EECS498-008
Formal Verification of Systems Software

Material and slides created by

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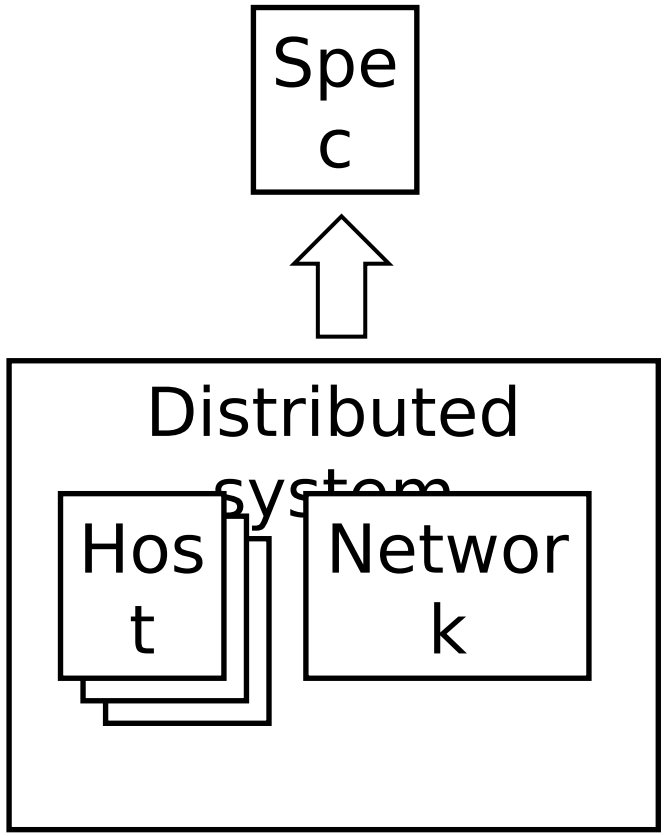
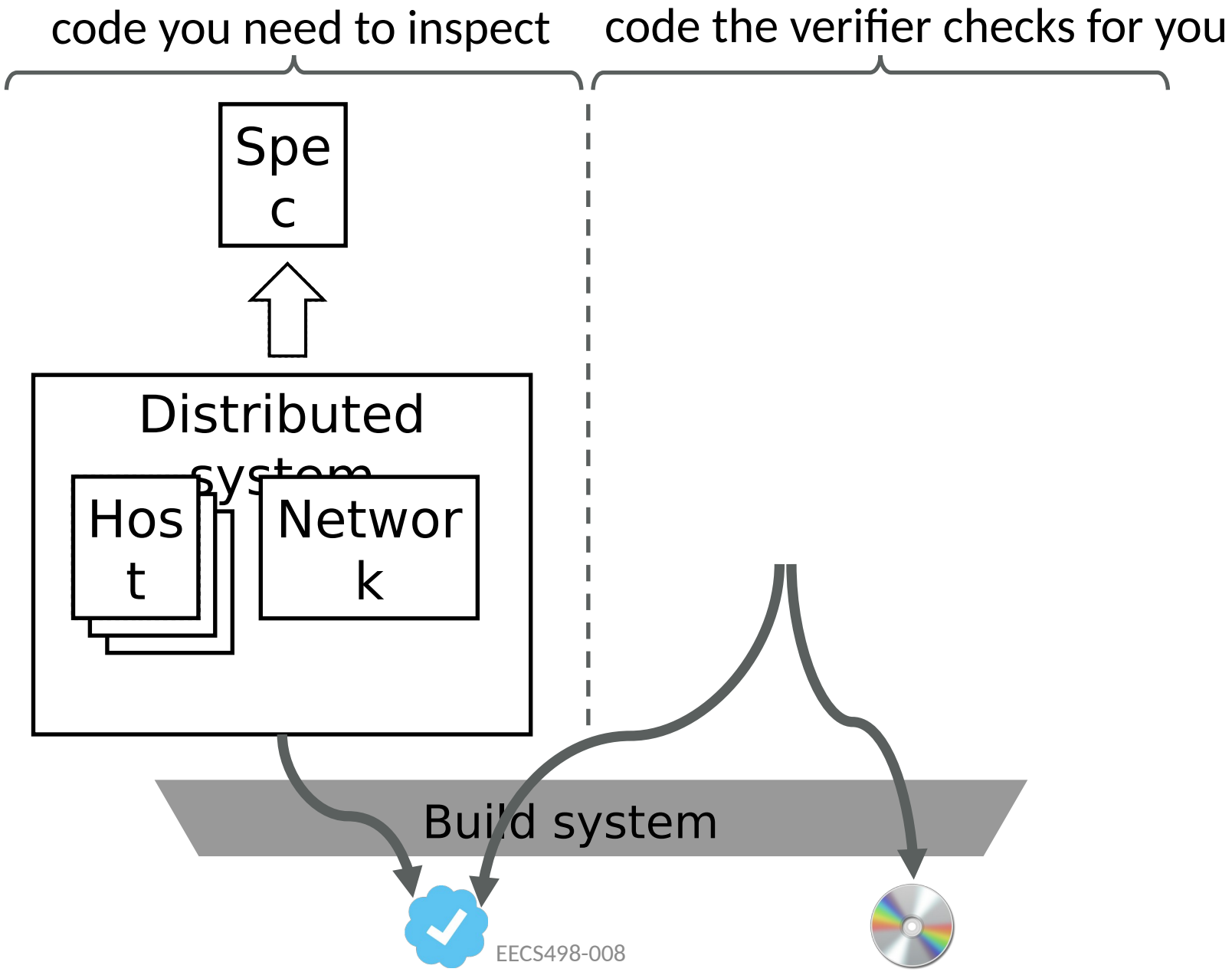
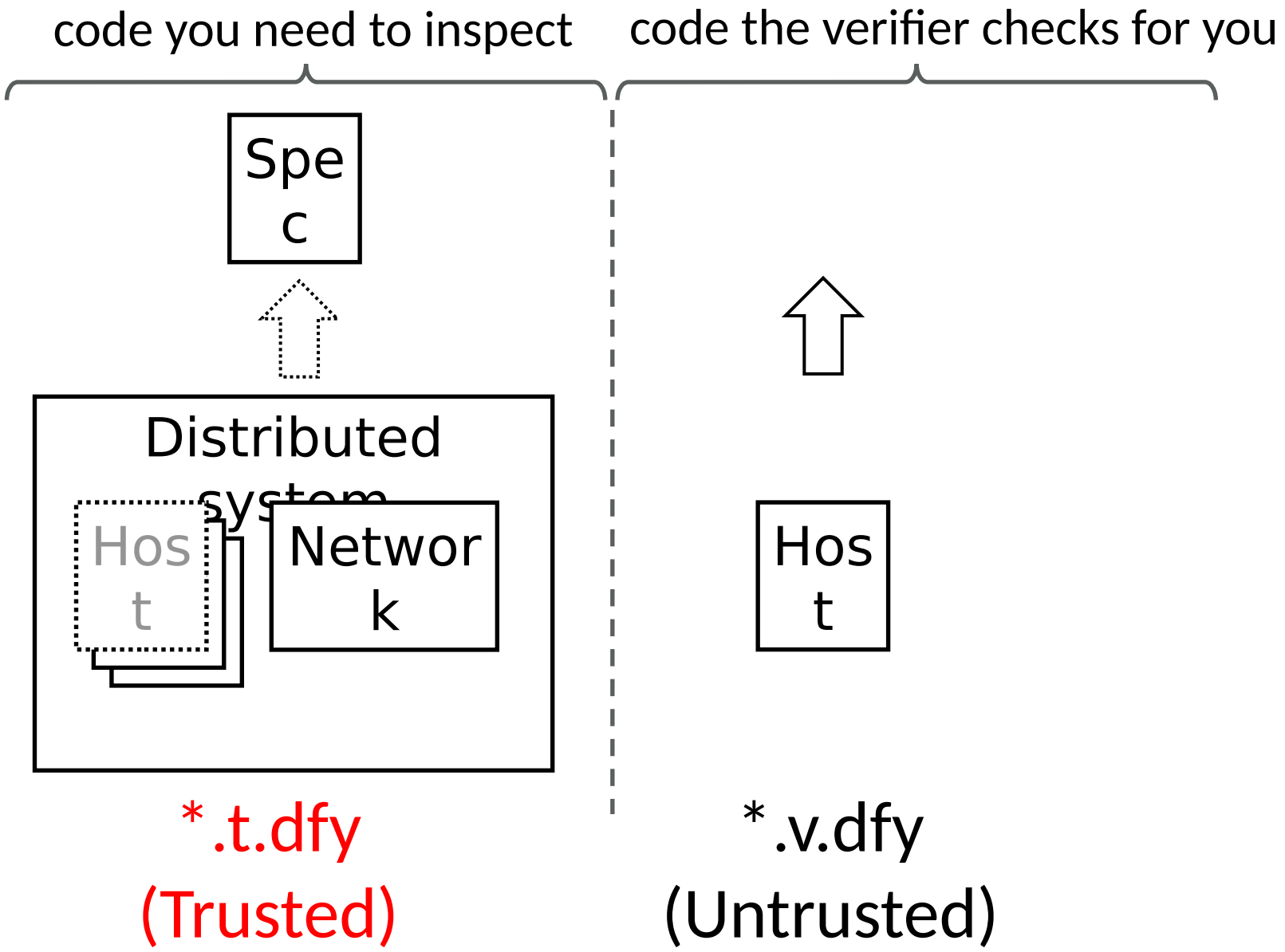
Refinement recap




```
function A(v:Variables) : Spec.Variables
predicate Inv(v:Variables) { … }

lemma Refinement(v, v')
  ensures Init(v) ⇒ SpecInit(A(v)) && Inv(v)
  ensures Next(v, v') && Inv(v)
    ⇒ (|| SpecNext(A(v), A(v')) && Inv(v')
        || A(v) == A(v')
          )
```


code you need to inspect
code the verifier checks for you
Spec
Distributed system
Host
Network
Build system


code you need to inspect
code the verifier checks for you
Spec
Distributed system
Host
Network
Host
*.t.dfy
(Trusted)
*.v.dfy
(Untrusted)

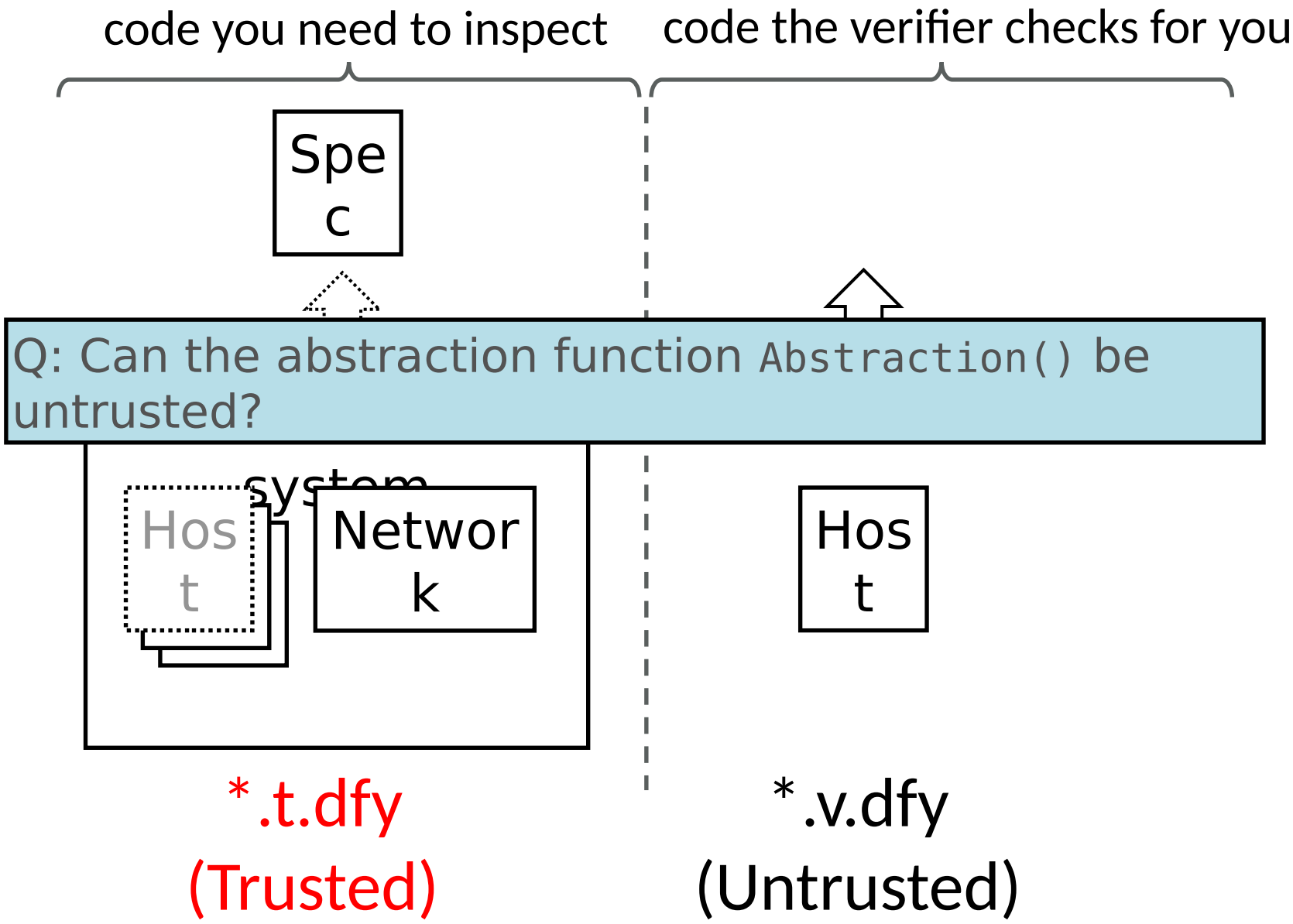
The verification game

- Player 1: the benign verification expert 
- Player 2: the malicious engineer 

Player 1 sets up the trusted environment
(i.e. all `.t.dfy` files)

Player 2 writes the implementation and proof
(i.e. all `.v.dfy` files)

Player 1 runs the build system


code you need to inspect
code the verifier checks for you
Spec
Q: Can the abstraction function Abstraction() be untrusted?
system
Host
Network
Host
*.t.dfy
(Trusted)
*.v.dfy
(Untrusted)

What if the abstraction function pretended nothing ever happened?

Always returns the initial state

```
function Abstraction(v:Variables) :
                Spec.Variables {
  var a0 :| SpecInit(a0);
  a0
  }

  predicate Inv(v:Variables)
{ true }
```

…or just made up a fake story?

Returns fake state

```
datatype Variables =
Variables(actualState: Stuff, fakeState:
HostState)

function Abstraction(v:Variables) :
Spec.Variables {
      v.fakeState
}
```

Maybe someone should inspect Abstraction()…

Make it **Abstraction.t.dfy** and have an examiner examine it…

…ugh, that's a bad idea! The examiner would have to read the entire protocol description

Application correspondence

Idea: use a trusted client-facing interface to constrain function `Abstraction()`

- Step 1: define a **trusted interface** that records requests and replies

```
module TrustedABI {
  datatype Variables = Variables(requests:set<Input>,replies:set<Output>)

  predicate AcceptRequest(v:Variables, v':Variables, request: Input)
{ ... }
  predicate DeliverReply(v:Variables, v':Variables, reply: Output)
{ ... }
  predicate ExecuteOp(c: Constants, v: Variables, v': Variables, abiOps:
ABIOps)
}
```

```
// Type of binding variable between Host and TrustedABI.
// Analogous to Network.MsgOps
datatype ABIOps = ABIOps(request:Option<Input>,
reply:Option<Output>)
```

Application correspondence

- Step 2: bind the transitions of this interface to the Host transitions

In DistributedSystem:

```
predicate HostNext(c: Constants, v: Variables, v':Variables,
hostIdx:HostIdx, abiOps: TrustedABI.ABIOps) {
  ...
  && Host.Next(c.hosts[hostIdx], v.hosts[hostIdx], v'.hosts[hostIdx],
abiOps)
  && TrustedABI.ExecuteOp(c.abi, v.abi, v'.abi, abiOps)
  ...
}
```

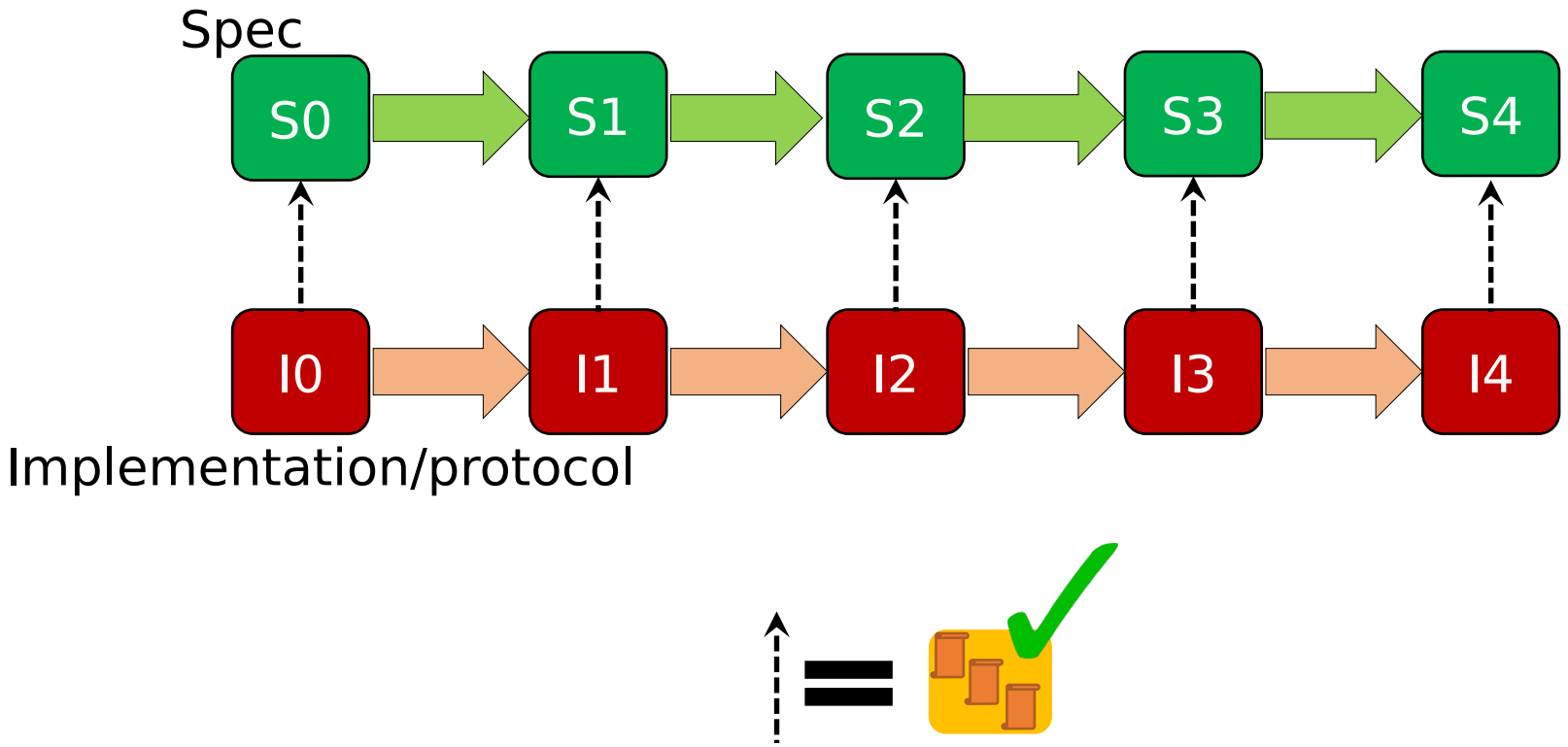
Application correspondence

- Step 3: add a refinement proof **obligation**

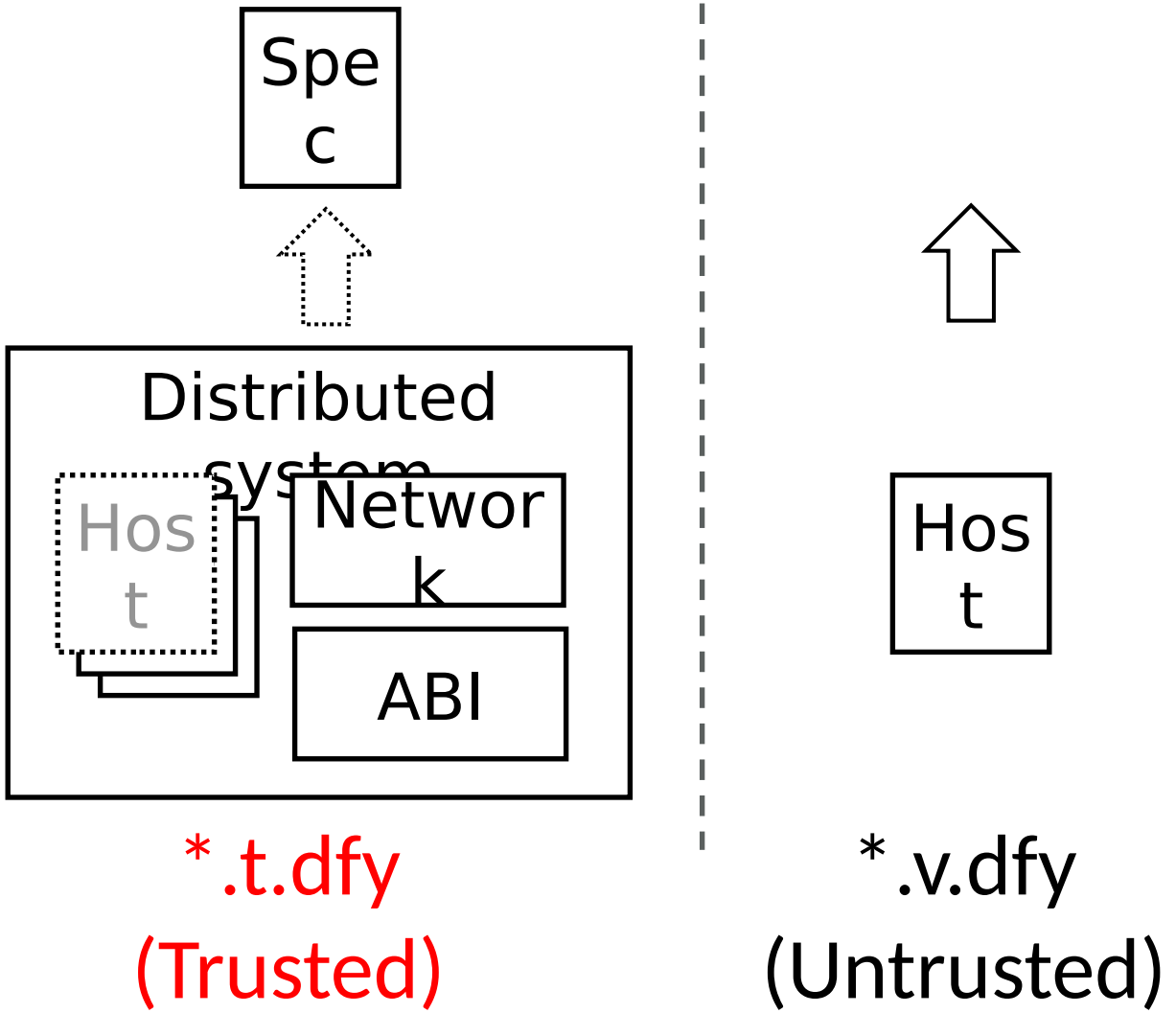
```
lemma RefinementHonorsApplicationCorrespondence(c: Constants, v:
Variables)
  requires Inv(c, v)
  ensures Abstraction(c, v).requests == v.abi.requests
  ensures Abstraction(c, v).replies == v.abi.replies
{
}
```

There is no longer a reason to inspect `Abstraction()`. It is just part of the proof that constructs `Spec.Variables` as `Abstraction(Variables)`.

Application correspondence



Revisiting the big picture



Administrivia

- Monday lecture given by Jon Howell

- Also, Jon's broader verification talk, Monday 11am, BBB 3725
  - Title: **The End of Testing?**
    The Promise of Verification-Driven Software Engineering
  - I strongly encourage you to attend, if you are available

Triggers

- **Q:** Does Dafny verify this code?

```
predicate P(x:int)
predicate Q(x:int)

method test()
  requires forall x :: P(x) && Q(x)
  ensures Q(0)
{
}
```

A: Only if it's smart enough to pick the right trigger

Imagine you are the solver

```
requires forall x :: P(x) && Q(x)
```

I wonder if P(0) is a useful fact...

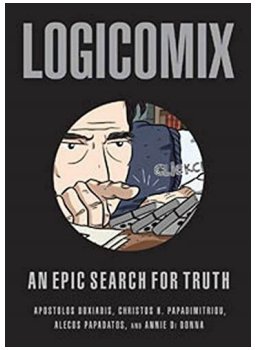
I wonder if P(8) is a useful fact...

I wonder if Q(0) is a useful fact...

I wonder if Q(8) is a useful fact...

Completeness vs Soundness

- Proving a program correct is undecidable
  - i.e. it is impossible to design a program that always correctly answers the question: is this program correct
- Side note:
  - Logicomix
  - Veritasium



- Provers embrace incompleteness while guarding soundness
  - Incompleteness: the prover will say “no” to some correct programs
  - Soundness: the prover will never say “yes” to an incorrect program

Triggers

- **What is a trigger?**

A syntactic pattern involving quantified variables

A heuristic to let the solver know when to **instantiate** the quantifier

Triggers

- **Q:** Does Dafny verify this code?

```
predicate P(x:int)
predicate Q(x:int)

method test()
  requires forall x {:trigger P(x)} :: P(x) && Q(x)
  ensures Q(0)
{

}
```