Software System Design and Implementation

Lecture 8: Static Analysis, Phantom Types

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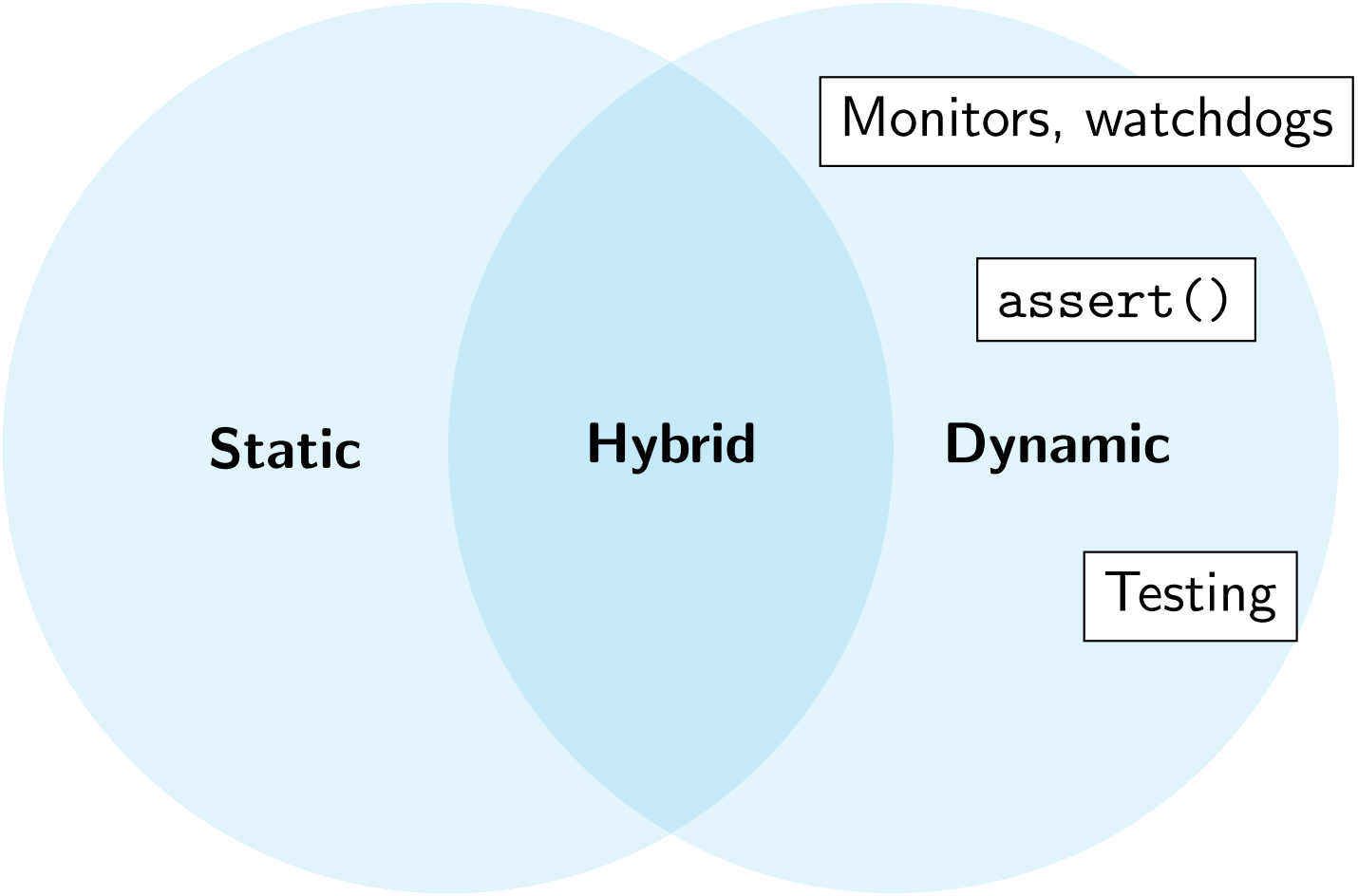
Methods of Assurance



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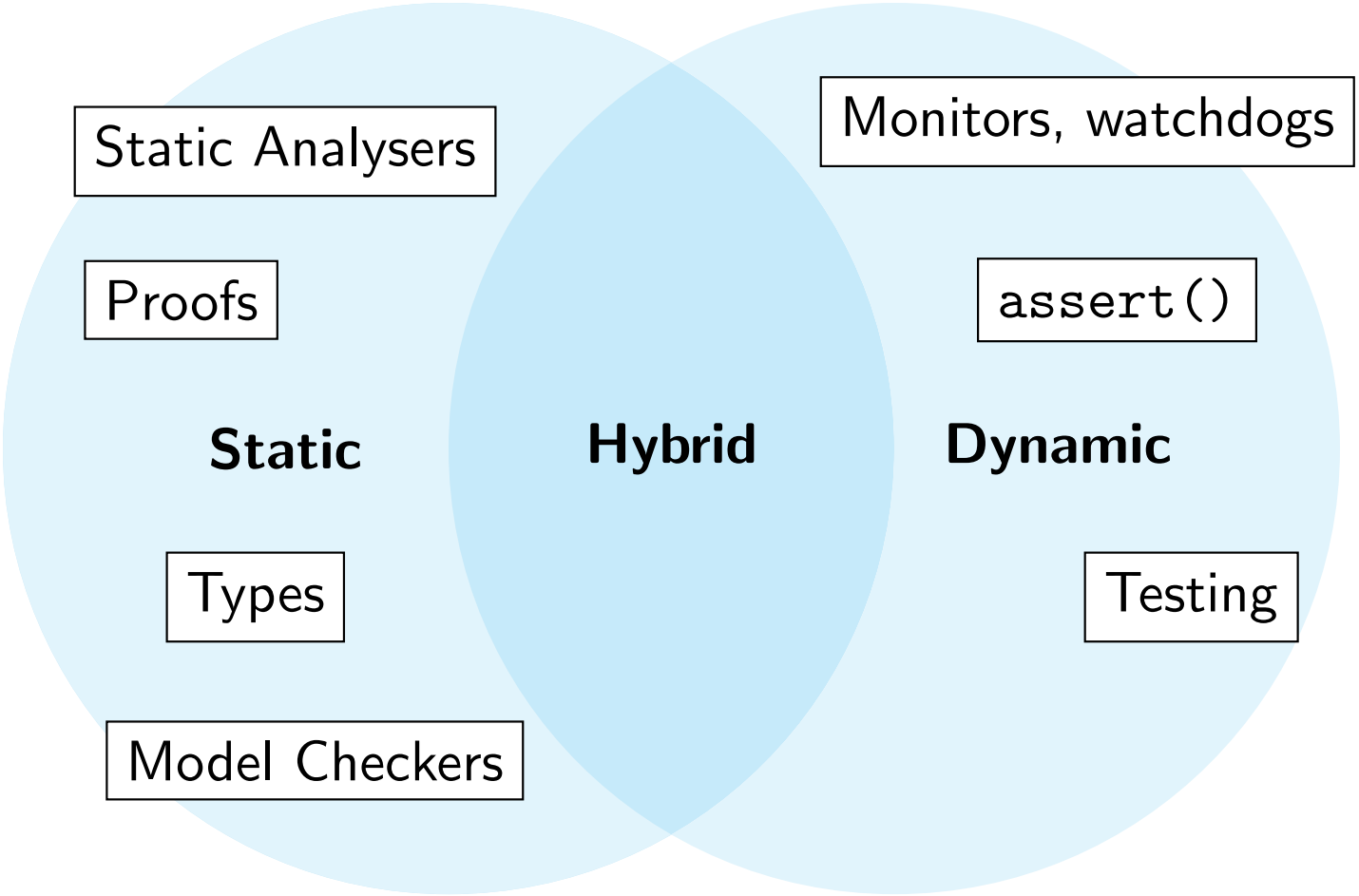

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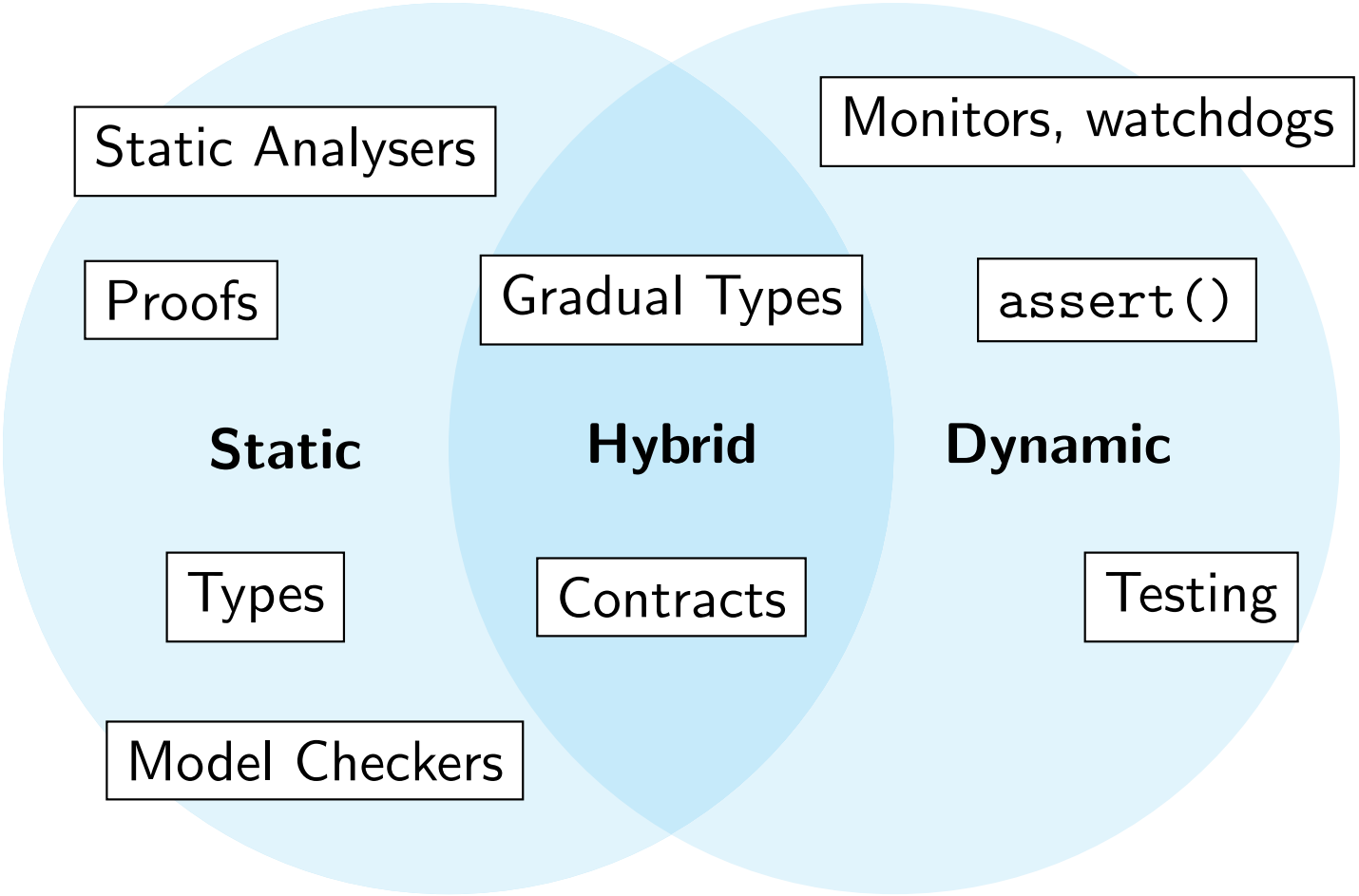

Static means of assurance analyse a program without running it.

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Exhaustivity

An exhaustive check is a check that is able to analyse all possible executions of a program.

- **However**, some properties cannot be checked statically in general (halting problem), or are intractable to feasibly check statically (state space explosion).
- Dynamic checks cannot be exhaustive, but can be used to check some properties where static methods are unsuitable.

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Types

Because types are integrated into the compiler, they cannot diverge from the source code. This means that type signatures are a kind of machine-checked documentation for your code.

Static Checks are Possible

Theorem (H. G. Rice)

All non-trivial properties of partial computable functions $\mathbb{N} \to \mathbb{N}$ are *undecidable*. A property is non-trivial if it is neither true for every partial computable function, nor false for every partial computable function.

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- **semantic**: about the function computed by the program
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Syntactic properties may be decidable; by Rice's theorem semantic ones aren't. But syntactic properties can imply semantic properties.

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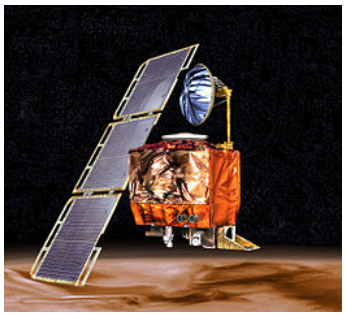
In the next two weeks, we'll look at techniques to encode various correctness conditions inside Haskell's type system.

Phantom Types

We'll start with Phantom Types.

Units of Measure

In 1999, badly written software confusing units of measure (U.S. Customary unit of force Pounds and SI/Metric unit of force Newtons) caused the Mars Climate Orbiter to burn up on atmospheric entry.



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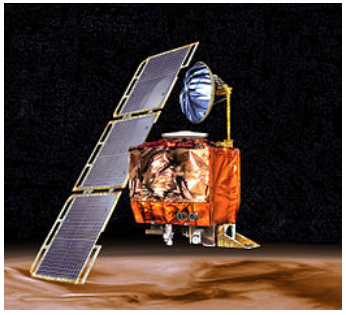

Demo 1: Units of Measure

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Definition

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Examples:

```
data DoubleUnit u = DoubleUnit Double
data NestedList r a = NestedList [[a]]
```

Non-examples:

```
data Maybe a = Nothing | Just a
data NamedMaybe e = NM String (Maybe e)
```

Borderline but non-example:

```
data StringWith r = Nil | Cons Char (StringWith r)
```

Phantom Types

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- We can use this parameter to track information about the representation (e.g. units of measure).
- There are some non-use-cases where regular old data types are preferable: the "database IDs" example you see all over the Internet is one such.

Demo 2: Student IDs

Datatype Promotion

```
data UG
data PG
data StudentID x = ZID Int
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Recall

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The `DataKinds` language extension lets us use data types as kinds:

```
{-# LANGUAGE DataKinds, KindSignatures #-}
data Stream = UG | PG
data StudentID (x :: Stream) = SID Int
-- rest as before
```

Making Illegal States Unrepresentable

If time, more demos!

FIN

1. **Thanks!**