Fuzzing the Solidity Compiler

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- Security engineer, Solidity team
- Semantic testing of Solidity compiler

Find security-critical bugs in the compiler before it is shipped

tl;dr:

- Threat model: Incorrect code generation
- Randomly generated valid Solidity programs test compiler
- Found 2 security relevant bugs in EVM optimizer
    - Low or very low security impact
- Found 5 other bugs in experimental optimizer
- Continuous fuzzing for early bug discovery

Introduction

Threat model

- Compiler user (developer) is not malicious
- Bugs introduced by the optimizer

```
function foo() -> x {
  x := 2
}
mstore(0, foo())
```

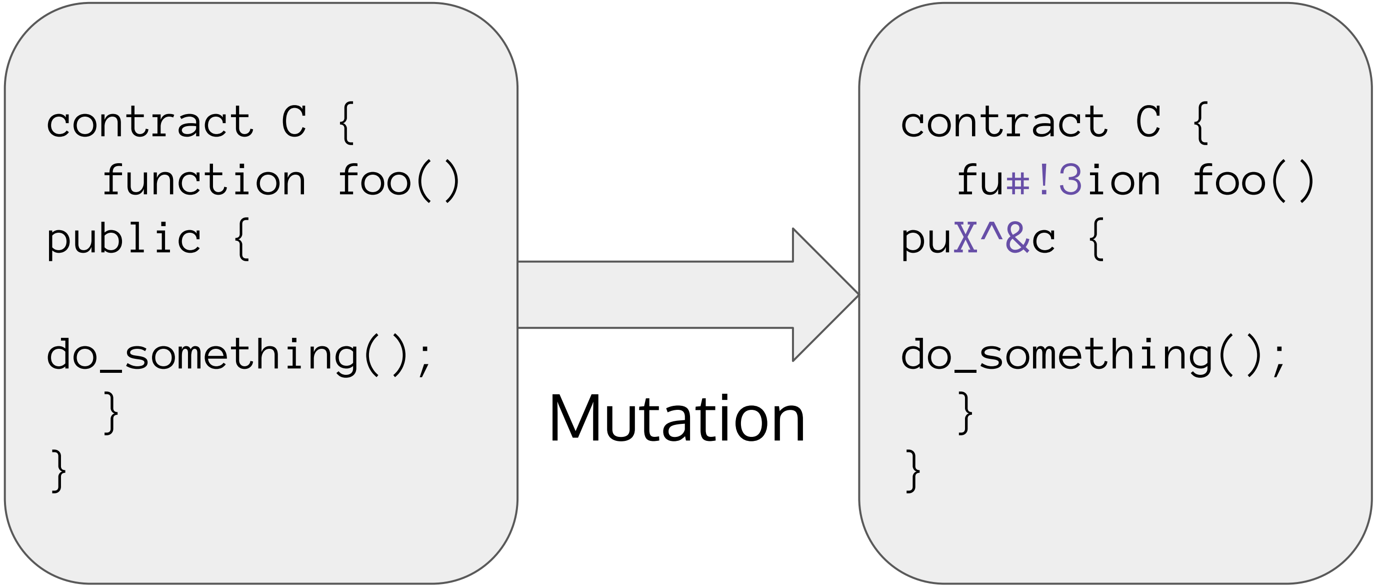
→

```
mstore(0, 2)
```

Fuzz testing in a nutshell

```
while not ctrl + c
do
    input=gen_input()
    runProgram(input)
done
```

Limitation of random fuzzing



```
contract C {
   function foo()
public {

do_something();
   }
}
```

Mutation

```
contract C {
   fu#!3ion foo()
puX^&c {

do_something();
   }
}
```

Accepted by parser

Rejected by parser

Fuzzing a compiler requires generating valid programs...

... generating a valid program requires structure awareness

Approach

Write a specification

Specification written in protobuf language

```
message Block {
  Repeated Statement stmts;
}
...
message program {
  repeated Block blocks;
}
```

Full spec:
https://github.com/ethereum/solidity/blob/develop/test/tools/ossfuzz/yulProto.proto

Input generation

- Input generated and mutated by libprotobuf-mutator
- Each input is a tree

```
blocks { stmts { ifstmt { condition {
binaryOp { eq { op1: varref{id: 0} op2: 0}
} } } } }
```

Input conversion

- Converter is source-to-source translator
- Input: protobuf serialization format
- Output: yul program

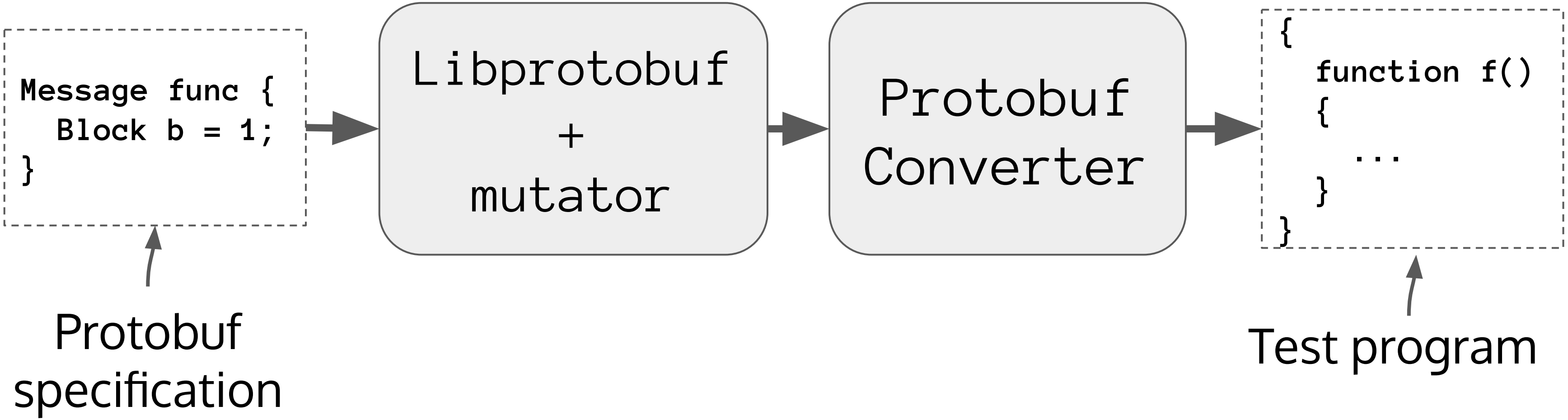
Example

```
blocks { stmts { ifstmt { condition {
binaryOp { eq { op1: varref{id: 0} op2: 0}
} } } } }
```

Conversion

```
if (x_0 == 0)
```

Test program generation



```
Message func {
  Block b = 1;
}
```

Protobuf specification

Libprotobuf + mutator

Protobuf Converter

```
{
  function f()
  {
     ...
  }
}
```

Test program

Correctness testing requires encoding expectation somehow

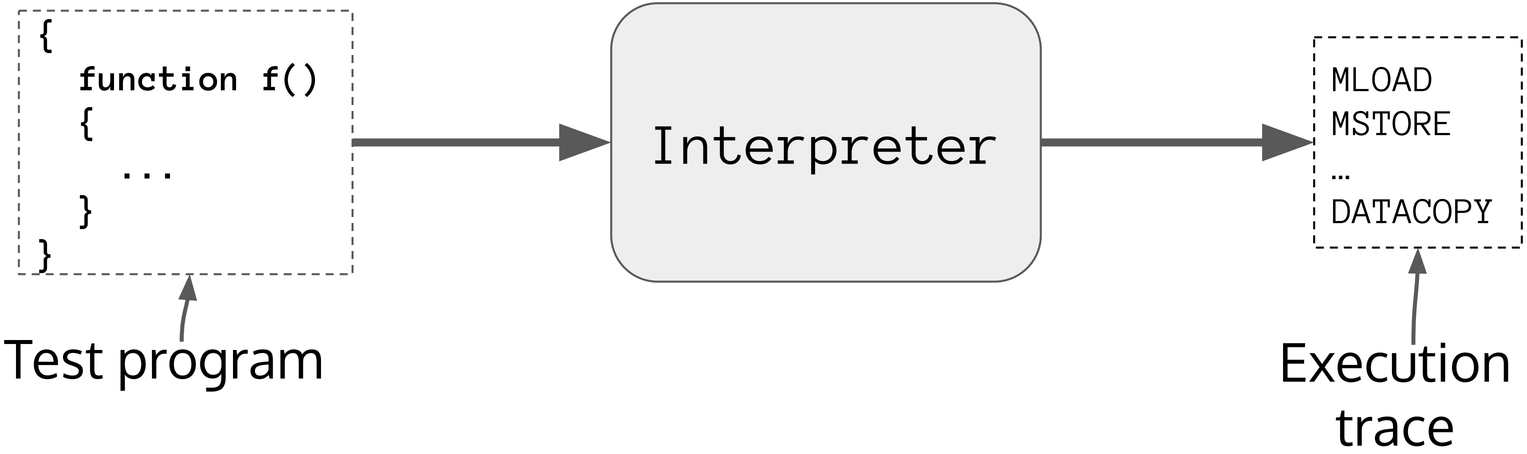
Differential fuzzing

- Track side-effects of execution
- Run program
- Run optimized program
- Compare side-effects

Yul interpreter

- Interprets arbitrary yul program
- Outputs side-effects as a trace (string)

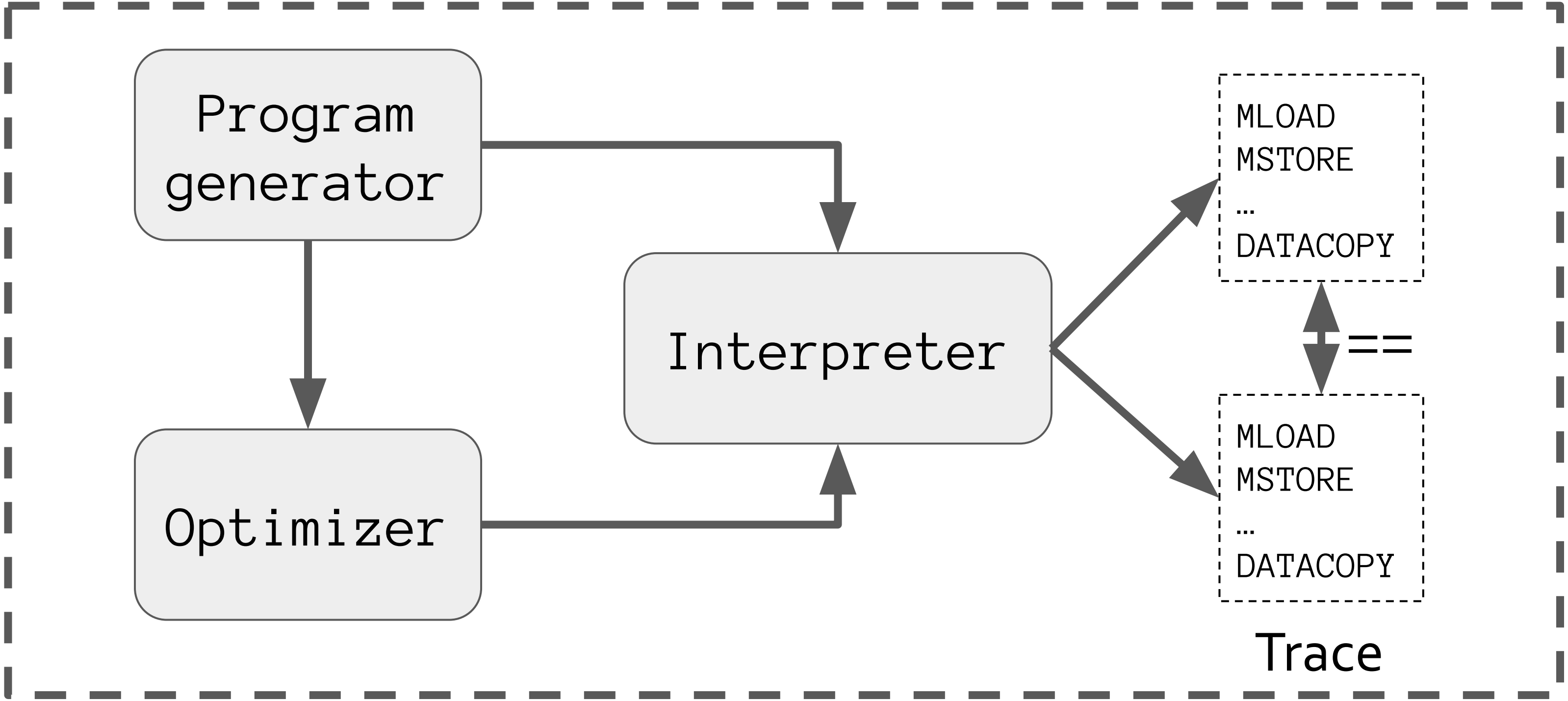
Yul interpreter



```
{
  function f()
  {
    ...
  }
}
```

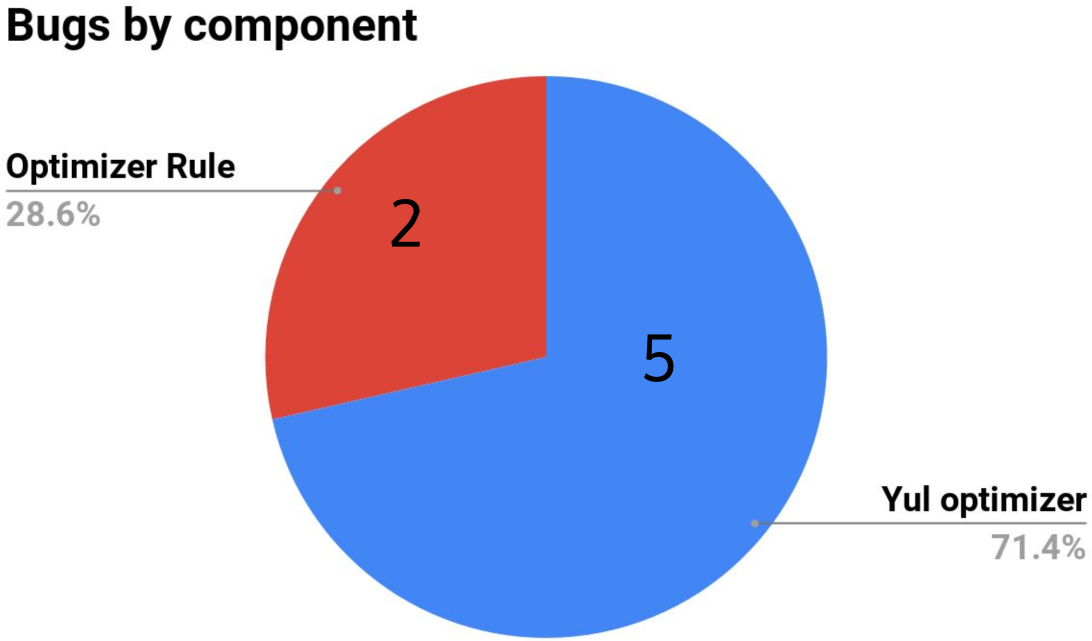
```
MLOAD
MSTORE
…
DATACOPY
```

Fuzzing Setup

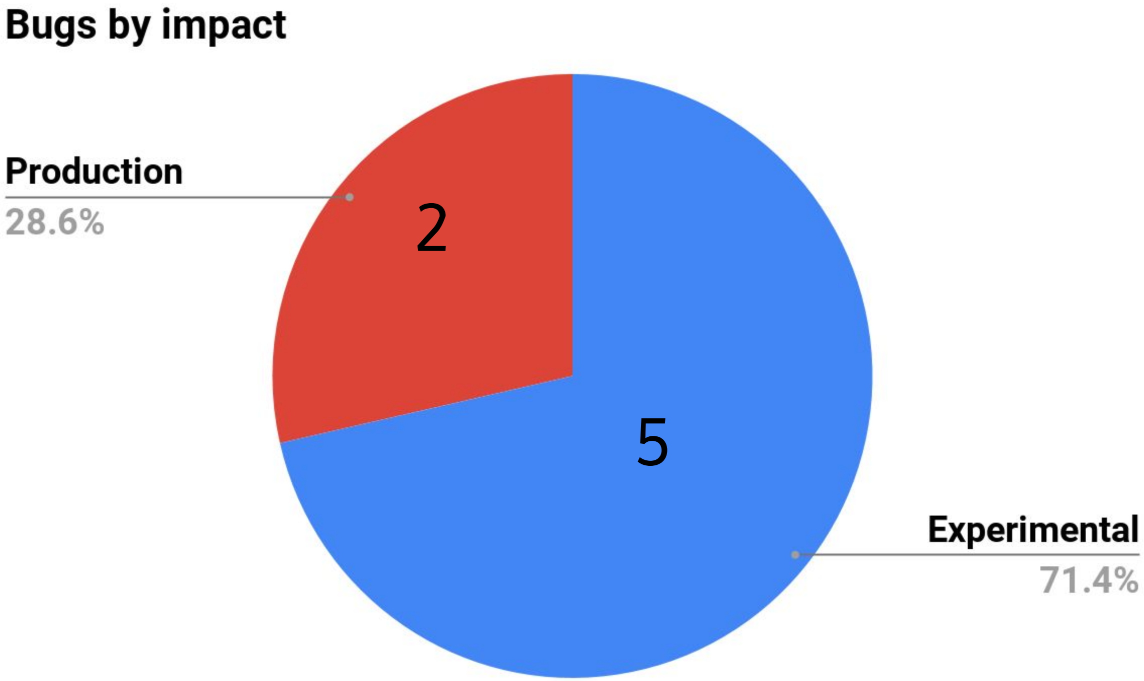


Results

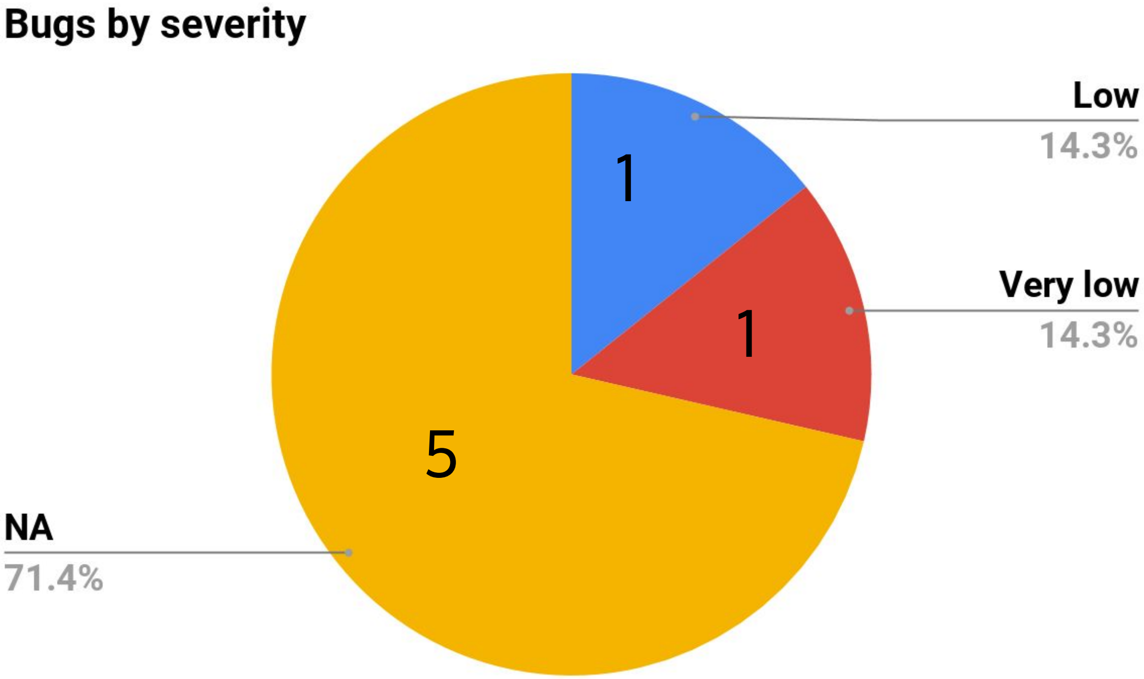
Bugs by component



Bugs by impact



Bugs by severity



Challenges

- Find high-severity bugs using fuzz testing
  - Slow test throughput (~1 test per second)
- Test Abiv2encoder
    - Generate test program (Reasonably fast)
    - Compile program (Slowest)
    - Run program on EVM (Slow)
    - Assert output validity (Very fast)

Conclusion

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- Continuous structure-aware fuzzing for early bug discovery
- Useful for testing optimizer and data en/decoding
- Decent assurance
    - Evidence that it works
    - No formal guarantees though

Thank you!

https://github.com/ethereum/solidity