Extended Static Checking for Java

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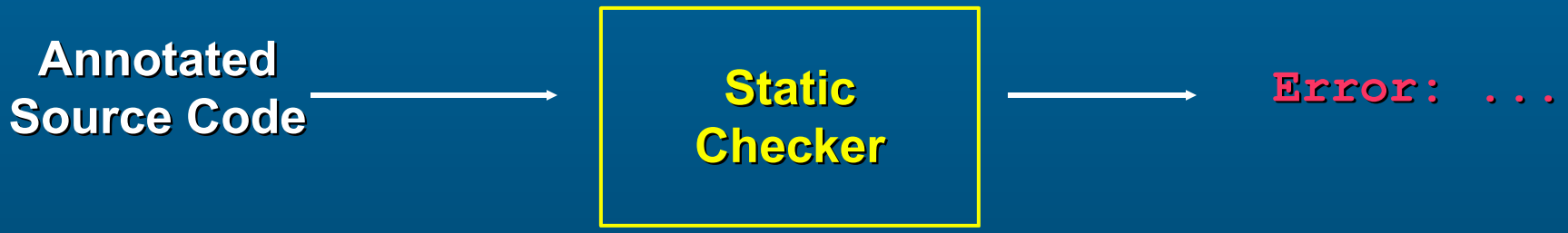
COMPAQ

What is “Static Checking”?



type systems

```
Error: wrong number of arguments in method call
```

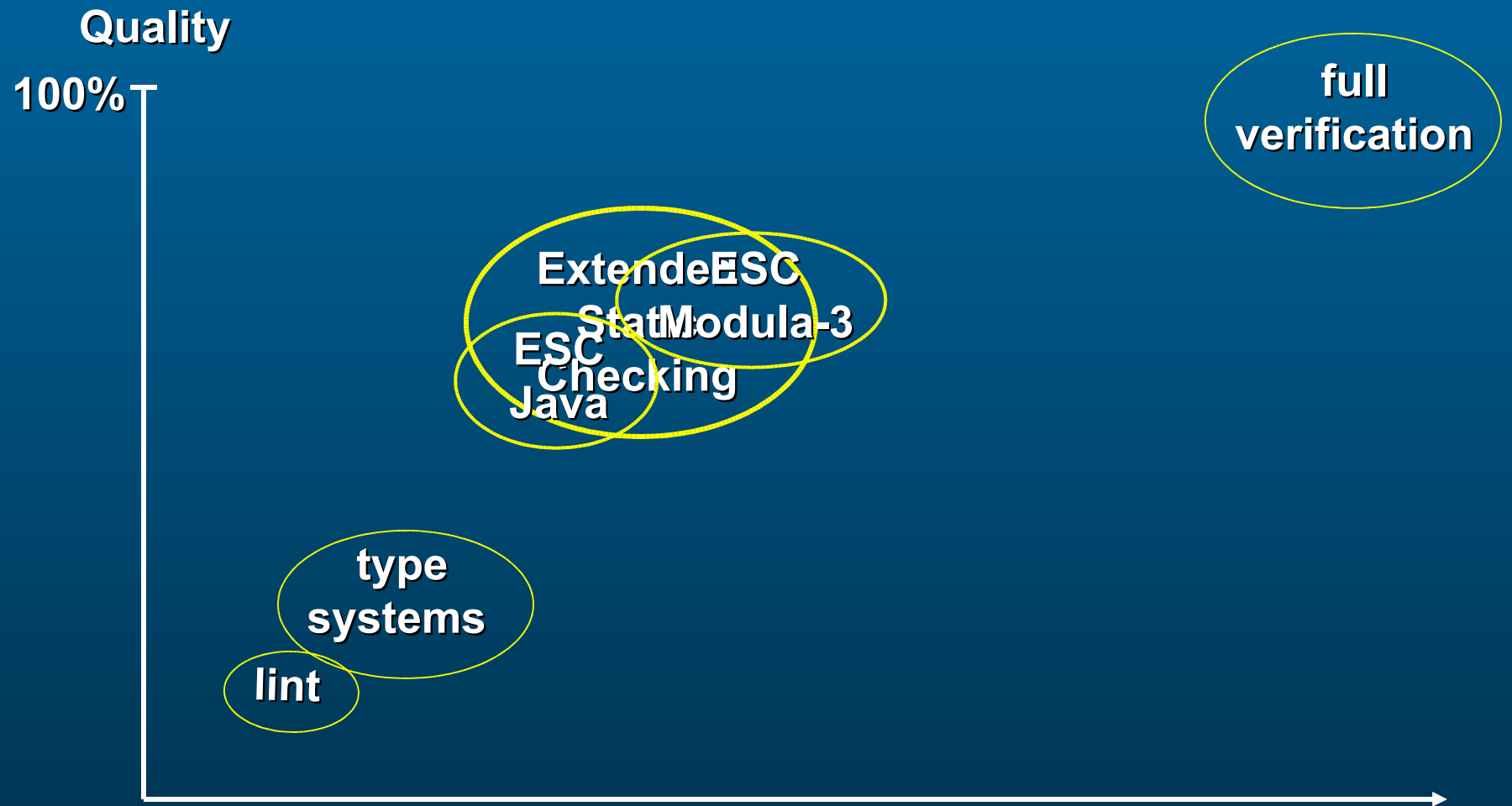
lint

```
Error: unreachable code
```

full program verification

```
Error: qsort does not yield a sorted array
```

Comparison of Static Checkers



Note: Graph is not to scale

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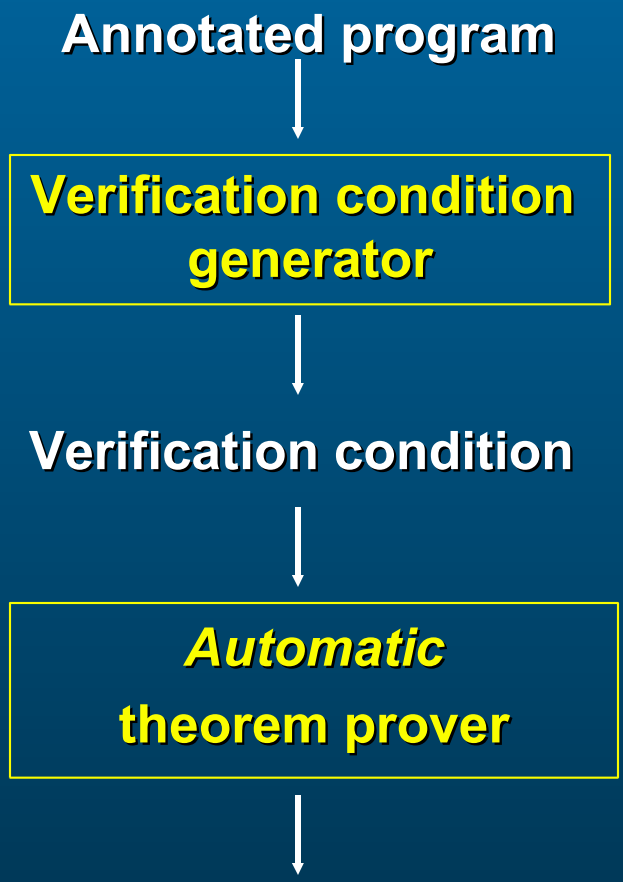
ESC/Java

- Detect common run-time errors
  - null dereferences
  - array bounds
  - type casts
  - race conditions
  - deadlocks
  - ...
- Check other properties
  - object invariants
  - method specifications
  - ...

Architecture of ESC/Java



Not Full Verification

Prove absence of run-time errors, not full functional correctness

- Simpler method specifications
- Verification conditions easier to prove

Example

```
void sort2(int[] a)
 //@ requires a != null && a.length == 2
 //@ ensures a[0] <= a[1]
{
  if( a[0] > a[1] )
  {
       int t = a[0];
       a[0] = a[1];
       a[1] = t;
  }
}
```

```
No more errors detected :-(
```

Under the Hood

Verification condition large but “dumb”

```
(FORALL (t1) (FORALL (t2) (IMPLIES (AND (NEQ a null) (EQ (arrayLength a) 2))
(AND (NEQ a null) (AND (AND (<= 0 0) (< 0 (arrayLength a))) (AND (NEQ a
null) (AND (AND (<= 0 1) (< 1 (arrayLength a))) (AND (IMPLIES (> (select
(select elem a) 0) (select (select elem a) 1)) (FORALL (t3) (AND (NEQ a
null) (AND (AND (<= 0 0) (< 0 (arrayLength a))) (FORALL (t) (IMPLIES (EQ t
(select (select elem a) 0)) (FORALL (t1) (IMPLIES (EQ t1 a) (AND (NEQ a
null) (AND (AND (<= 0 1) (< 1 (arrayLength a))) (AND (NEQ t1 null) (AND (AND
(<= 0 0) (< 0 (arrayLength t1))) (FORALL (t2) (IMPLIES (EQ t2 a) (AND (NEQ
t2 null) (AND (AND (<= 0 1) (< 1 (arrayLength t2))) (AND (<= (select (select
(store (store elem t1 (store (select elem t1) 0 (select (select elem a) 1)))
t2 (store (select (store elem t1 (store (select elem t1) 0 (select (select
elem a) 1))) t2) 1 t)) a) 0) (select (select (store (store elem t1 (store
(select elem t1) 0 (select (select elem a) 1))) t2 (store (select (store
elem t1 (store (select elem t1 0 (select (select elem a) 1))) t2 1 t)) a)
1)) (EQ true true))))))))))))))))) (IMPLIES (NOT (> (select (select elem a)
0) (select (select elem a) 1))) (AND (<= (select (select elem a) 0) (select
(select elem a) 1)) (EQ true true)))))))))))
```

Proved in < 1 second

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ESC/Java vs. Testing

Testing essential but

- Expensive
- Finds errors late
- Misses errors

ESC/Java ... ?

ESC/Java Summary

Finds more errors than type checking

Costs less than full verification

Currently working on small test programs

www.research.digital.com/SRC/esc/Esc.html

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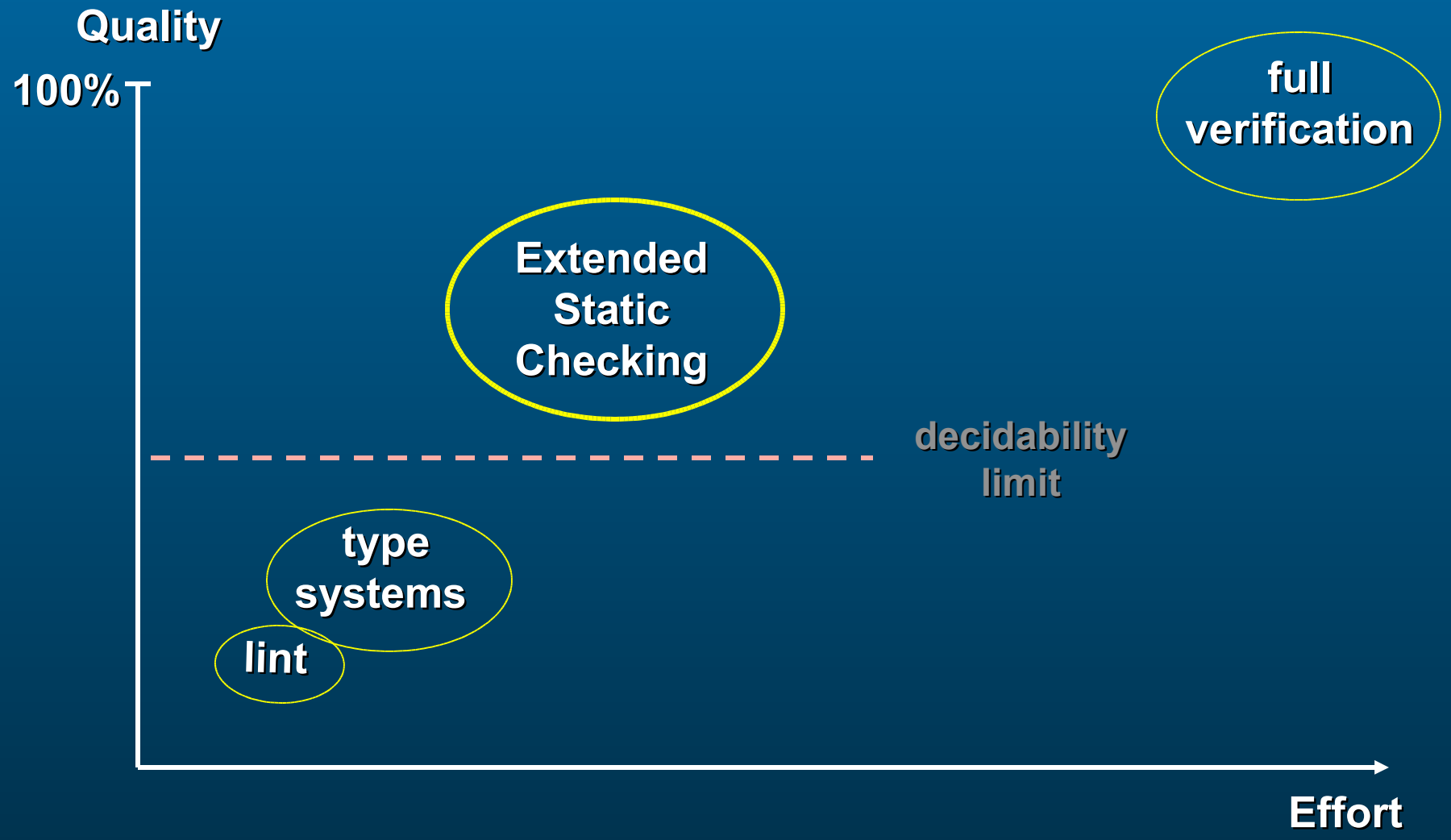

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Metrics for Static Checkers

Cost

- of using the tool

Quality

- Does it miss errors?
- Does it give spurious warnings?