COMPUTER SCIENCE & ENGINEERING

EECS498-008
Formal Verification of Systems Software

Material and slides created by

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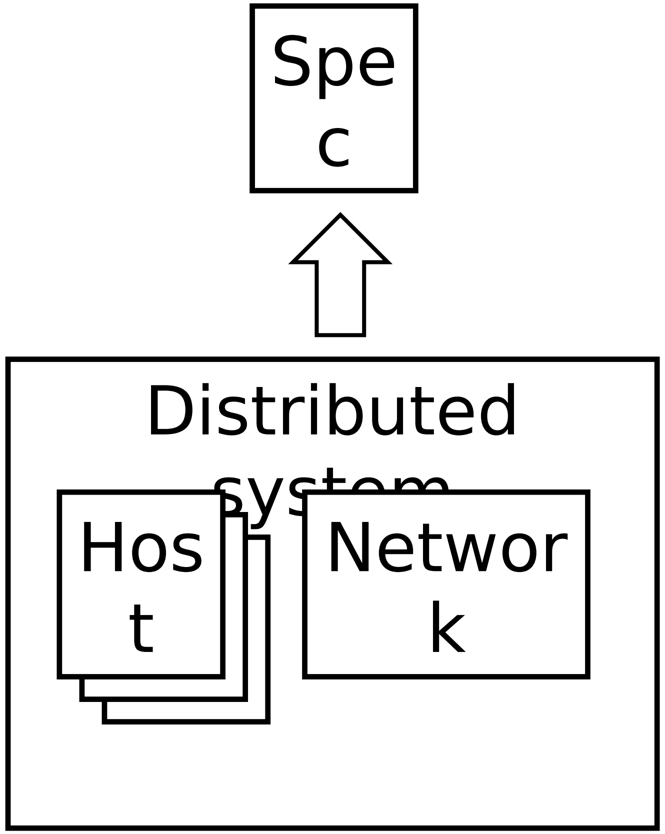
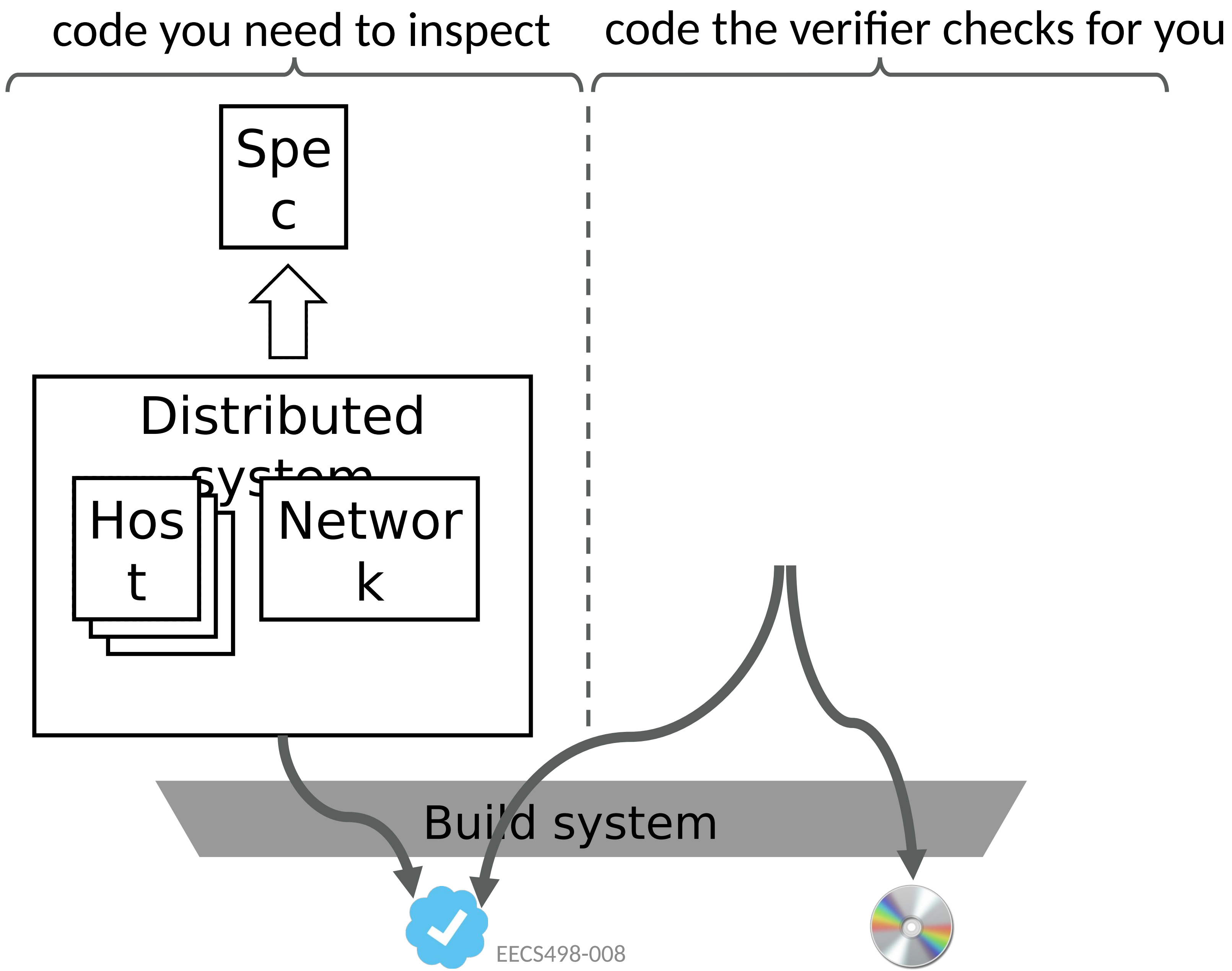
Refinement recap



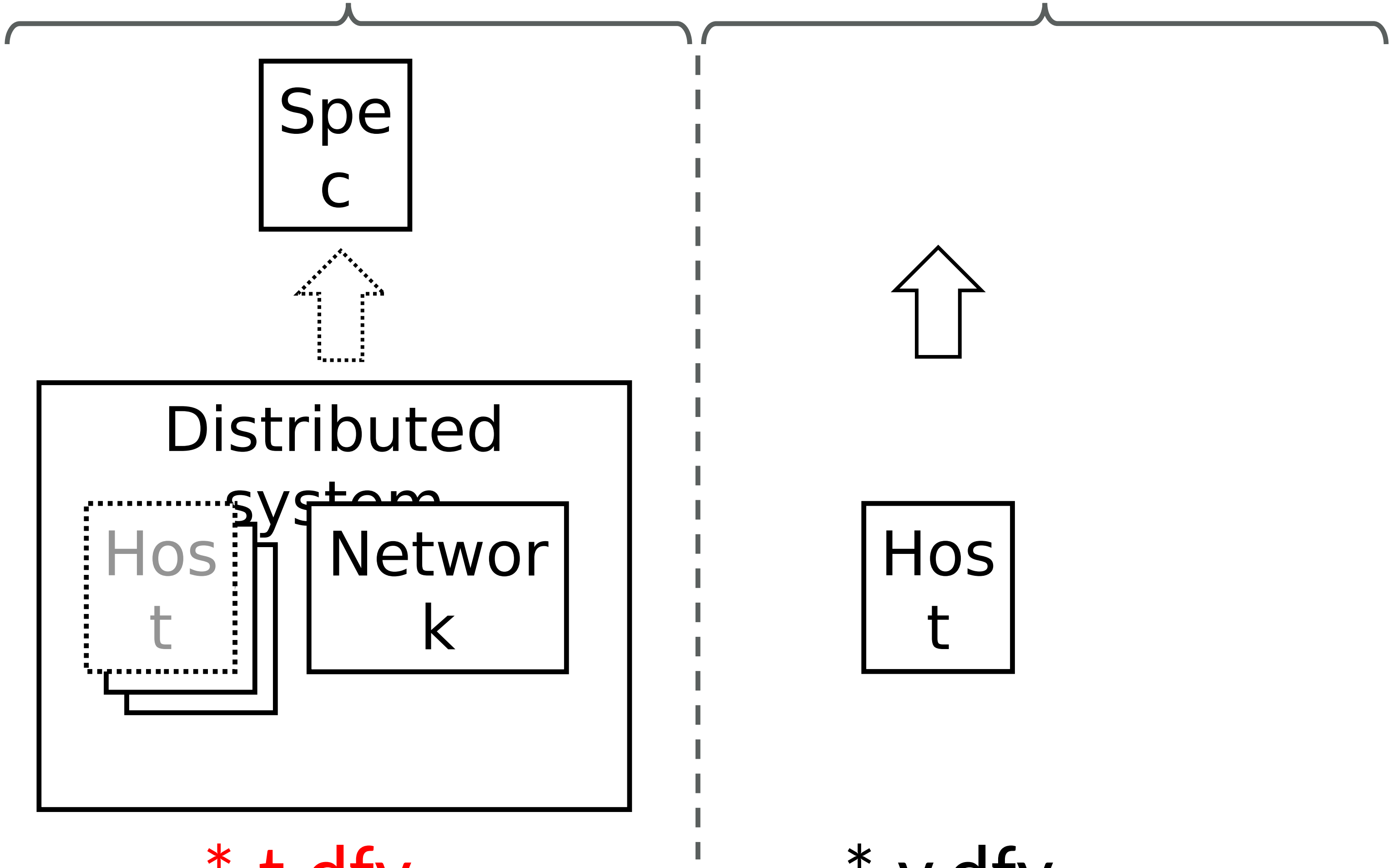

```
function A(v:Variables) : Spec.Variables
predicate Inv(v:Variables) { … }

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



*.t.dfy
(Trusted)

*.v.dfy
(Untrusted)

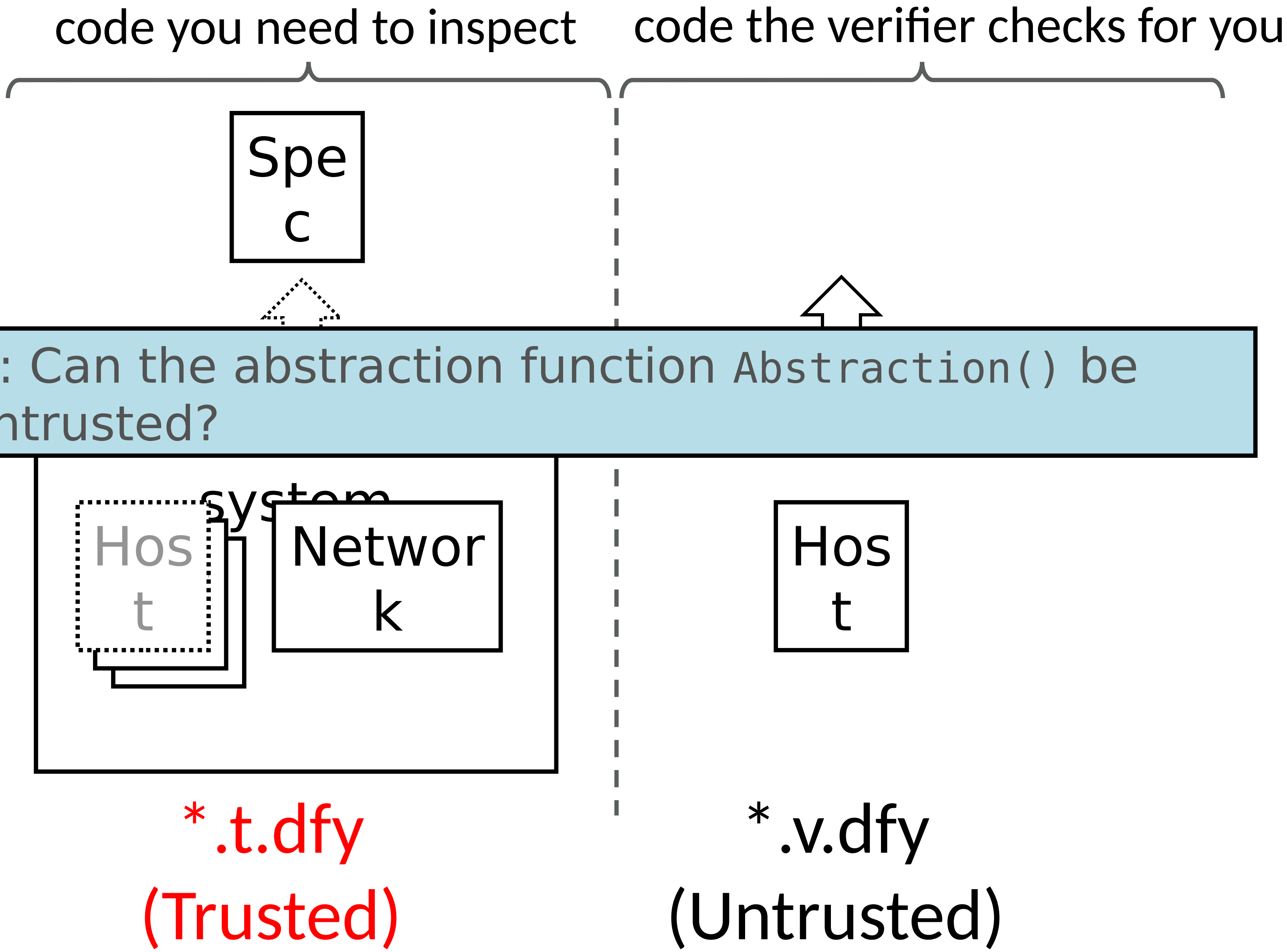
The verification game

- 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



Q: Can the abstraction function `Abstraction()` be untrusted?

What if the abstraction function pretended nothing ever happened?

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

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

Always returns the initial state

…or just made up a fake story?

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

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

Returns fake state

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)
  ...
}
```

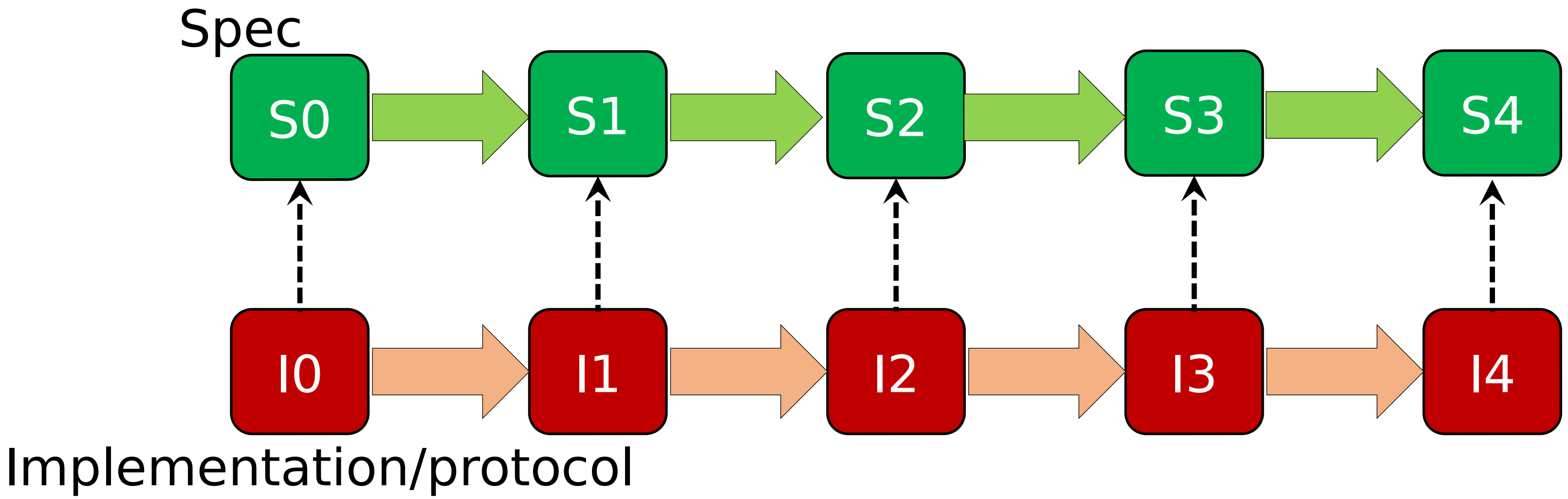
Application correspondence

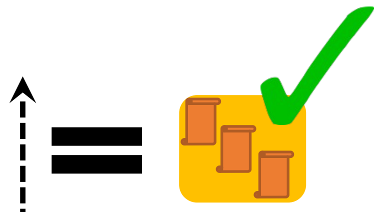
- Step 3: add a refinement proof **obligation**

```
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
{
}
```

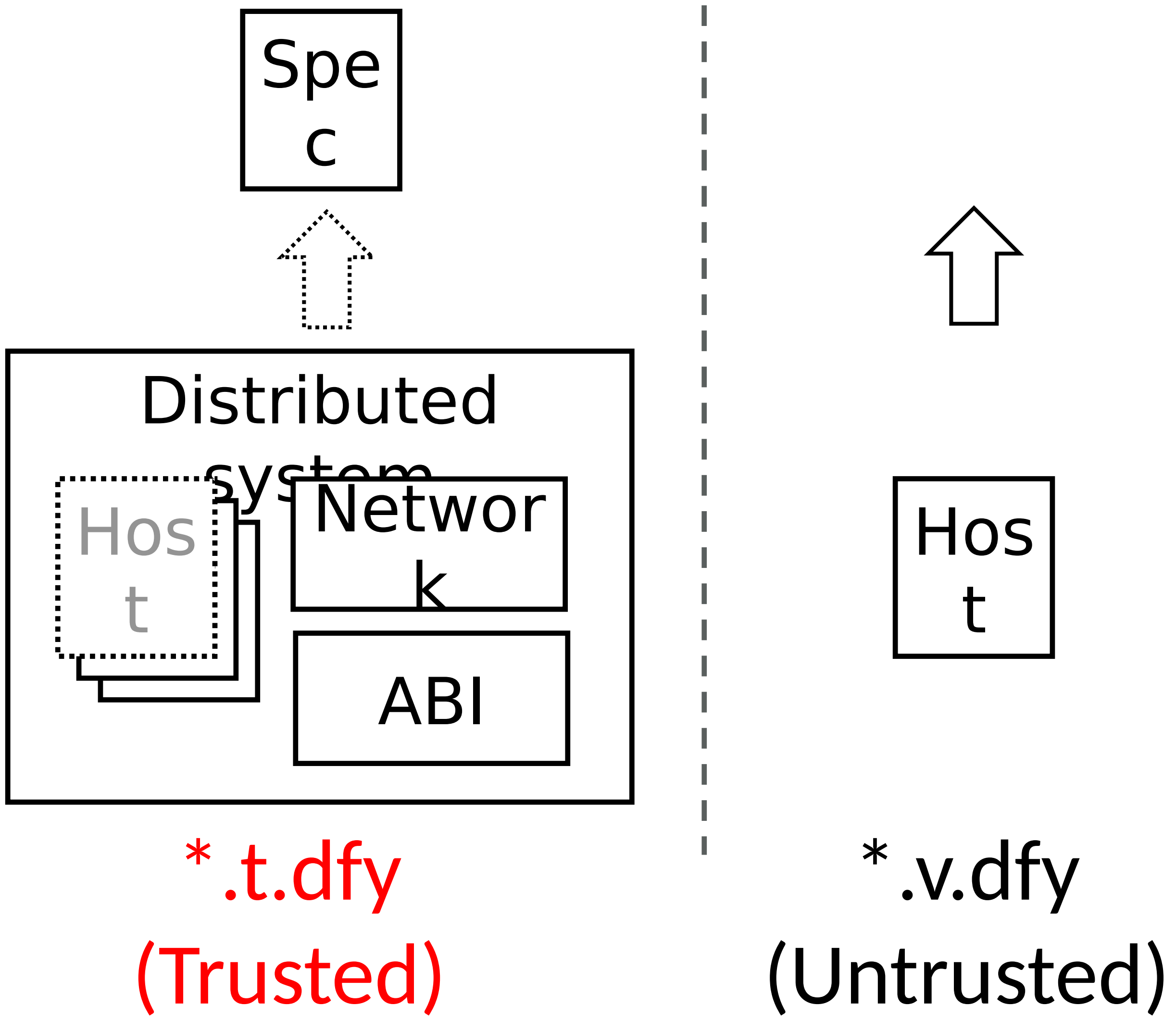
There is no longer a reason to inspect `Abstraction()`. It is just part of the proof that constructs `Spec.Variables` as `Abstraction(Variables)`.

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(9) is a useful fact…

I wonder if P(17) is a useful fact…

I wonder if P(8) is a useful fact…

I wonder if Q(0) is a useful fact…

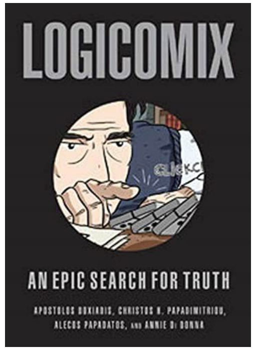
I wonder if Q(9) is a useful fact…

I wonder if Q(17) 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)
{

}
```