Concolic Testing: An Application of Solvers

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A Foundation for Software Engineering

Logic Abstractions of Computation

Bob Floyd (1967)
Tony Hoare (1968,70)
Amir Pnueli (1977)
Ed Clarke (1982)
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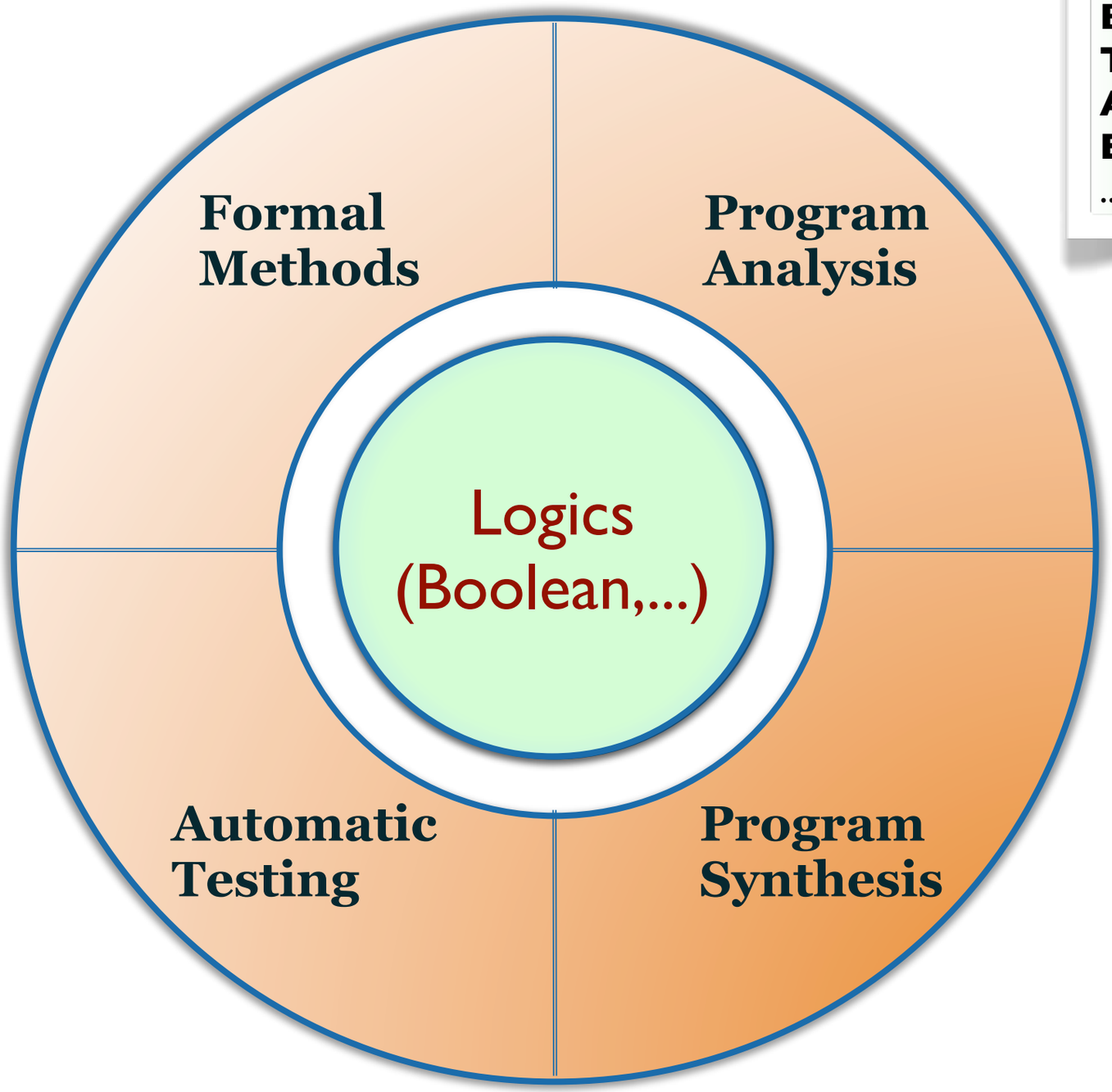
Logic Abstractions of Computation



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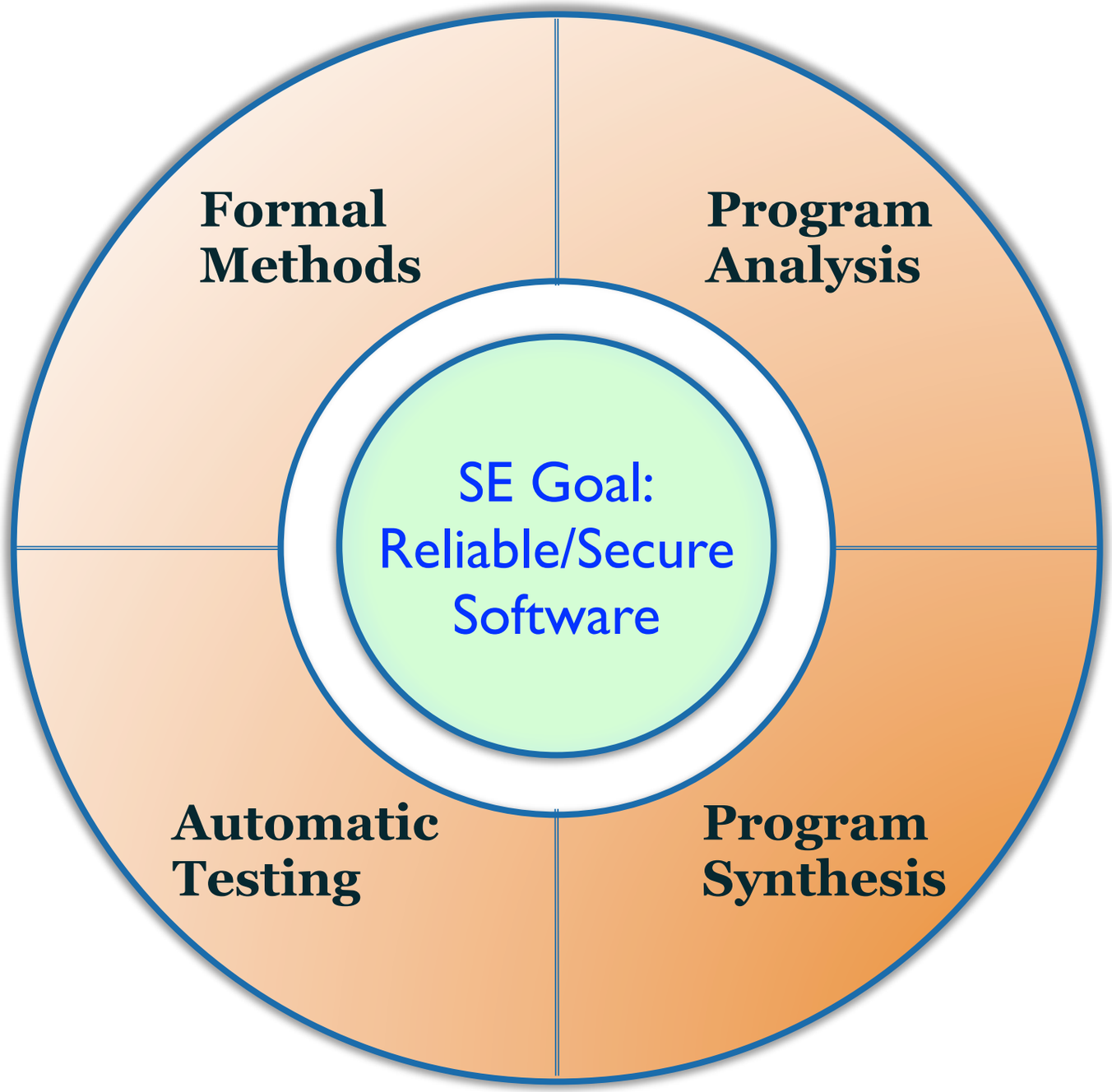
Software Engineering & SAT/SMT Solvers

An Indispensable Tactic for Any Strategy



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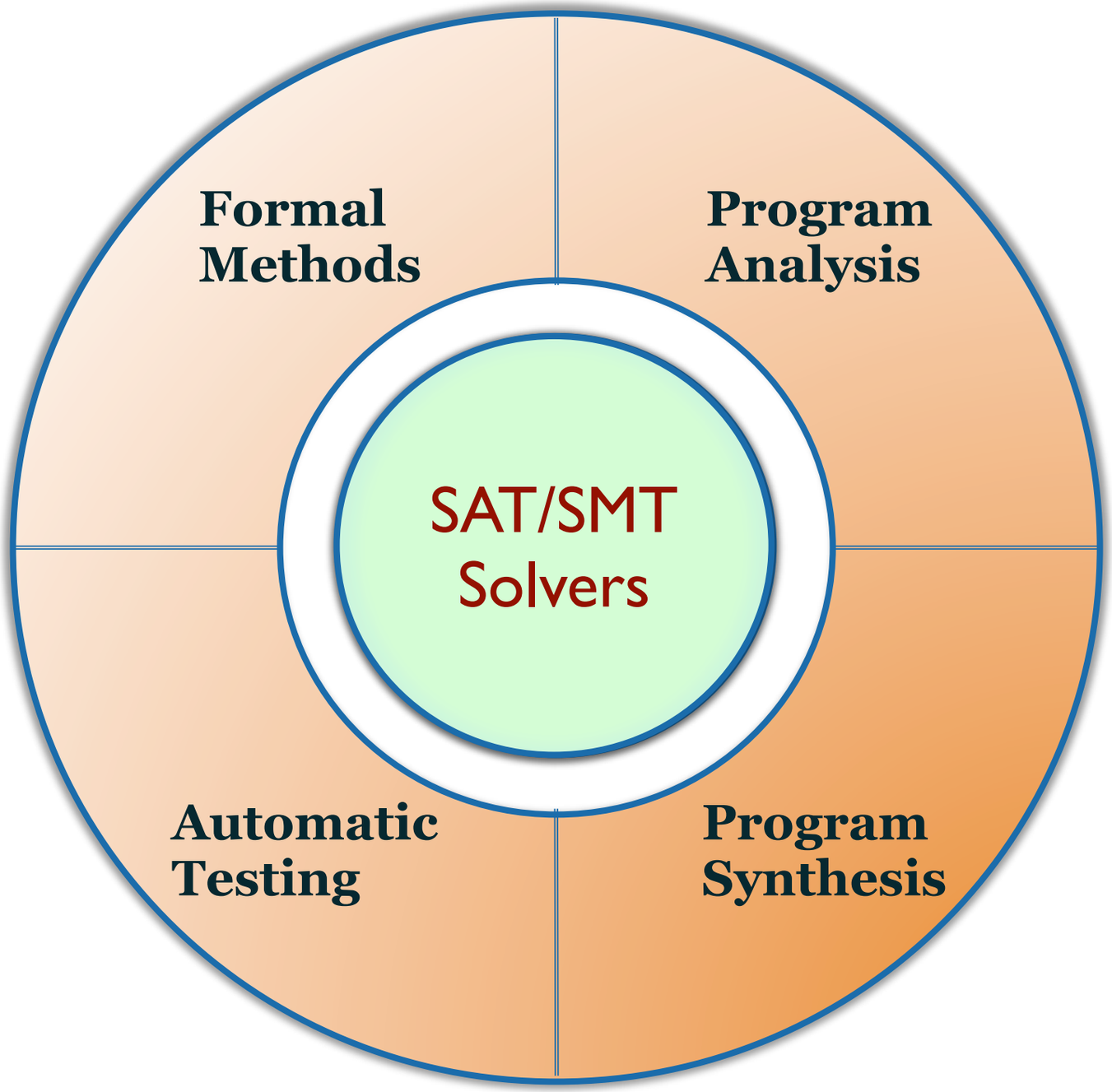
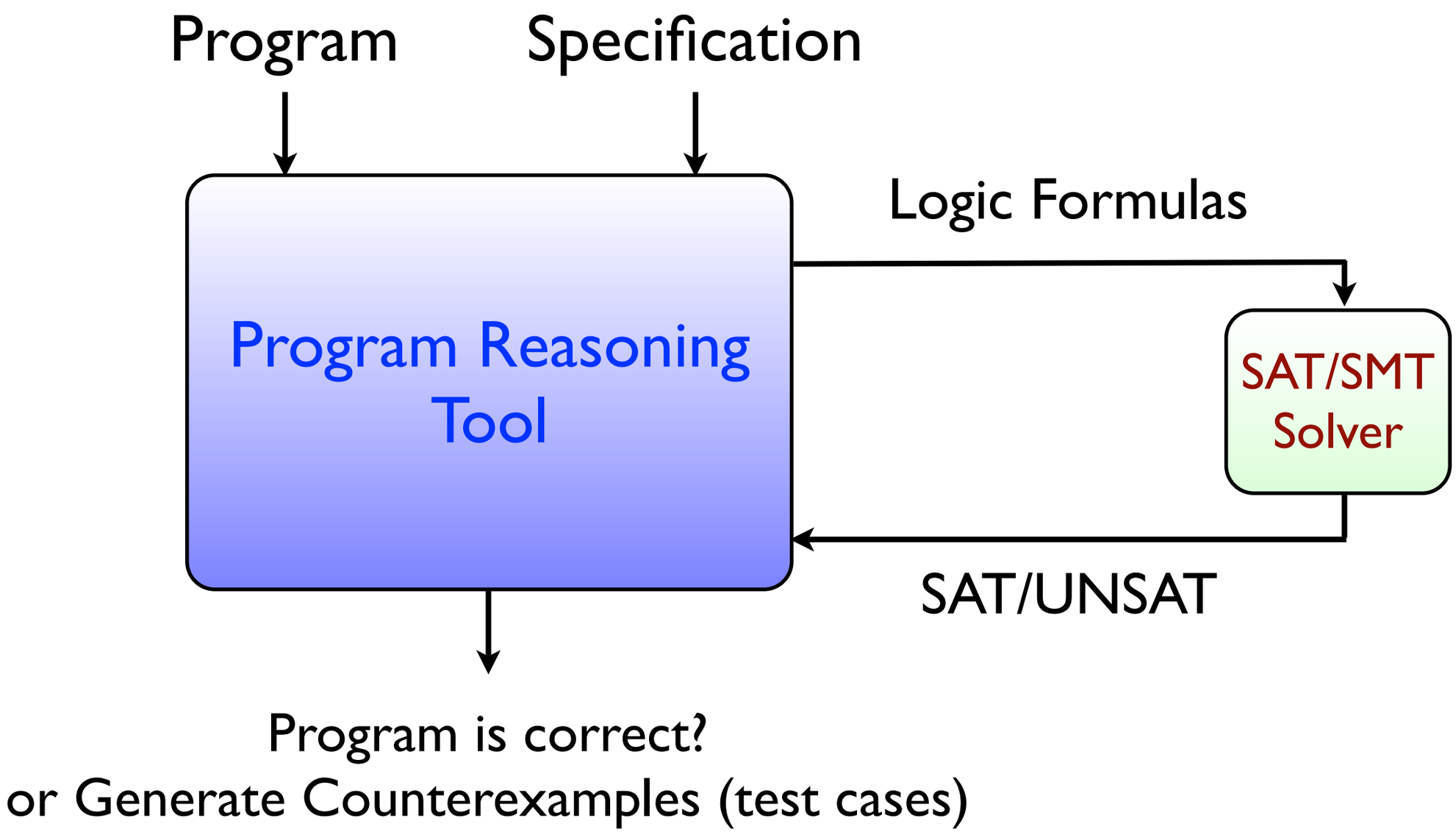


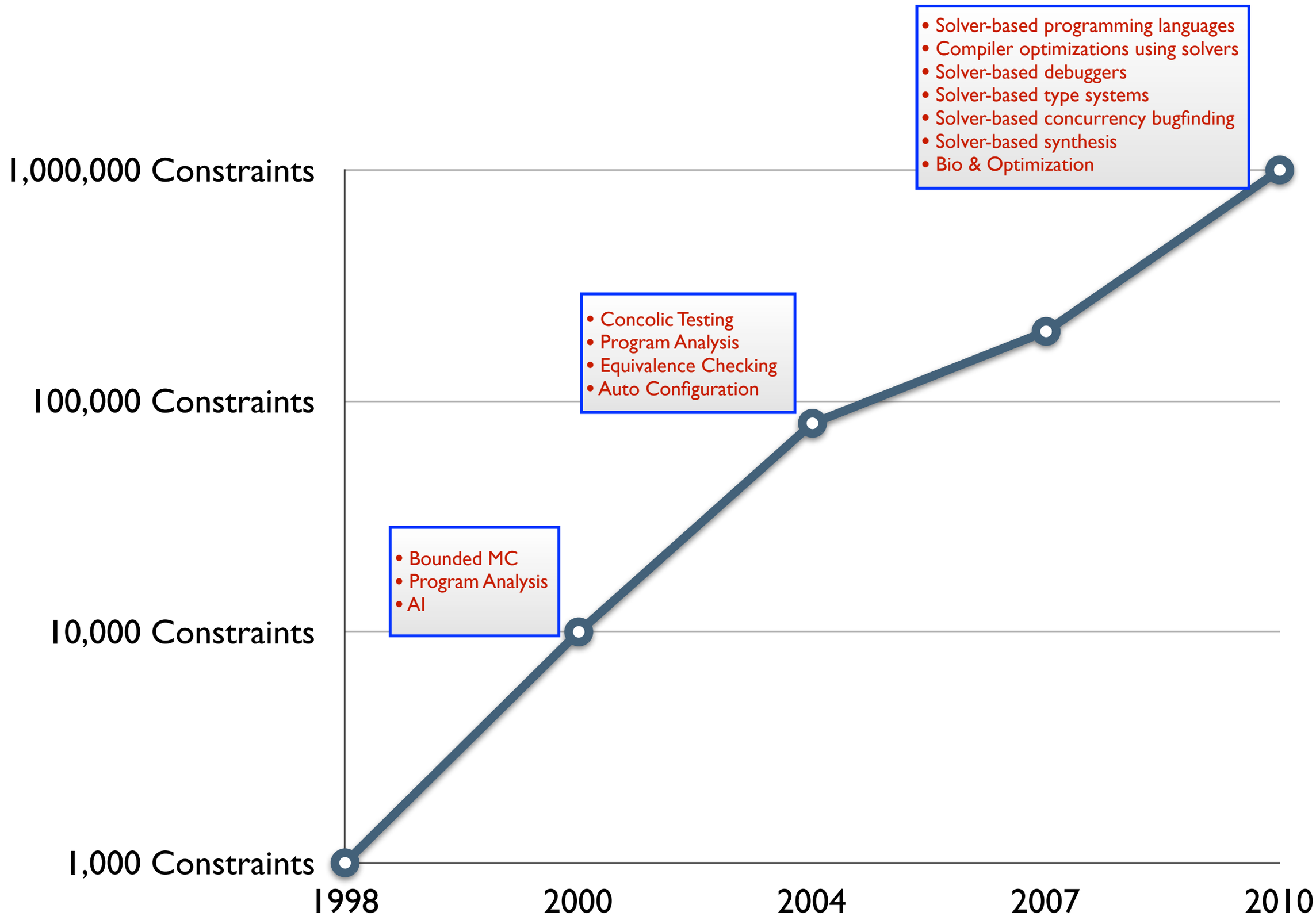
Software Engineering using Solvers

Engineering, Usability, Novelty



SAT/SMT Solver Research Story

A 1000x Improvement: Democratization of Logic



The SAT/SMT Problem

- Rich logics (Modular arithmetic, Arrays, Strings,...)
- NP-complete, PSPACE-complete,...
- Practical, scalable, usable, automatic
- Enable novel software reliability approaches

Dynamic Systematic Testing

Some History

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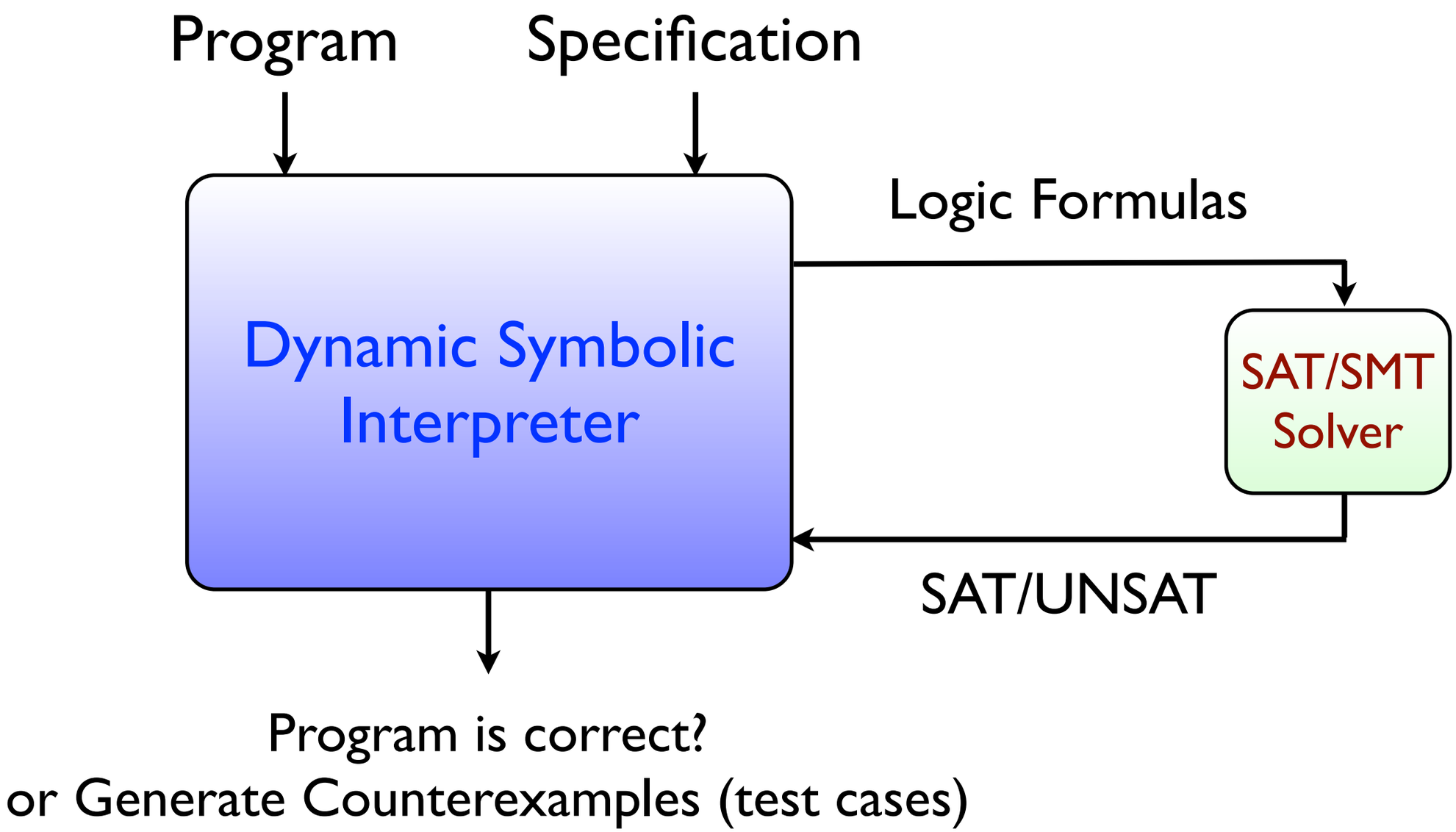
- ☑ Beyond testing: Fault localization, repair, security,...

Dynamic Symbolic Testing

Symbolic/Concrete Execution + Solvers



Concolic Testing: Example

```
int double (int v) {
    return 2*v;
}

void testme (int x, int y) {
    z = double (y);
    if (z == x) {
        if (x > y+10) {
            ERROR;
        }
    }
}
```

The concolic testing slides are courtesy Koushik Sen

Concolic Testing: Example

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int double (int v) {
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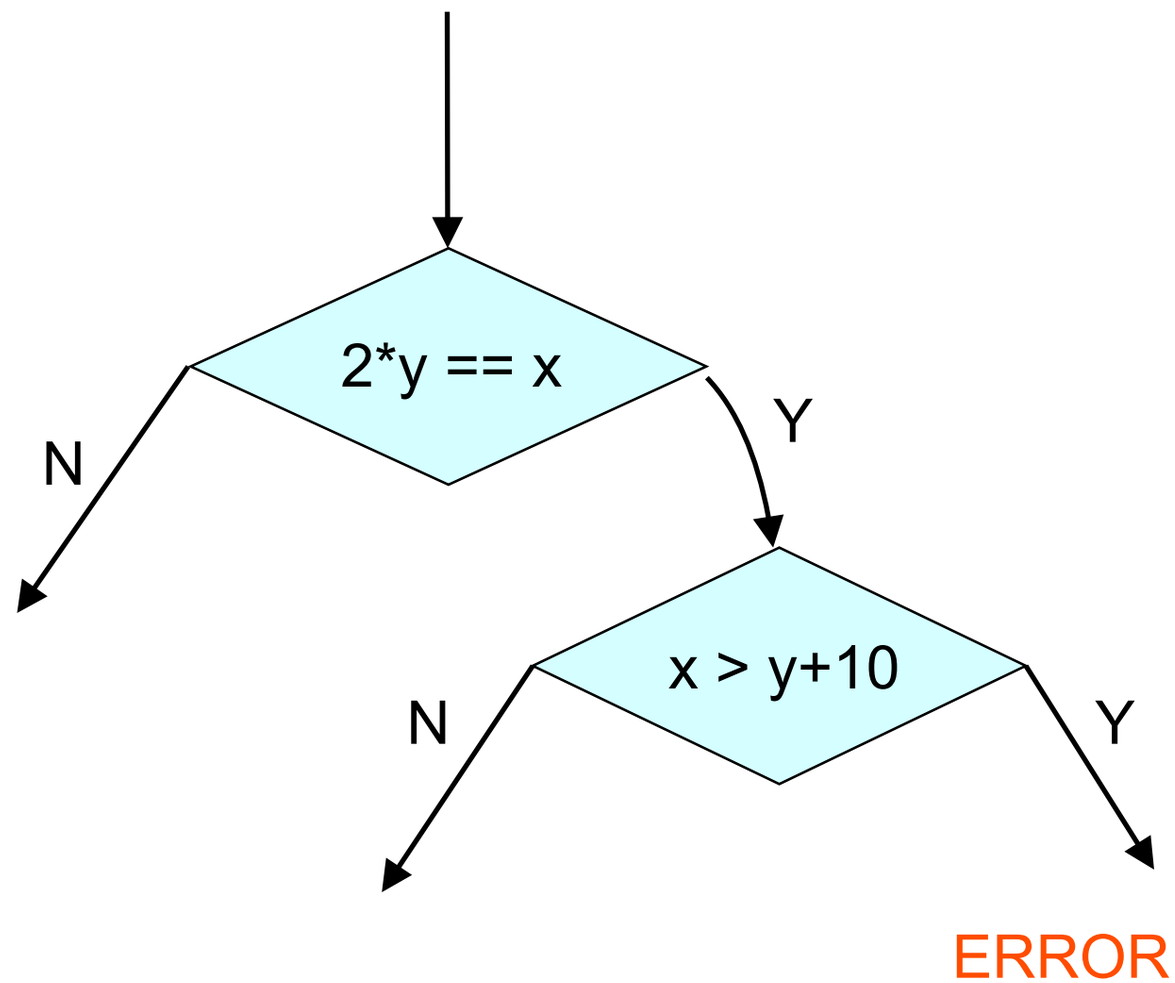

Concolic Testing Approach

```
int double (int v) {
    return 2*v;
}

void testme (int x, int y) {
    z = double (y);
    if (z == x) {
        if (x > y+10) {
            ERROR;
        }
    }
}
```

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 22, y = 7$	$x = x_0, y = y_0$	

Concolic Testing Approach

```
int double (int v) {
    return 2*v;
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void testme (int x, int y) {
    z = double (y);
    if (z == x) {
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        }
    }
}
```

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 22, y = 7,$	$x = x_0, y = y_0,$	
$z = 14$	$z = 2*y_0$	

Concolic Testing Approach

```
int double (int v) {
    return 2*v;
}

void testme (int x, int y) {
    z = double (y);
    if (z == x) {
        if (x > y+10) {
            ERROR;
        }
    }
}
```

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 22, y = 7, z = 14$	$x = x_0, y = y_0, z = 2*y_0$	$2*y_0 != x_0$

Concolic Testing Approach

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int double (int v) {
    return 2*v;
}

void testme (int x, int y) {
    z = double (y);
    if (z == x) {
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}
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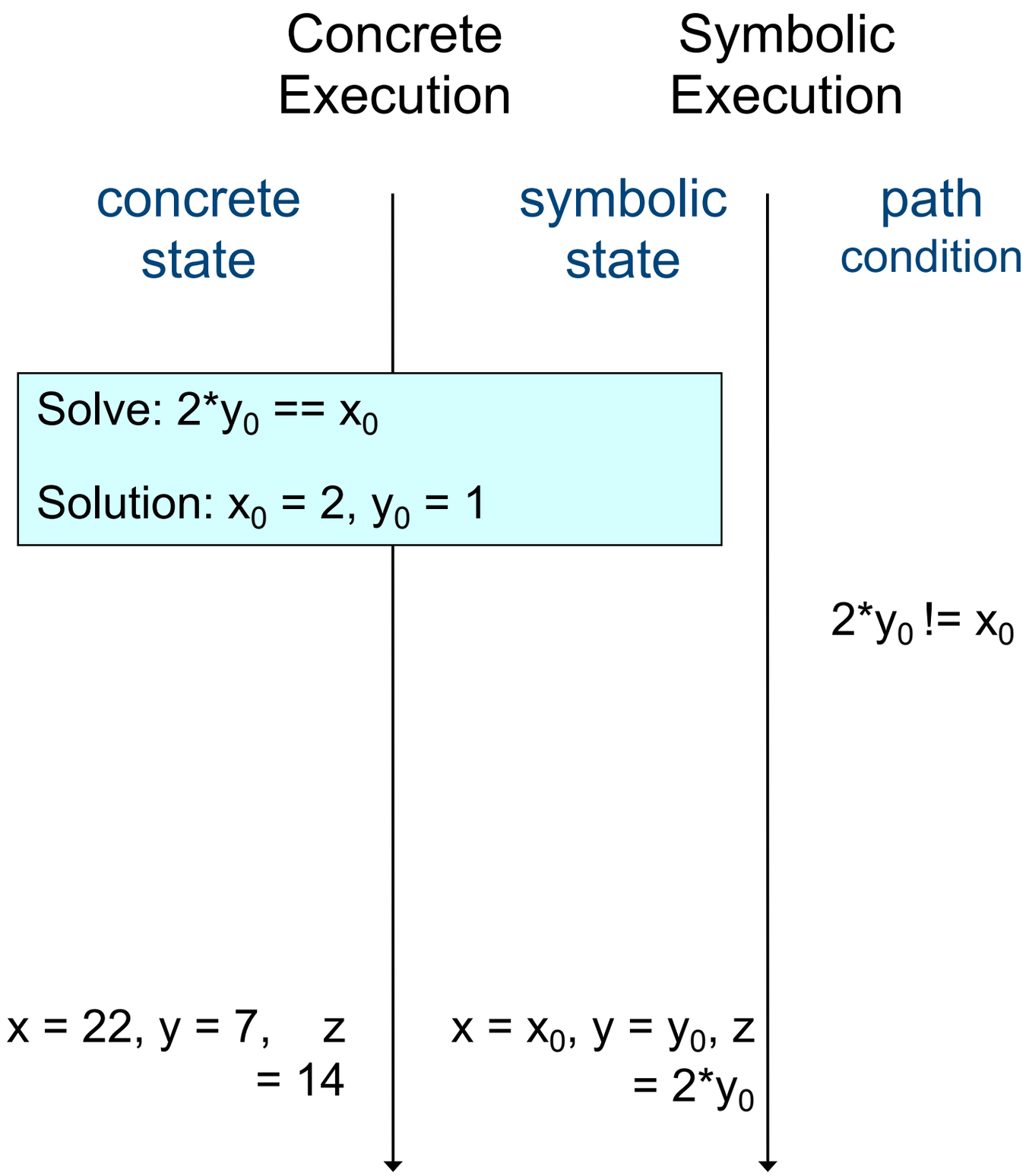

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    if (z == x) {
        if (x > y+10) {
            ERROR;
        }
    }
}
```

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 2, y = 1,$ $z = 2$	$x = x_0, y = y_0,$ $z = 2*y_0$	$2*y_0 == x_0$

Concolic Testing Approach

```
int double (int v) {
    return 2*v;
}

void testme (int x, int y) {
    z = double (y);
    if (z == x) {
        if (x > y+10) {
            ERROR;
        }
    }
}
```

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 2, y = 1, z = 2$	$x = x_0, y = y_0, z = 2*y_0$	$2*y_0 == x_0$
		$x_0 > y_0+10$

Concolic Testing Approach

```
int double (int v) {
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}

void testme (int x, int y) {
    z = double (y);
    if (z == x) {
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}
```

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 2, y = 1, z = 2$	$x = x_0, y = y_0, z = 2*y_0$	$2*y_0 == x_0$
		$x_0 \cdot y_0+10$

Solve: $(2*y_0 == x_0)$ **AND** $(x_0 > y_0 + 10)$

Solution: $x_0 = 30$, $y_0 = 15$

Concolic Testing Approach

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Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
$x = 30, y = 15$	$x = x_0, y = y_0$	

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int double (int v) {
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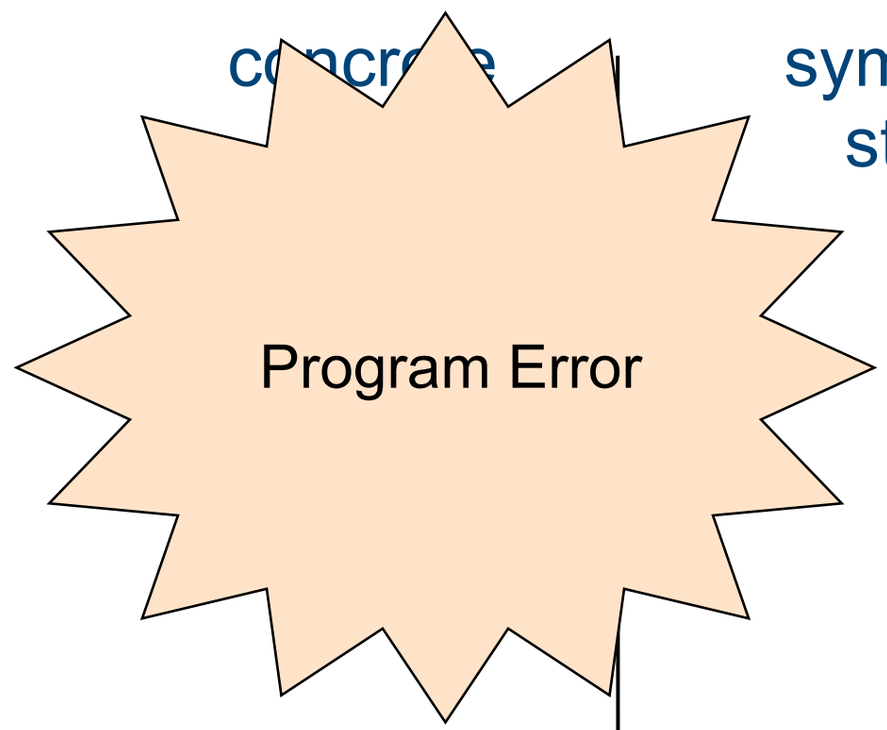

Concrete Execution	Symbolic Execution	
concrete state	symbolic state	path condition
		$2*y_0 == x_0$
		$x_0 > y_0+10$
$x = 30, y = 15$	$x = x_0, y = y_0$	

Explicit Path (not State) Model Checking

- Traverse all execution paths one by one to detect errors
  - assertion violations
  - program crash
  - uncaught exceptions
- combine with valgrind to discover memory errors