Self-Tuning Coverage

Jonathan Bromley

Overview

- Coverage reuse needs flexibility, configurability
  - SELF TUNING in response to configuration, parameters etc
- Coverage can mislead!
  - See Verilab papers DVCon-US 2015 and suggestions in this tutorial
- SV covergroups are not easy to configure
  - More detail and recommendations later in this tutorial
- SV covergroups are not easy to **re**configure
  - More detail and recommendations later in this tutorial

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COVERAGE GUIDELINES

Coverage Encapsulation

- Coverage should be encapsulated for maintenance
  - isolate coverage code
  - separate class for coverage
  - each coverage class should be in its own file
  - minimize SV assertion-based coverage

specific purpose, often verbose

not extensible, no factory

- **but** architecture of coverage classes needs care
  - more details in later sections

Implementation Options in SV

- Coverage in a subscriber class
- Extend a component to add coverage groups
- Instantiate a coverage class in some component

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Implementation Options in SV

- Coverage in a subscriber class

environment structure

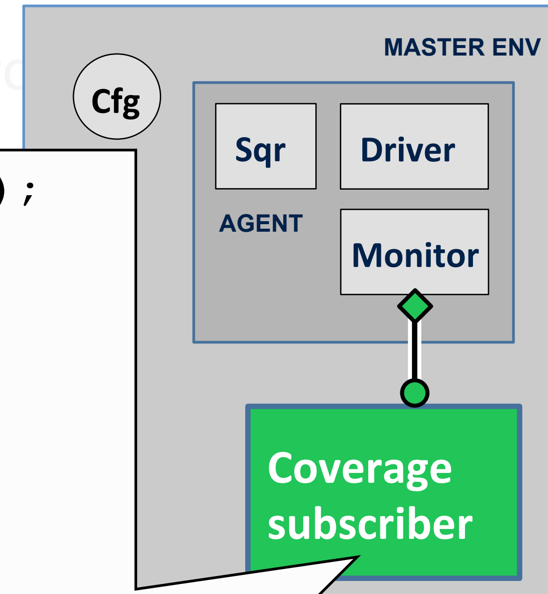
```
class ... extends uvm_subscriber#(dvcon_txn);

  dvcon_txn cov_txn;

  covergroup cg;
    ...
    coverpoint cov_txn.size {...}
    ...
  endgroup

  function void write(dvcon_txn t);
    cov_txn = t;
    cg.sample();
  endfunction
```

no need for deep copy



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Implementation Options in SV

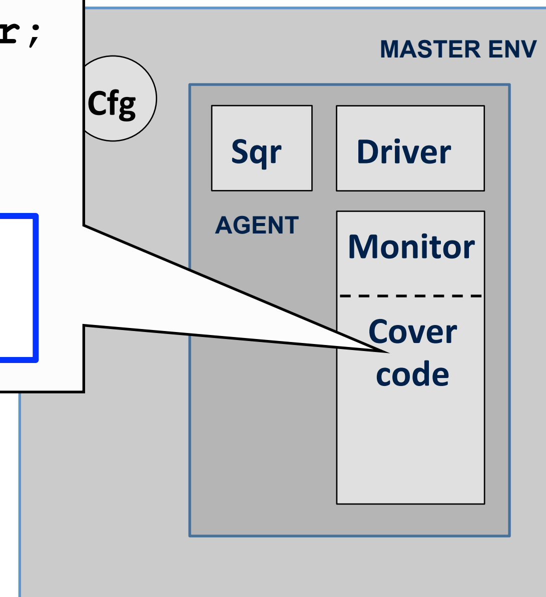
- Coverage in a subscriber class
- Extend a component to add coverage groups

inheritance

```
class dvcon_cov_monitor extends dvcon_monitor;
  `uvm_component_utils(dvcon_cov_monitor)

  covergroup cg;
    ...
  endgroup
  ...
```

- *can be sampled at any point in the code*
- *has access to all class members*




```
uvm_factory f = uvm_factory::get();
f.set_type_override_by_type (
  dvcon_monitor::get_type(),
  dvcon_cov_monitor::get_type()
);
```

no override, no coverage!

Implementation Options in SV

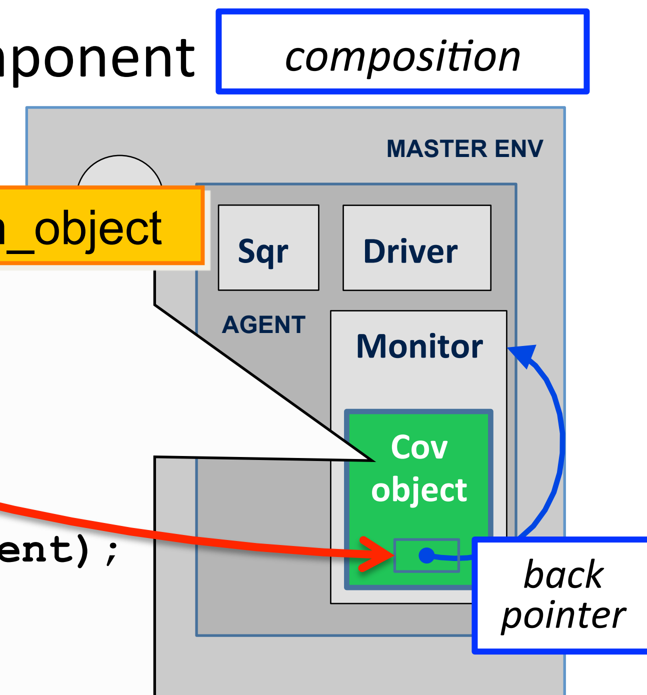
- Coverage in a subscriber class
- Extend a component to add coverage groups
- Instantiate a coverage class in some component

composition

```
class dvcon_cov extends uvm_component;
  `uvm_component_utils(dvcon_cov)
  dvcon_monitor p_monitor;
  covergroup cg;
    coverpoint p_monitor.value {...}
    ...
  function new(string name, uvm_component parent);
    super.new(name, parent);
    $cast(p_monitor, parent);
    cg = new();
  endfunction
```

or uvm_object

No instance, no coverage!



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Implementation Options - review

- Coverage in a subscriber class
  - restricted to contents of a single object (transaction, transaction-set)
  - but otherwise provides good isolation

environment structure

- extend monitor class to add coverage groups
  - flexible, but limits TB structure
  - instantiate correct monitor type, else coverage missed!

inheritance

cannot factory-replace coverage alone

- instantiate coverage class in another component
  - coverage class has handle to component, sees all contents
  - allows all coverage implementation including control/timing
  - most flexible solution

composition

Best choice depends on application!

Coverage Is Distributed

- Coverage of individual transactions: easy but insufficient
  - cover each txn from monitor – *transaction coverage*
- DUT behaviour coverage is also important, but sampling and data gathering likely to be distributed across...
  - parts of verif env
    - activity on other interfaces
    - register state and changes
    - end-to-end matching
  - time
    - what else happened during the life of this txn/instruction/...?
    - DUT state at start, end, other key points in txn lifetime?

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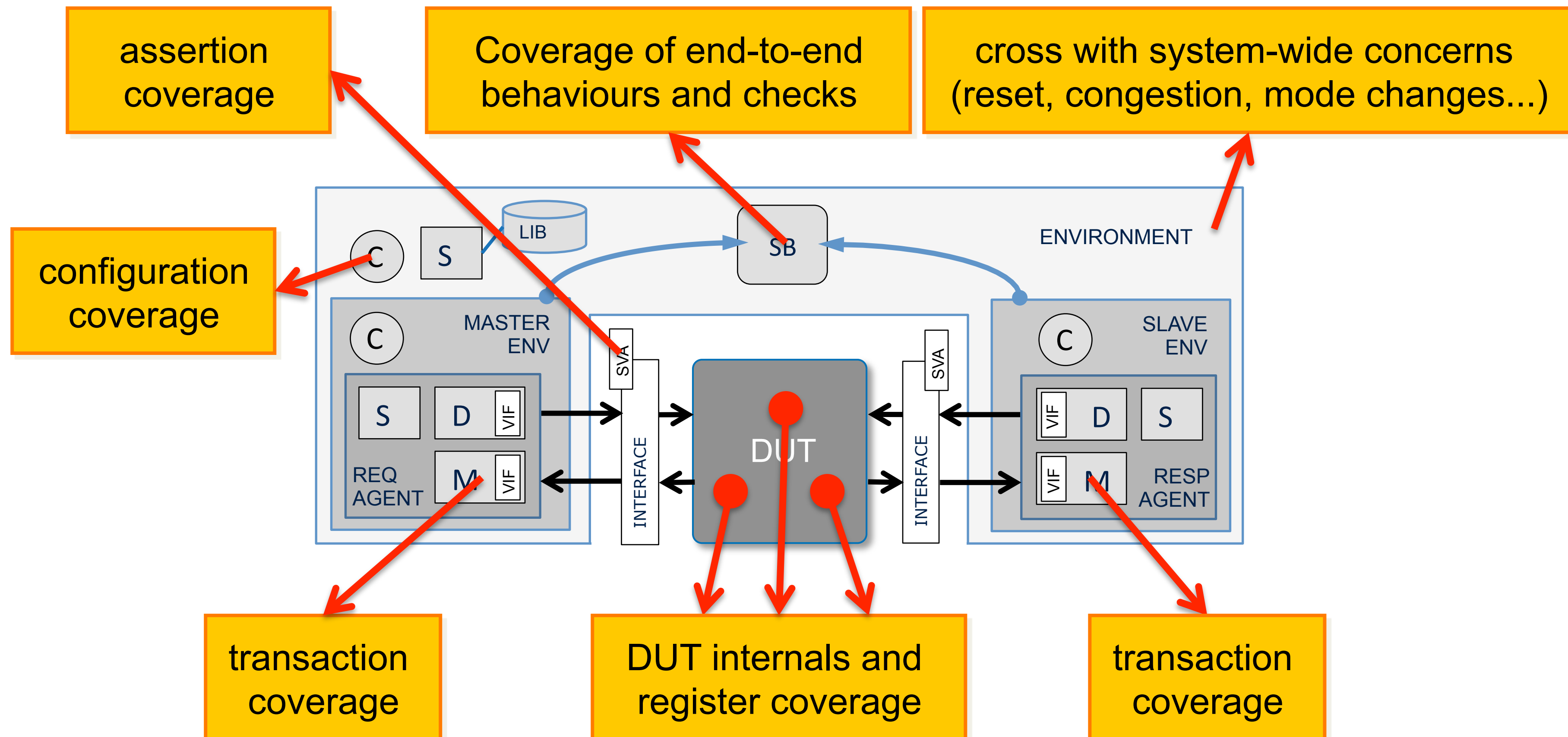
Coverage Is Distributed

- Coverage from *many places* contributes to verif plan



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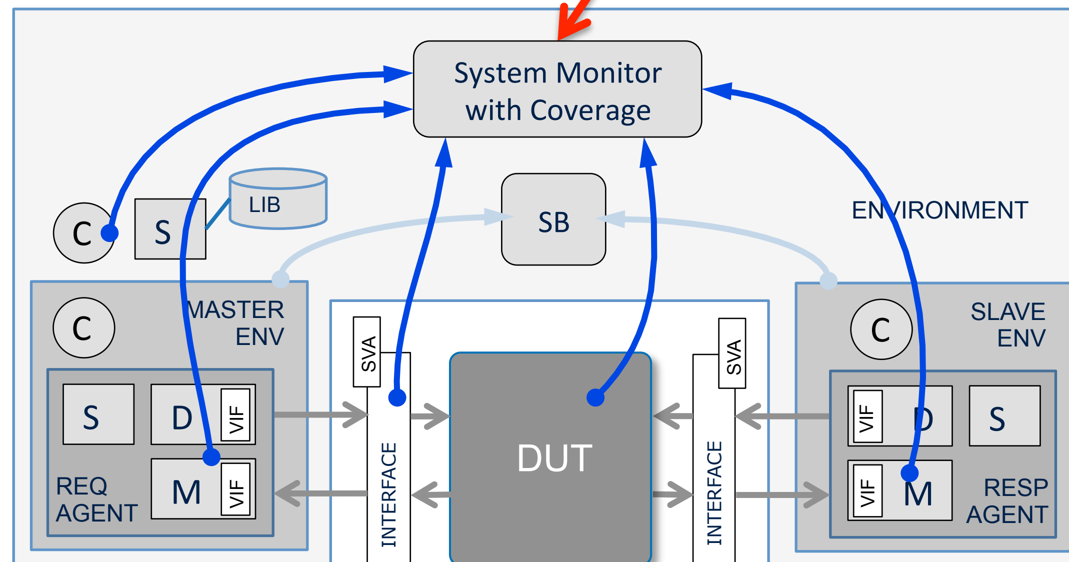
Coverage Is Distributed

- Coverage from *many places* contributes to verif plan
- Encapsulate!
- Many connections may be required

cross with system-wide concerns (reset, congestion, mode changes...)



Coverage Tuning

- Modify the coverage model to suit our requirements
  - for example exhaustive block-level coverage not appropriate for top-level verification requirements, so reduce scope
- Reuse the same mechanism for sampling coverage
  - this is built into the component implementation
  - fully identifies what cover points are sampled and when
- Redefine the coverage groups and coverpoints
  - modify the number of coverpoints in existing cover group
  - modify range and conditions of existing coverpoint bins
  - ***e*** uses AOP to redefine existing coverpoints
  - *SystemVerilog* uses OOP factory to replace existing class

IMPLEMENTING FLEXIBLE COVERAGE

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Making Coverage Flexible

- Traditional approaches to configurable points/bins
  - sample() wrapper – map sampled data to coverage-friendly value
  -
  -
  -
  -
- SV
  -
  -

```
enum {normal, fizz, buzz, fizzbuzz} fb;
```

```
bit this_bit;
int bit_num;
covergroup cg;
  coverpoint this_bit;
  coverpoint bit_num;
  cross this_bit, bit_num;
endgroup
function sample (bit [31:0] x);
  for (bit_num = 0; bit_num < 32; bit_num++) begin
    this_bit = x[bit_num];
    cg.sample();
  end
endfunction
```

Recent Language Enhancements

- Available SV-2012 options:
  - bin **`with()`** function (value filter)
  - bin set expression (value list specification)
  - cross bin **`with()/matches`** (tuple filter, match threshold)
  - cross bin set expression (queue of value tuples)
- Many scope visibility gotchas
  - good examples are hard to find
  - meanwhile, read LRM carefully and try small test examples
- Patchy tool support
  - **`with()`** functions are widely supported
  - set expressions in some tools

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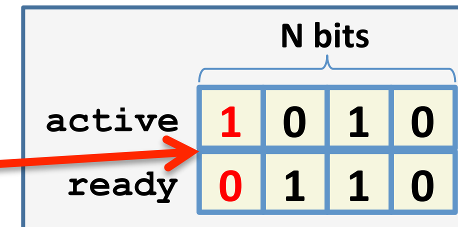
Bin Specification Improvements

- Illegal cross bins example taken from a real-world problem:
  - Illegal if **`active==0`** or if **`active==ready`**
  - Illegal if **`active`** has any bits set that are not set in **`ready`**

illegal example



- **`binsof`** expressions: messy, inflexible

Easy in SV-2012!

```
covergroup cg_active_ready(int Nbits);
  ...
  active_X_ready: cross active, ready {
    function CrossQueueType all_illegals(int n);
      for (int R=0; R<(1<<n); R++)
        for (int A=0; A<(1<<n); A++)
          if ( A==0 || A==R || (A & ~R)!=0 )
            all_illegals.push_back( '{A,R} );
    endfunction
    illegal_bins bad_active = all_illegals(Nbits);
  }
endgroup
```

self-tuning for Nbits

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RECONFIGURABLE COVERAGE

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Configurable Coverage

- Any good reusable VC or env has a **configuration object**
- Can we use this config object to tune coverage?
- YES, but there are challenges:
  - covergroup must be created in a class's constructor
  - this is too early in a UVM component; config is not yet known
- Following slides offer two solutions
  1. wrap covergroup in uvm_object, get config from UVM config DB
     - straightforward
  2. embedded class constructed much later, after config is known
     - applicable to both components and objects
     - components locate coverage securely in the topology

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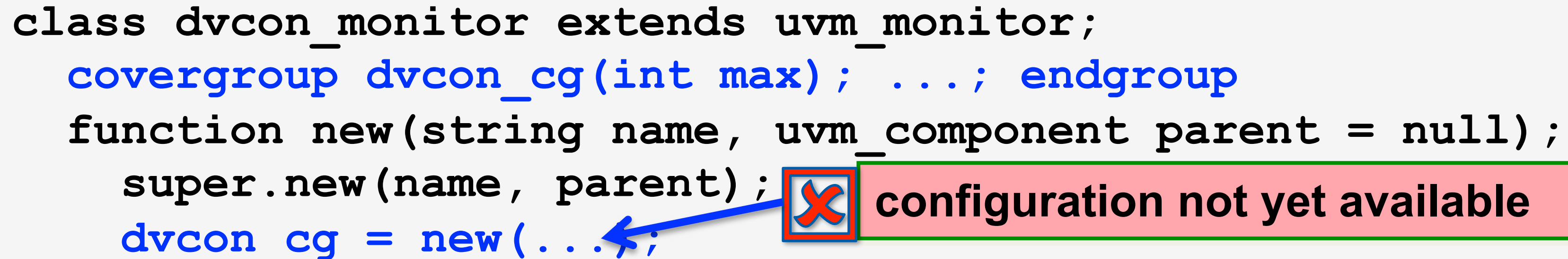
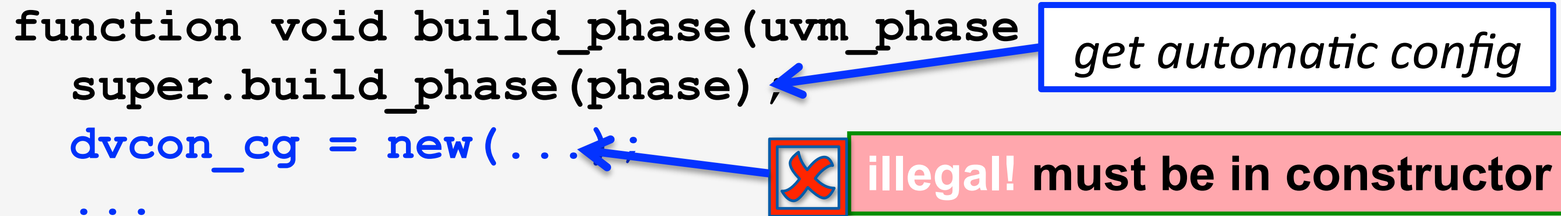
Making It Configurable

- Covergroup in a component can't be configured:



- Config information is available much later



- We need a workaround...

Configurable Coverage Roadblock

- Key problem:

CG must be created in enclosing class's `new()`

but...

UVM classes have fixed constructor arguments

- Solution 1: constructor gets info from config_db before CG **`new`**
  - OK for uvm_object, supports factory
  - Parent object must prepare config_db entries before creation
  - Unhelpful for uvm_component *config info may not be available*
- Solution 2: Encapsulate CG in a non-UVM class
  - pass config in constructor arguments
  - factory cannot replace a non-UVM class

good for dedicated coverage components

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Workaround 1: Coverage Object

```
class my_component...
  ...
  dvcon_cov cov_wrap;
  string cov_name = "cov_wrapper";
  function void start_of_simulation_phase(...);
   dvcon_cov_cfg cfg = new("cov_cfg");
   ...  populate cfg object
   uvm_config_db#(dvcon_cov_cfg)::set(
     null, cov_name, "cfg", cfg);
   cov_wrap = dvcon_cov::type_id::create(cov_name);
  endfunction
  ...
```

component needs configurable coverage

coverage object can be factory-overridden

late config and creation

```
class dvcon_cov extends uvm_object;
  `uvm_object_utils(dvcon_cov)
  covergroup dvcon_cg(int max); ... endgroup
  dvcon_cov_cfg cfg;
  function new(string name = "");
    super.new(name);
    uvm_config_db#(dvcon_cov_cfg)::get(
      null, name, "cfg", cfg);
    dvcon_cg = new(cfg.max);
  endfunction
endclass
```

coverage wrapper class

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Workaround 2: Coverage Wrapper

- For easy factory replacement, component is coverage ***only***!

```
class dvcon_txn_cvg extends uvm_subscriber #(dvcon_txn);
  `uvm_component_utils(dvcon_txn_cvg)
  class cov_wrapper;
    covergroup dvcon_cg(int max); ...; endgroup
    function new(string name, dvcon_config cfg); ...
    ...
  endclass
  dvcon_config cfg;
  cov_wrapper cov;
  virtual function void create_coverage();
    cov = new({get_full_name(), ".cov"}, cfg);
  endfunction
  virtual function void write(dvcon_txn txn);
    cov.sample(txn);
  endfunction
  ...
```

register with factory

nested (local) class definition

cfg set from above in build_phase or later

do not call until cfg is ready

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Coverage Wrapper Details

- Delegate sampling to virtual methods for easy extension

```
class cov_wrapper;
  dvcon_txn txn;
  covergroup dvcon_cg(int max);
    cp_len: coverpoint txn.length {
      bins tiny[]  = {[0     :3     ]};
      bins mid     = {[4     :max-4]};
      bins limit[] = {[max-3:max   ]};
    }
  endgroup
  function new(...); ...; endfunction
  virtual function void sample(dvcon_txn t);
    txn = t;
    dvcon_cg.sample();
  endfunction
endclass
```

arbitrary covergroup arguments used to configure bin shapes

no need for object copy – `txn` is used only during `sample()`

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Configurable Coverage Component

SUMMARY

- nested (wrapper) class contains covergroup(s)
- not a uvm_object – arbitrary constructor signature OK
- nested-class object can be constructed any time
  - postpone until config is fully known
- component encapsulates responsibility for:
  - understanding and preparing configuration
  - constructing nested-class object
  - data collection and sampling
- prepare for extension, factory applicability

Reference

- Guidance on coverage design:
  - avoid lies
  - maximise effectiveness

DVCon US 2015, Mark Litterick

Lies, Damned Lies, and Coverage

DVCon US 2015: Jason Sprott, Paul Marriott, Matt Graham

Navigating The Functional Coverage Black Hole:
Be More Effective At Functional Coverage Modeling

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