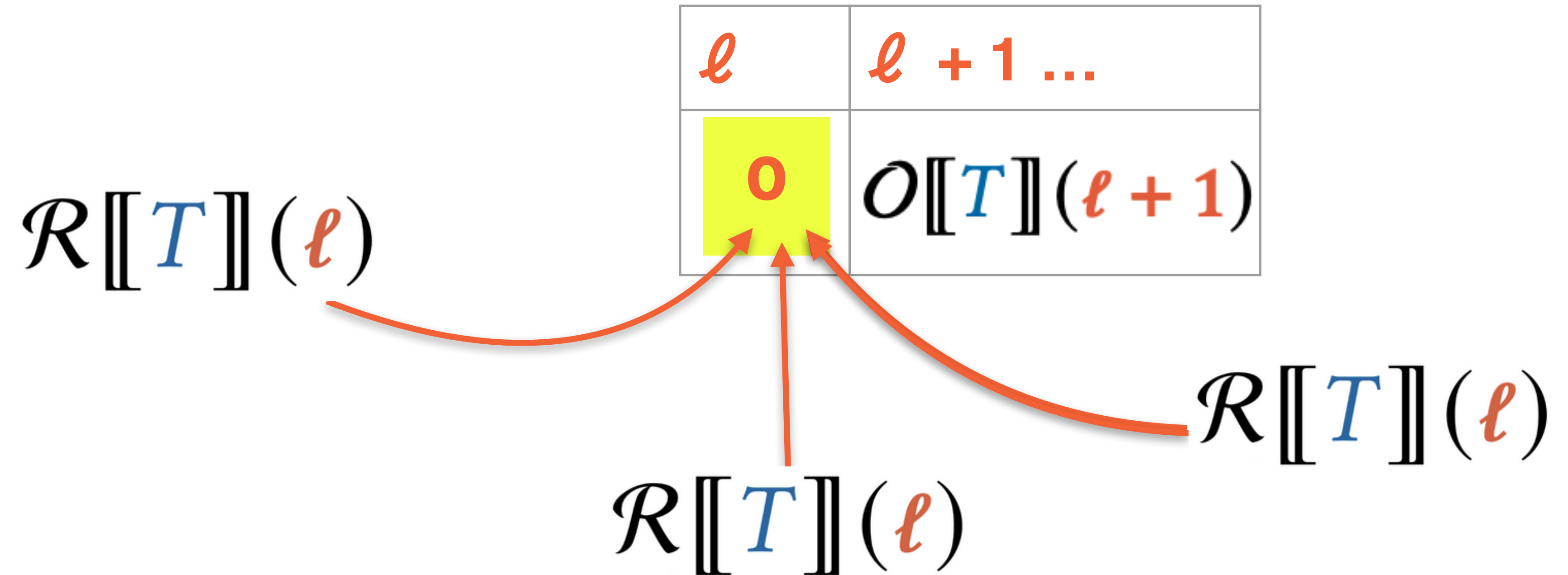
Formalization: Ownership + Sharing



RC-INCR

$$\left\{ \mathcal{R}[[T]](\ell) \right\} ++\ell \left\{ n. \lceil n > 1 \rceil \star \mathcal{R}[[T]](\ell) \star \mathcal{R}[[T]](\ell) \right\}$$

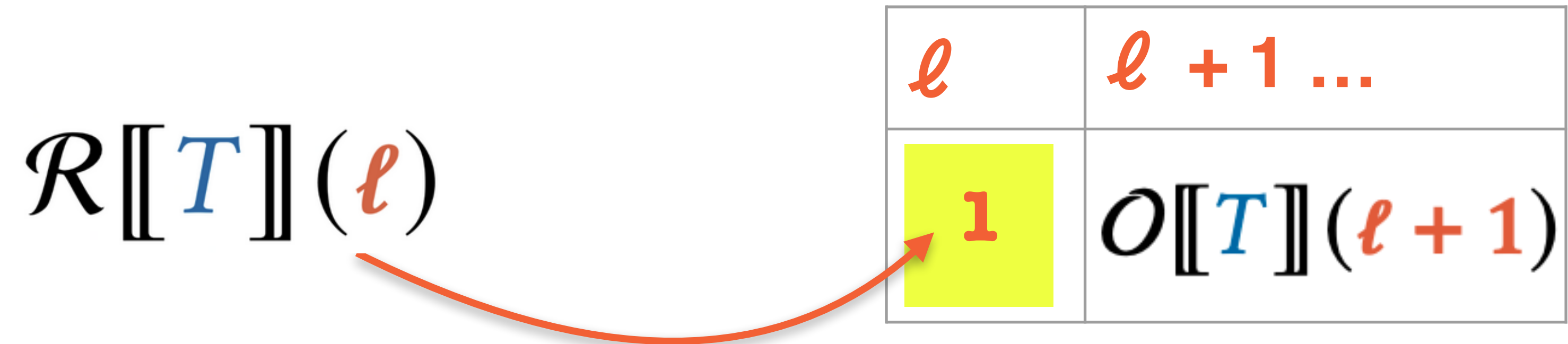
Formalization: Ownership + Sharing



RC-DECR

$$\left\{ \mathcal{R}[[T]](\ell) \right\} \dashv\vdash \ell \left\{ n. \left(\ulcorner n > 0 \urcorner \wedge \text{emp} \right) \vee \left(\ulcorner n = 0 \urcorner \star \ell \mapsto 0 \star O[[T]](\ell + 1) \right) \right\}$$

Formalization: Ownership + Sharing

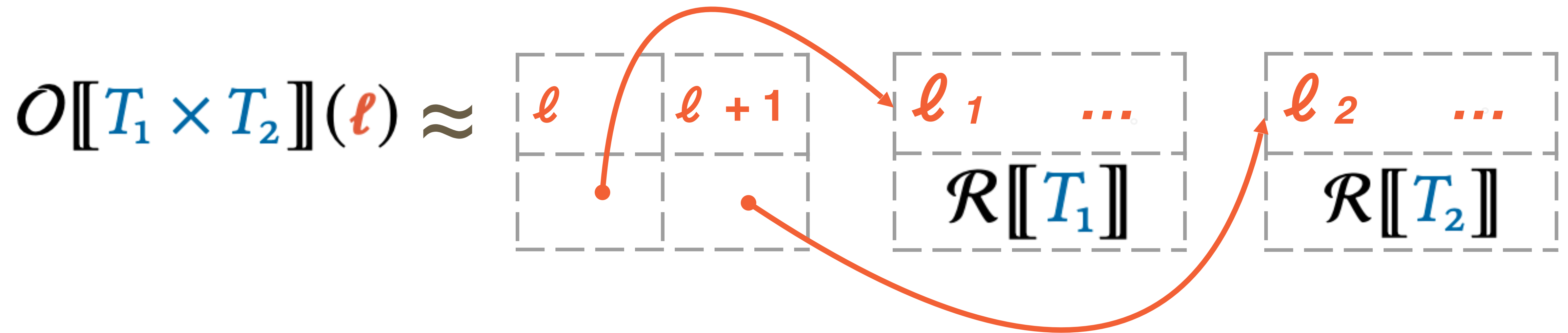


RC-NEW

$$\left\{ \mathcal{R}[\![T]\!](\ell) \right\} e \left\{ \mathcal{Q} \right\}$$

$$\left\{ \ell \mapsto \mathbf{1} \star \mathcal{O}[\![T]\!](\ell + 1) \right\} e \left\{ \mathcal{Q} \right\}$$

Formalization: Compound Layout



$$O[[T_1 \times T_2]](\ell) \triangleq \exists \ell_1, \ell_2.$$

Also:
Records and
variants

$$\begin{array}{c}
 \ell \quad \mapsto \ell_1 \\
 \star \ell + 1 \mapsto \ell_2
 \end{array}
 \star \mathcal{R}[[T_1]](\ell_1) \star \mathcal{R}[[T_2]](\ell_2)$$

Formalization: Calling Convention

$$O[[T_1 \rightarrow T_2]](\ell) \triangleq \exists f. \ell \mapsto f \star$$

Pointer to function

$$\forall \ell_1. \{\mathcal{R}[[T_1]](\ell_1)\} f(\ell_1) \{\ell_2. \mathcal{R}[[T_2]](\ell_2)\}$$

Calling convention:
Caller retain

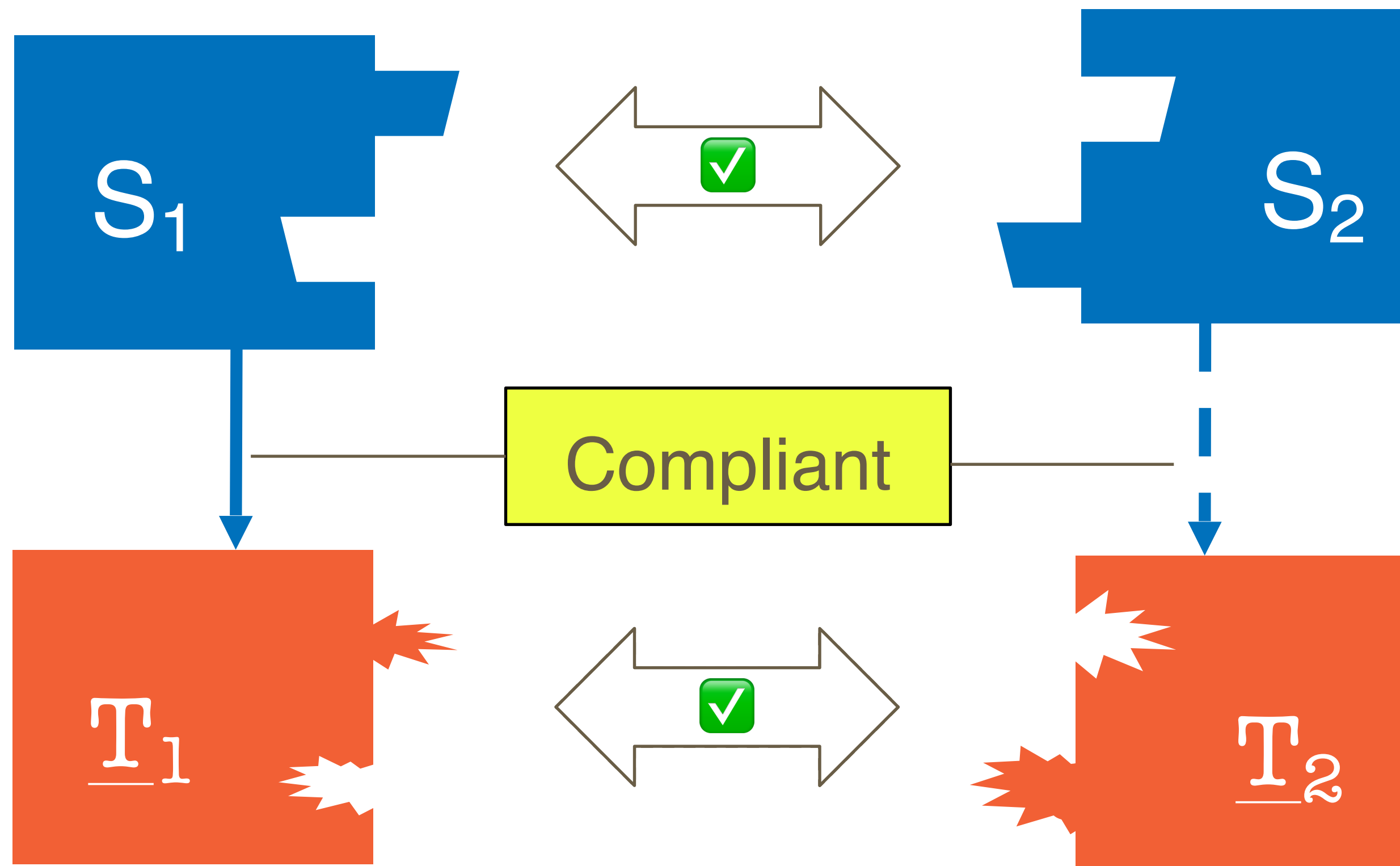
VS.

$$\forall \ell_1. \{\mathcal{R}[[T_1]](\ell_1)\} f(\ell_1) \{\ell_2. \mathcal{R}[[T_2]](\ell_2) \star \underbrace{\mathcal{R}[[T_1]](\ell_1)}_{\text{Callee retain}}\}$$

Callee retain

Also:
Closures

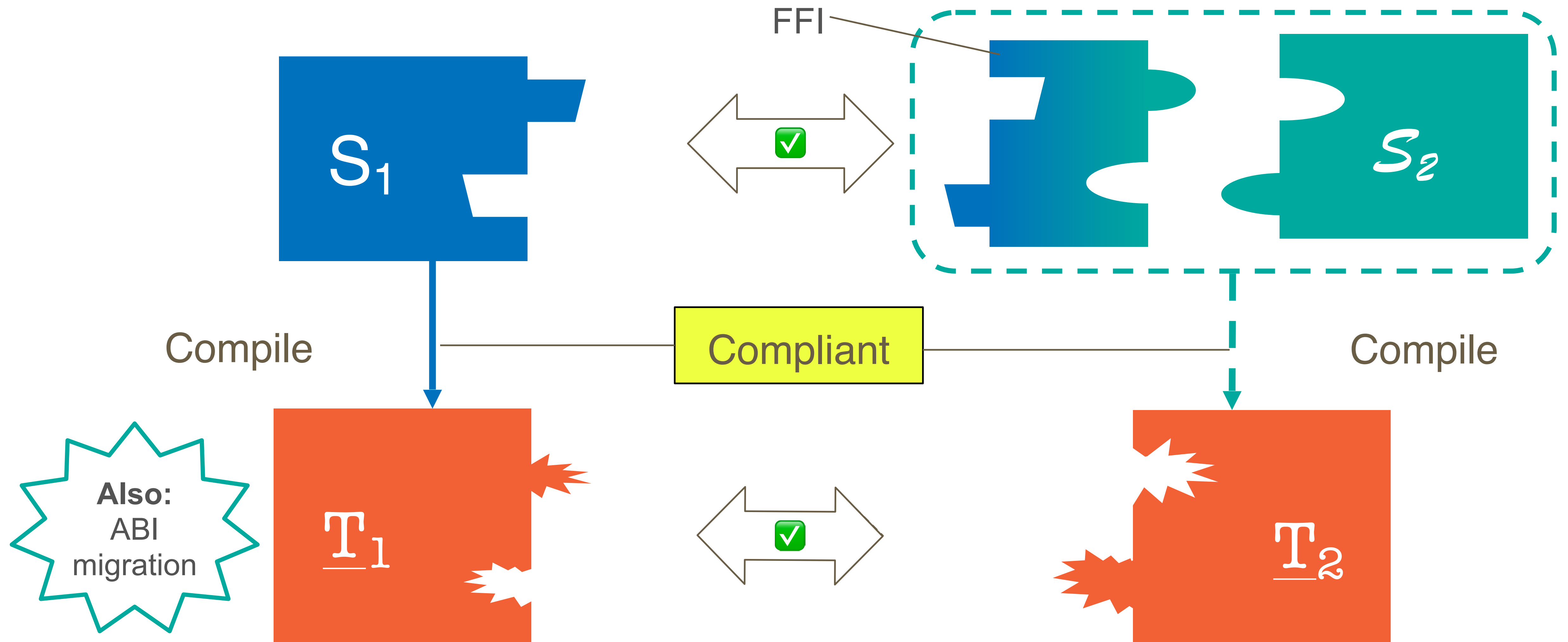
Application: Compiler Compliance



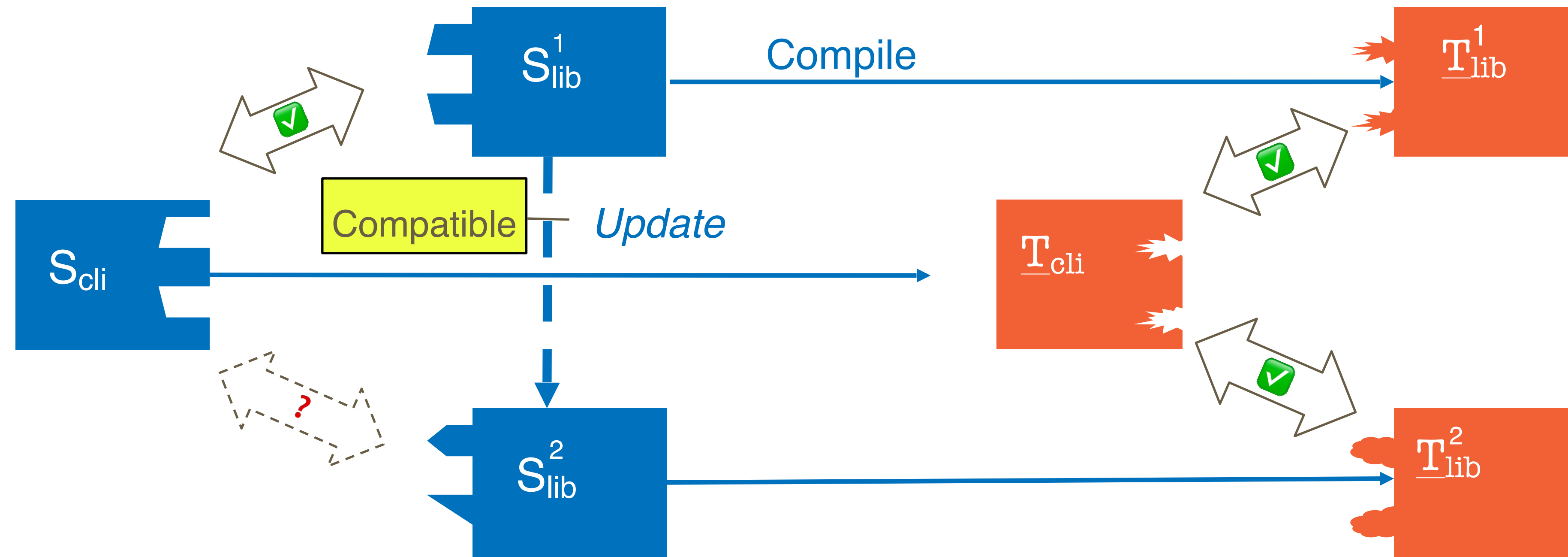
\rightsquigarrow is an **compliant compiler** if

$S : \tau$ and $S \rightsquigarrow \underline{T}$ implies $\underline{T} \in \llbracket \tau \rrbracket$

Application: FFI Safety



Application: Library Compatibility



Swift ? C

←————→

Flexible Rigid

τ_2 is an **compatible update** from τ_1 if

$\underline{T} \in \llbracket \tau_2 \rrbracket \text{ implies } \underline{T} \in \llbracket \tau_1 \rrbracket$

Next Steps

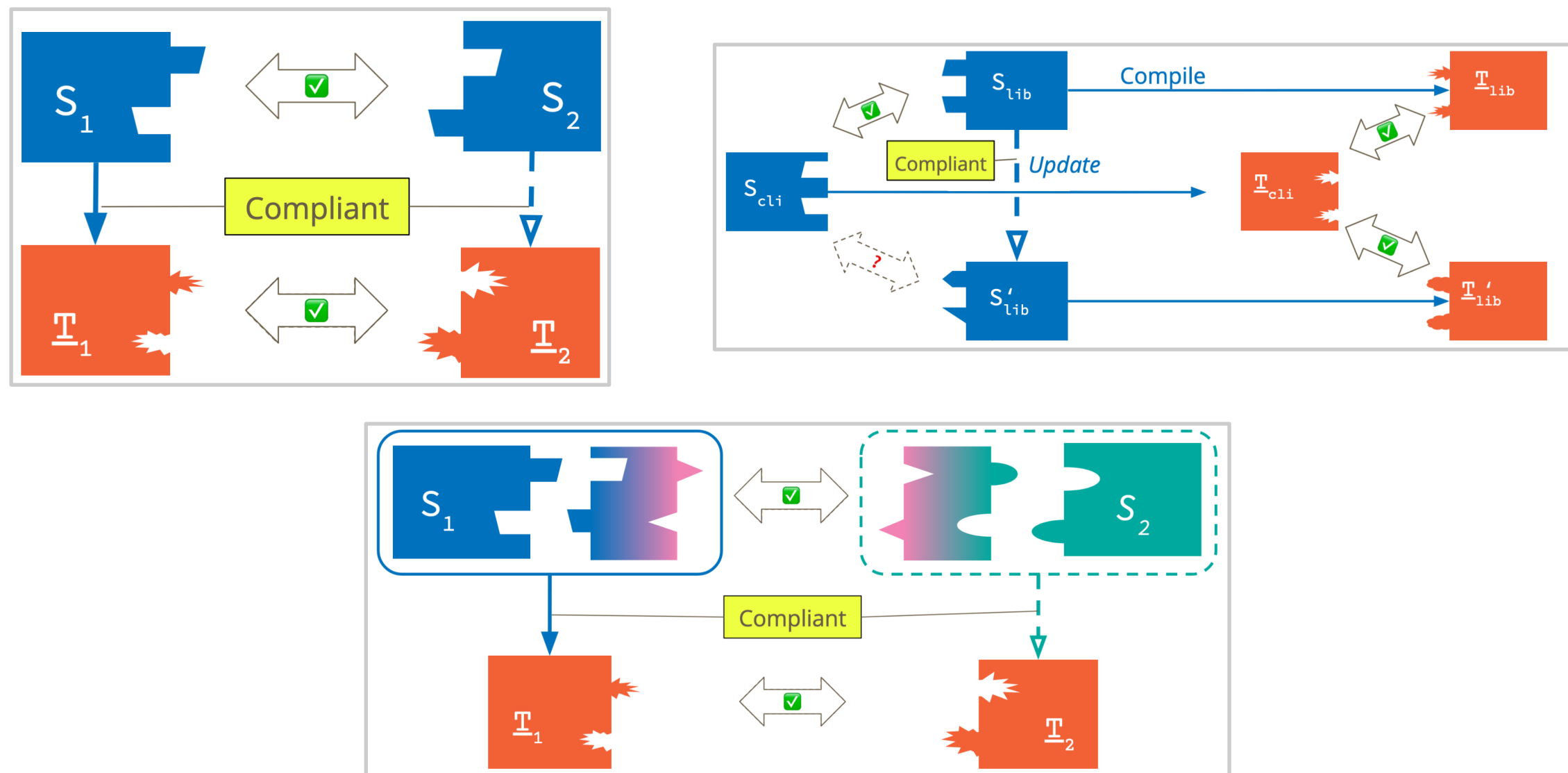
- ★ Wrapping up case study
 - ◆ Variations on design
- ★ Idiosyncrasies of Swift ABI
 - ◆ Resilient type layouts, reabstraction (polymorphism)
- ★ Rust ABI over Wasm
 - ◆ Component Model (prev. Interface Types) building blocks

Takeaways

Formalization

$$\underline{T} \in \llbracket \tau \rrbracket$$

Application



Let's Chat!

Email: ahwagner@ccs.neu.edu

Web: andrewwagner.io

