2018 DESIGN AND VERIFICATION™ DVCON CONFERENCE AND EXHIBITION UNITED STATES

Managing Highly Configurable Design and Verification

Jeremy Ridgeway

Broadcom, Ltd.

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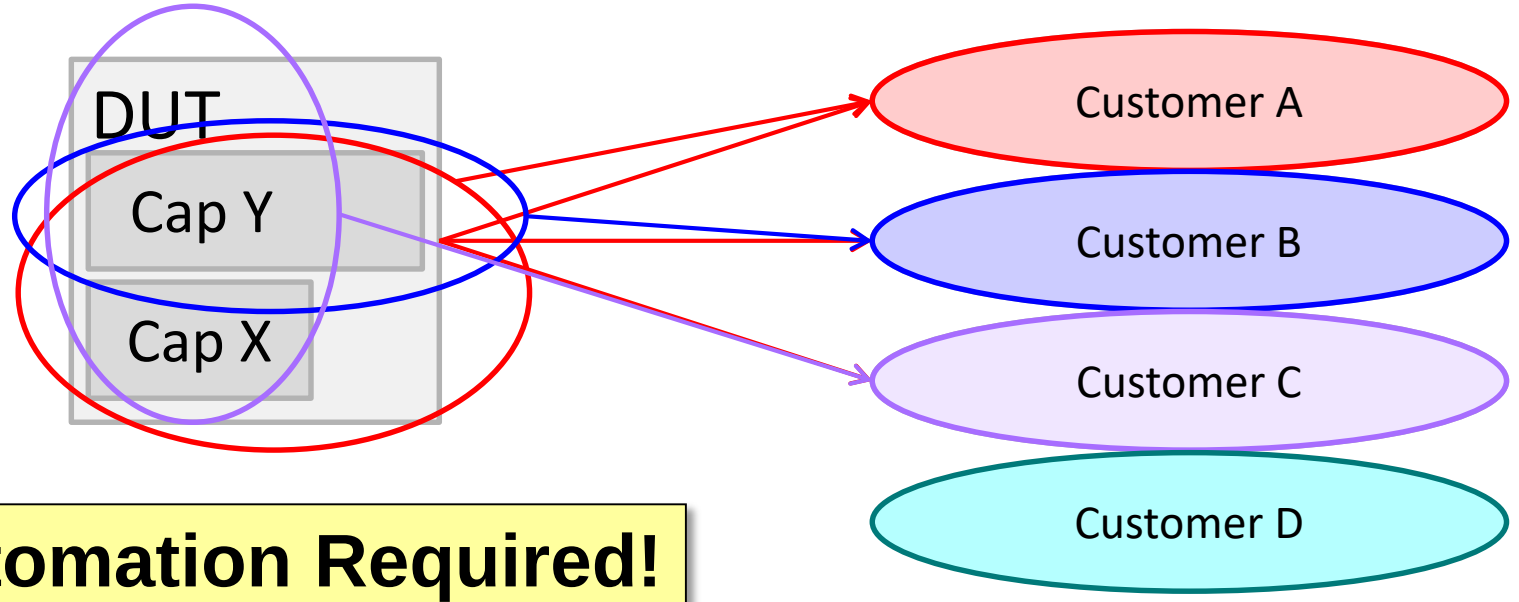
Agenda

- Root of the problem
- Automation required
  - DUT
  - Verification Planning
  - Test bench
  - Reporting Structures
- Conclusions

Hardware Configurations

- One RTL set to target multiple customers
- Configuration due to modify a common capability
- Configuration due to add/remove a specific capability

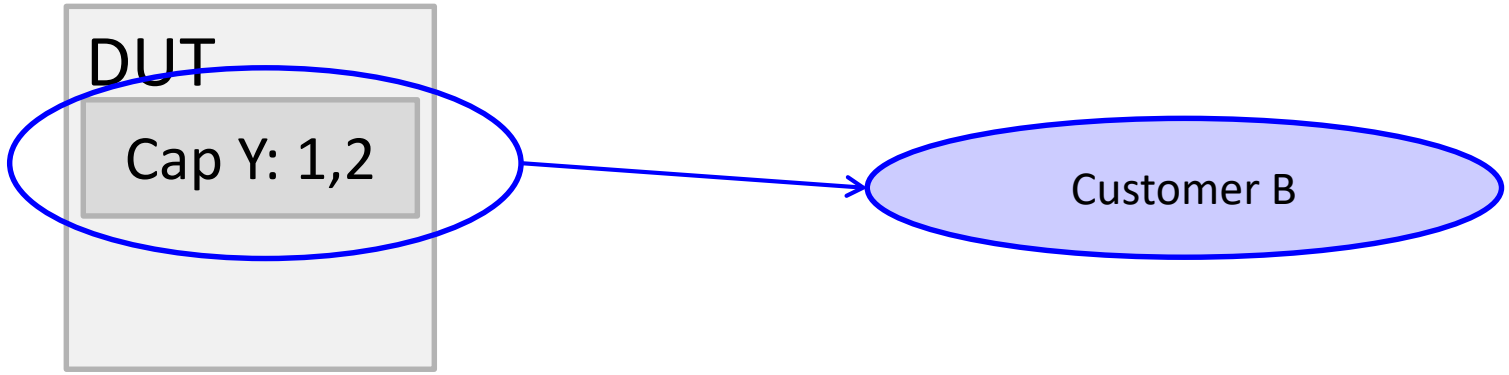


Automation Required!

Common Architectural Theme

- Super-set thing
- Customer-specific thing

Most important



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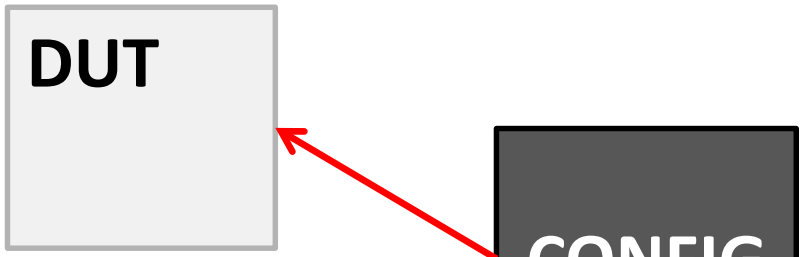
Configuration Matrix and Object

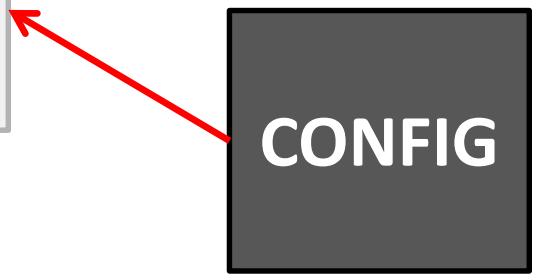
Configuration	Values	Customer Selection
CAP Y	1, 2	?
CAP X	Y / N	?
…		

```
Cust_A
CAP_Y => [ 1, 2 ]
CAP_x => 1
…
```

- Must match a configuration matrix agreed upon with the customer
  - We chose Perl5 (could be any OOP language)

Config: Center of Verification Universe

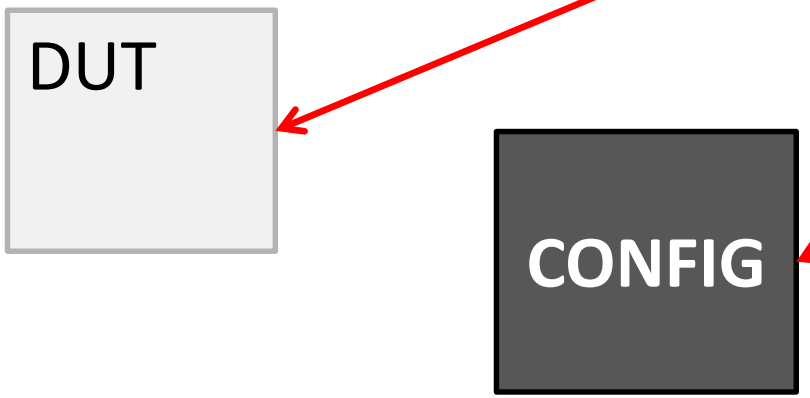




The CONFIG object drives the DUT transformation

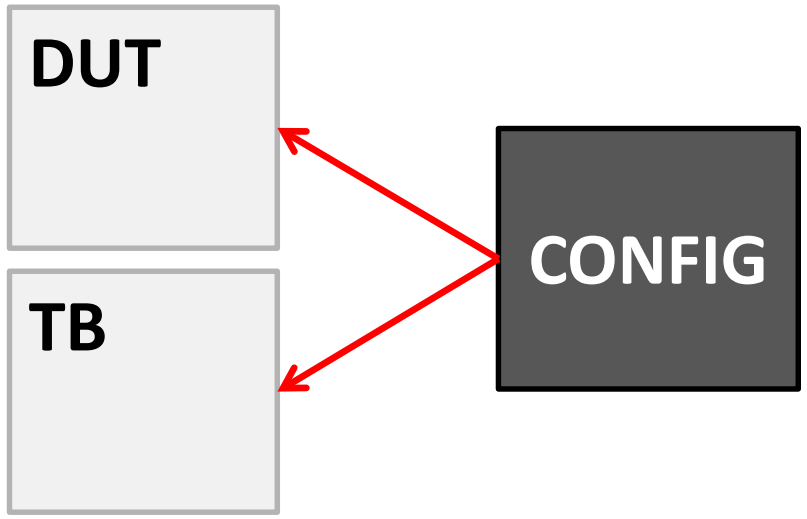
Config: Center of Verification Universe

Configuration	Values	Customer Selection
CAP Y	1, 2	?
CAP X	Y / N	?

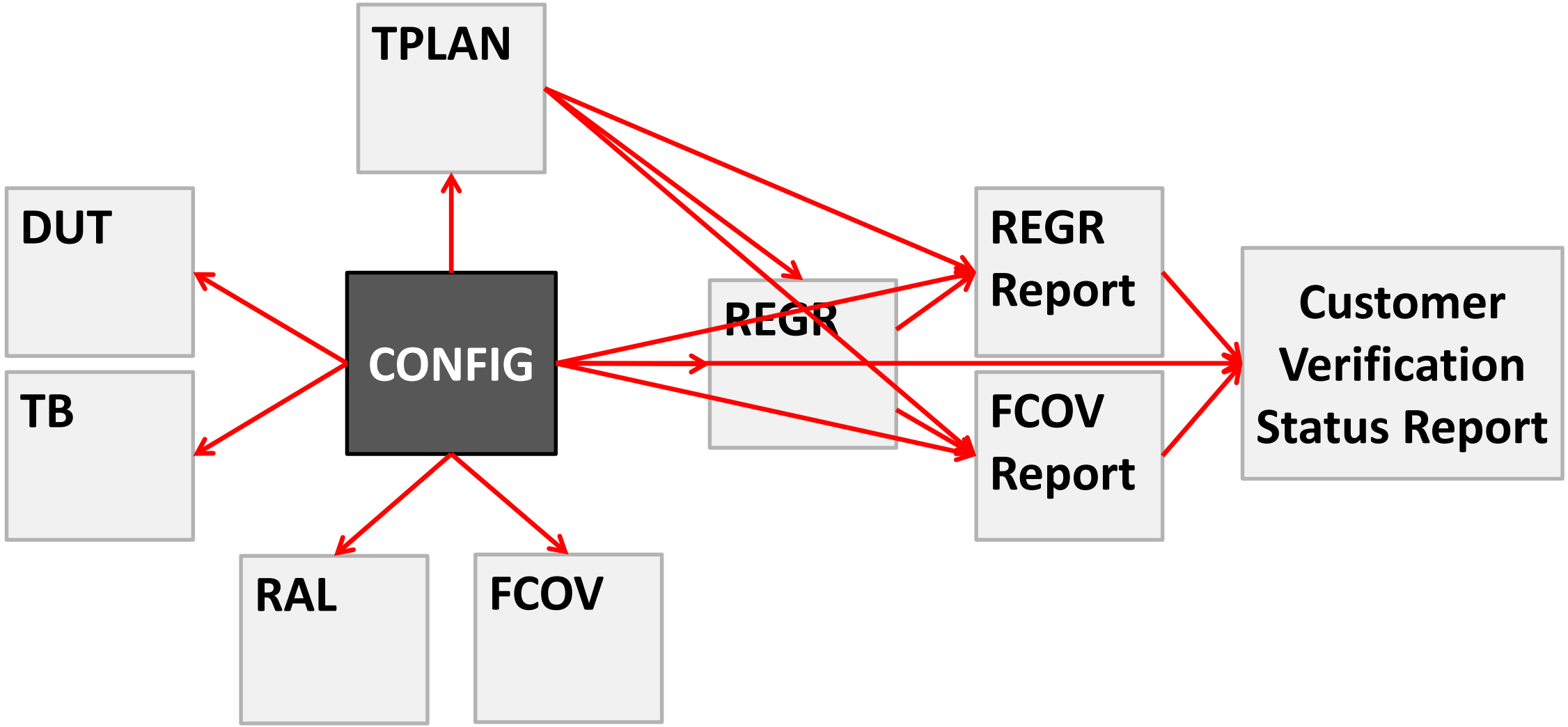


- The configuration matrix drives:
  - DUT Architecture & Implementation
  - CONFIG Structure & Value Selection

Config: Center of Verification Universe



Config: Center of Verification Universe



CONFIG Object Representation

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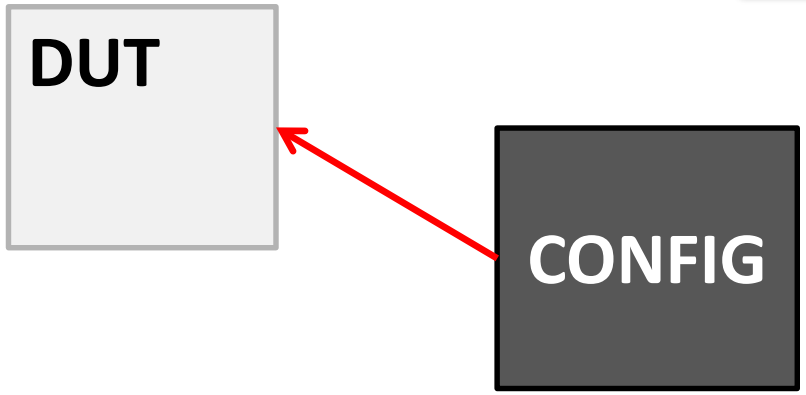
DUT Guidelines

- NO RTL should be simulated that is NOT delivered to customer

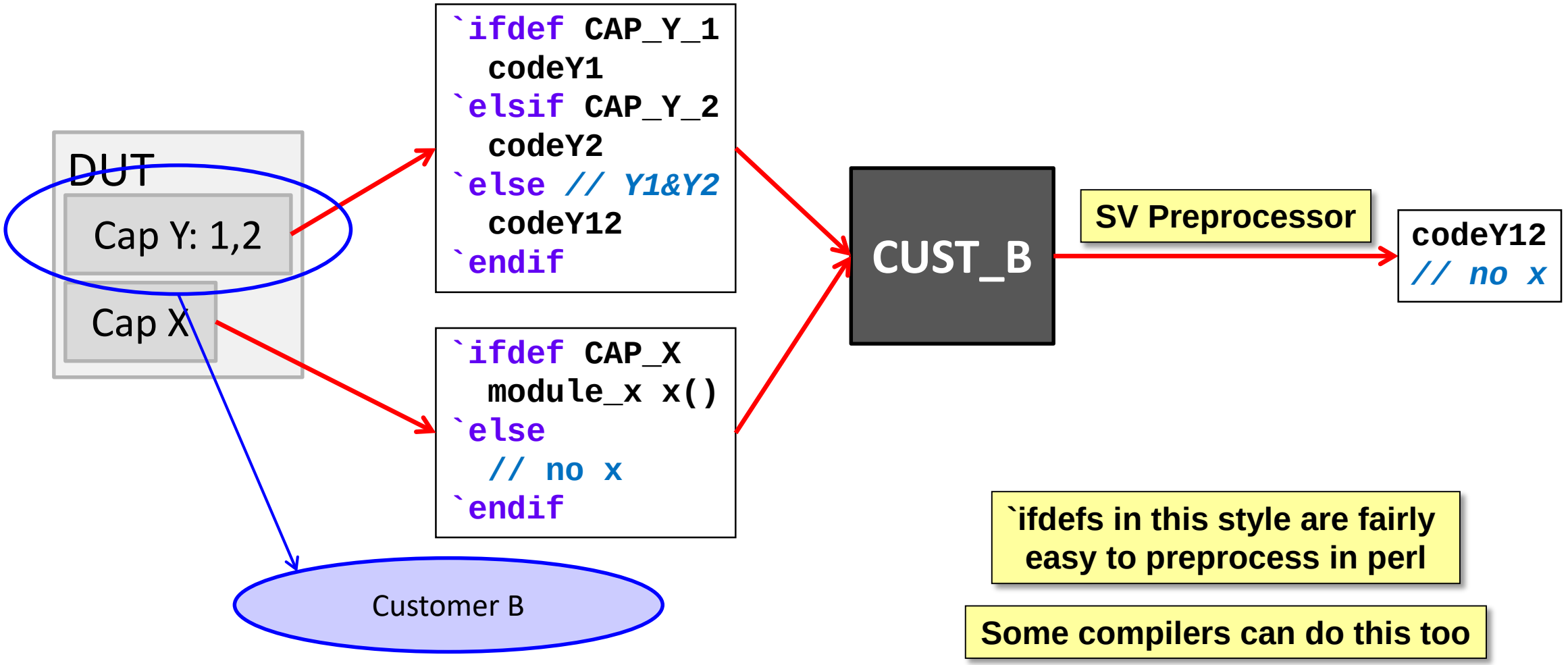
NO Superset Simulation / Verification

- Minimize the ability for the customer to make mistakes

Remove `ifdefs whenever possible



DUT Transformation



`ifdefs in this style are fairly easy to preprocess in perl

Some compilers can do this too

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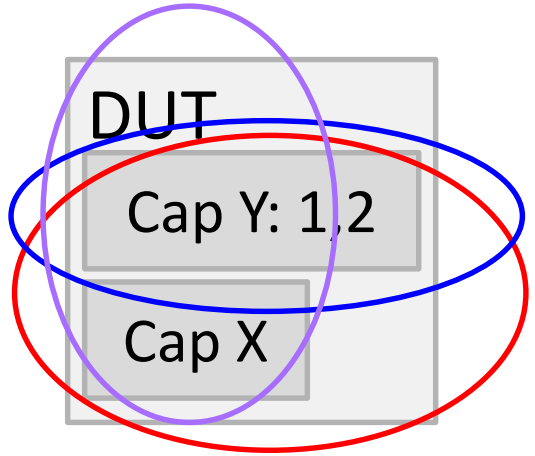
Testplan: A Live Document

Scenario ID	Feature	Subfeature	Generate	Expect
CAP_X.DATA.1	CAP X Data	Good	…stimulus…	…verification…
ERR.CAP_X.1	CAP X Data	Bad data	…	…
CAP_Y.MODE_1.1	CAP Y Mode 1	Select mode 1	…	…
CAP_Y.MODE_1.2	CAP Y Mode 1	Set FW mode 1	…	…
CAP_Y.MODE_2.1	CAP Y Mode 2	Select mode 2	…	…
ERR.CAP_Y.1	CAP Y Bad	Bad select	…	…

- ALL testing scenarios uniquely identified: the superset case

Testplan: A Live Document

Scenario ID	CUST_A	CUST_B	CUST_C
CAP_X.DATA.1	Y		Y
ERR.CAP_X.1	Y		Y
CAP_Y.MODE_1.1	Y	Y	Y
CAP_Y.MODE_1.2	Y	Y	Y
CAP_Y.MODE_2.1	Y	Y	
ERR.CAP_Y.1	Y	Y	Y



- Customer-specific scenarios are indicated in the testplan

Testplan: A Live Document

Scenario ID	CUST_A	CUST_B	CUST_C
CAP_X.DATA.1	Y		Y
ERR.CAP_X.1	Y		Y
CAP_Y.MODE_1.1	Y	Y	Y
CAP_Y.MODE_1.2	Y	Y	Y
CAP_Y.MODE_2.1	Y	Y	
ERR.CAP_Y.1	Y	Y	Y

Scenario ID	CUST_B
CAP_Y.MODE_1.1	Y
CAP_Y.MODE_1.2	Y
CAP_Y.MODE_2.1	Y
ERR.CAP_Y.1	Y

- Transform the testplan with customer CONFIG object
- Result indicates components required for customer-specific testbench

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Testing Scenarios

- Directed tests
- Directed-random tests
- Constrained-random test bench

Directed Testing

- Scenario ID not tested when tests not run
- Scenario ID verified when tests run & pass
- Scenario ID fails when tests run & fail

Scenario ID	Test	Regr
CAP_Y.MODE_1.1	Test1	Y
CAP_Y.MODE_1.2	Test2	Y
CAP_Y.MODE_2.1	Test3	
ERR.CAP_Y.1	Test4	

not run

- No functional coverage required
- Regression report sufficient for verification status
- No scenarios outside testplan expected

No Unknown Scenario Coverage

Directed-Random Testing

- Scenario ID not tested when tests not run
- Scenario ID verified when tests run & pass and functional coverage hit
- Scenario ID fails when tests run & fail

Scenario ID	Test	Regr
CAP_Y.MODE_1.1	Test1	Y
CAP_Y.MODE_1.2	Test1	Y
CAP_Y.MODE_2.1	Test1	
ERR.CAP_Y.1	Test2	

- Functional coverage required
- Regression report + functional coverage sufficient for verification status

Some Unknown Scenario Coverage

Constrained-Random Testbench

- Scenario ID not tested when functional coverage not hit
- Scenario ID verified when functional coverage hit & tests pass
- Scenario ID fails when functional coverage hit & tests fail

Scenario ID	Coverage	Test	Regr
CAP_Y.MODE_1.1	group: a	Base	Y
CAP_Y.MODE_1.2	group: b	Base	Y
CAP_Y.MODE_2.1	group: c	Base	
ERR.CAP_Y.1	group: d	EnErrs	

Unknown Scenarios Likely

- Functional coverage required and is focus
- Regression report + functional coverage required for verification status

Functional Coverage Model

- Developed independent of testbench
- Metrics per scenario indicated in the Testplan
- Hierarchical spreadsheet format employing configuration values

Scenario ID	Coverage	Test	Regr
CAP_Y.MODE_1.1	group: a	Base	Y
CAP_Y.MODE_1.2	group: b	Base	Y
CAP_Y.MODE_2.1	group: c	Base	
ERR.CAP_Y.1	group: d	EnErrs	

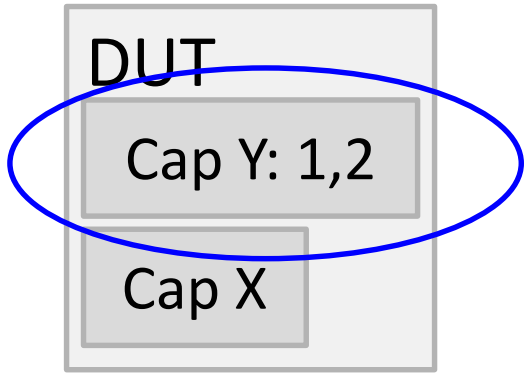
Functional Coverage XLSX

Scenario ID	Subfeature
CAP_X.DATA.1	Good
ERR.CAP_X.1	Bad data
CAP_Y.MODE_1.1	Select mode 1
CAP_Y.MODE_1.2	Set FW mode 1
CAP_Y.MODE_2.1	Select mode 2
ERR.CAP_Y.1	Bad select

Testplan Superset

Variable	Range	Description
C_CAP_X	0,1	Capability X support (>0)
C_CAP_Y	0,1,2	Capability Y support (>0) and range
M_CAP_Y	0,1,2	Capability runtime select
FW_SEL	0,1	Capability Y selected by firmware
SEL_INVALID	0,1	Capability Y selection failed

Coverpoint Superset



- Transform functional coverage model with CONFIG

Covergroup for CAP_Y.MODE_1.1

sel_mode_1 is valid for CUST_B

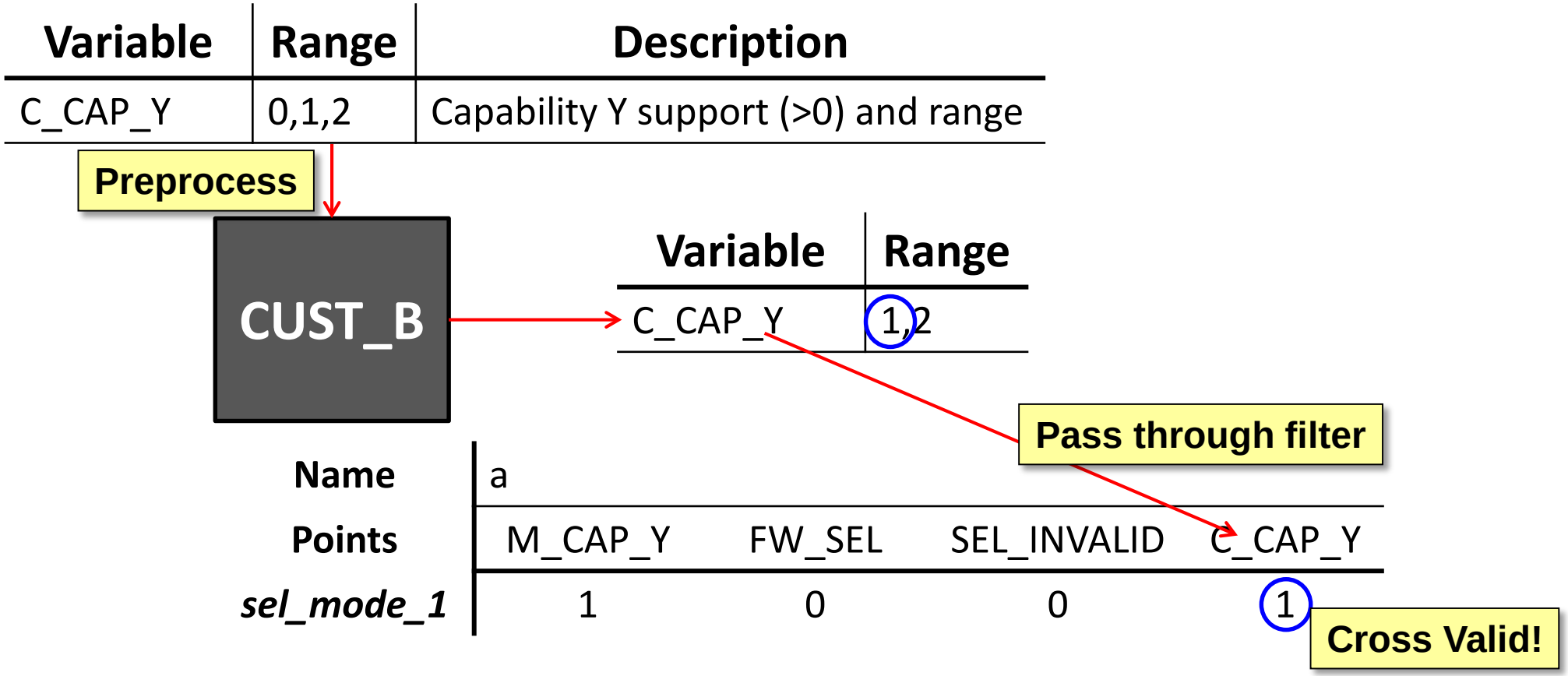
Name	a			
Points	M_CAP_Y	FW_SEL	SEL_INVALID	C_CAP_Y
sel_mode_1	1	0	0	1

```
covergroup a;

endgroup
```

Scenario ID	Subfeature	Coverage
CAP_Y.MODE_1.1	Sel mode 1	group: a
CAP_Y.MODE_1.2	FW mode 1	group: b
CAP_Y.MODE_2.1	Sel mode 2	group: c
ERR.CAP_Y.1	Bad sel	group: d

Configuration Filtering: Valid



- C_CAP_Y is defined in CUST_B CONFIG object as: CAP_Y: 1,2

Covergroup for CAP_Y.MODE_1.1

Name	a			
Points	M_CAP_Y	FW_SEL	SEL_INVALID	C_CAP_Y
sel_mode_1	1	0	0	1

```
covergroup a;
{                                                    }
endgroup
```

Scenario ID	Subfeature	Coverage
CAP_Y.MODE_1.1	Sel mode 1	group: a
CAP_Y.MODE_1.2	FW mode 1	group: b
CAP_Y.MODE_2.1	Sel mode 2	group: c
ERR.CAP_Y.1	Bad sel	group: d

Covergroup for CAP_Y.MODE_1.1

Name	a			
Points	M_CAP_Y	FW_SEL	SEL_INVALID	C_CAP_Y
sel_mode_1	1	0	0	1

```
covergroup a;
  coverpoint M_CAP_Y { bins B0 = { 1 };}
  coverpoint FW_SELECT { bins B0 = { 0 };}
  coverpoint SEL_INVALID { bins B0 = { 0 };}




endgroup
```

Scenario ID	Subfeature	Coverage
CAP_Y.MODE_1.1	Sel mode 1	group: a
CAP_Y.MODE_1.2	FW mode 1	group: b
CAP_Y.MOD		c
ERR.CAP_		d

Cross sel_mode_1 actually covers the scenario

Configuration Filtering: Invalid

Variable	Range	Description
C_CAP_X	0,1	Capability X support (>0)

Preprocess

CUST_B

Variable	Range
C_CAP_0	0

Name	CapXData		
Points	M_CAP_X	…	C_CAP_X
good_data	1	…	1

Cross Invalid!
Covergroup not applicable

- C_CAP_X is not part of CUST_B design, CUST_B CONFIG: CAP_X: 0

Covergroup for CAP_Y

Name	a			
Points	M_CAP_Y	FW_SEL	SEL_INVALID	C_CAP_Y
sel_mode_1	1	0	0	1
fw_mode_1	1	1	0	1
sel_mode_2	2	0	0	1
sel_err		*	1	1

Empty cells in a row indicate no dependency

Wildcard indicated all values are valid

```
sel_err0: FW_SEL==1 && SEL_INVALID==1
sel_err1: FW_SEL==0 && SEL_INVALID==1
```

Covergroup for CAP_Y

Name	a			
Points	M_CAP_Y	FW_SEL	SEL_INVALID	C_CAP_Y
sel_mode_1	1	0	0	1
fw_mode_1	1	1	0	1
sel_mode_2	2	0	0	1
sel_err		*	1	1

Scenario ID	Subfeature	Coverage	Test	Regr
CAP_Y.MODE_1.1	Sel mode 1	cross: tb::a.sel_mode_1	Base	Y
CAP_Y		mode_1	Base	Y
CAP_Y.MODE_2.1	Sel mode 2	cross: tb::a.sel_mode_2	Base	Y
ERR.CAP_Y.1	Bad sel	cross: tb::a.sel_err	EnErrs	Y

Covered when both sel_err crosses are hit

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Regression Report

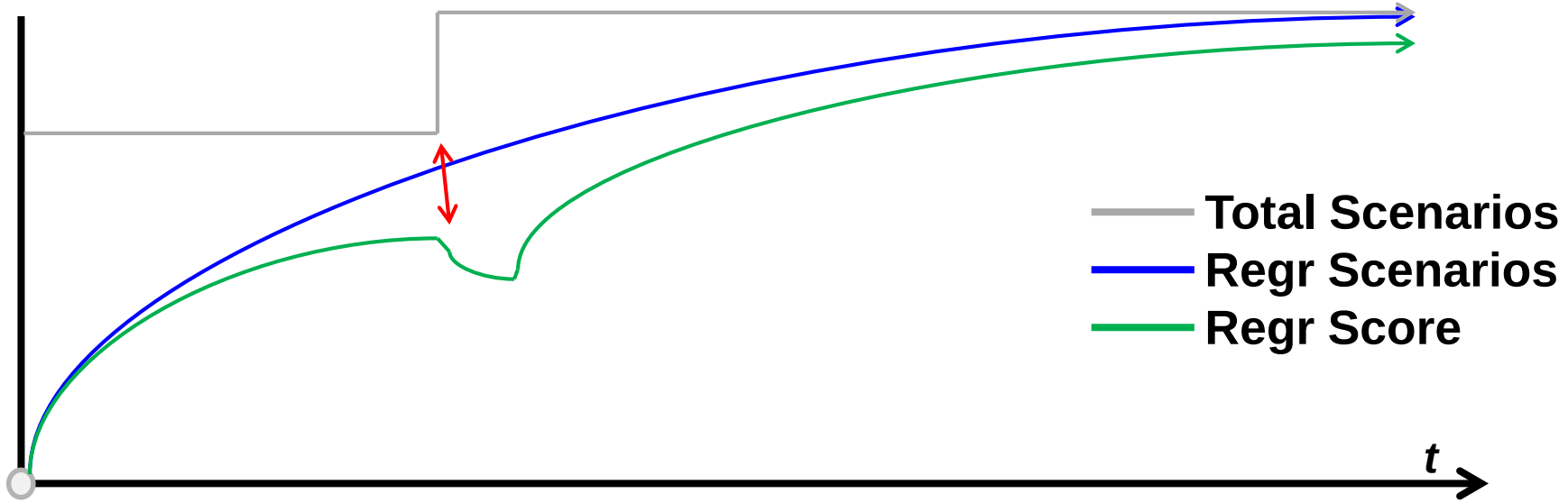
- In this regression, only Base test is run
  - Base test may be run 1000s of times
- Assume Base test passes 965 / 1000 times:

Regression score = (pass_rate * covered_scenarios) / total_scenarios

Regression score = (96.50% * 3) / 4 = 72.375%

Scenario ID	Subfeature	Coverage	Test	Regr
CAP_Y.MODE_1.1	Sel mode 1	cross: tb::a.sel_mode_1	Base	Y
CAP_Y.MODE_1.2	FW mode 1	cross: tb::a.fw_mode_1	Base	Y
CAP_Y.MODE_2.1	Sel mode 2	cross: tb::a.sel_mode_2	Base	Y
ERR.CAP_Y.1	Bad sel	cross: tb::a.sel_err	EnErrs	

Regression History



- Testplan is a live document:
  - Number of scenarios should (only) increase
  - Jumps will likely force the score down until regr scenarios catch up

Assuming 100% passing all time

Testplan Report

- Each scenario indicates pass/fail with simulation & coverage

Scenario ID/Metric		Instances	Rate	Result
CAP_Y_MODE_1.1				fail fcov_met
1	Base	1000	96.50%	fail
1	cross: tb::a.sel_mode_1		100%	fcov_met

Scenario ID	Subfeature	Coverage	Test	Regr
CAP_Y.MODE_1.1	Sel mode 1	cross: tb::a.sel_mode_1	Base	Y
CAP_Y.MODE_1.2	FW mode 1	cross: tb::a.fw_mode_1	Base	Y
CAP_Y.MODE_2.1	Sel mode 2	cross: tb::a.sel_mode_2	Base	Y
ERR.CAP_Y.1	Bad sel	cross: tb::a.sel_err	EnErrs	

Testplan Report

- Testplan score combines functional coverage with regression score
- Assume 96.50% pass rate and CAP_Y.MODE_1.2 not covered

Regression score = (pass_rate * covered_scenarios) / total_scenarios)

Testplan score = Regression score * functional_coverage_score

Testplan score = ((96.50% * 3) / 4) * (2 / 3) = 48.25%

Scenario ID	Subfeature	Coverage	Test	Regr
CAP_Y.MODE_1.1	Sel mode 1	cross: tb::a.sel_mode_1	Base	Y
CAP_Y.MODE_1.2	FW mode 1	cross: tb::a.fw_mode_1	Base	Y
CAP_Y.MODE_2.1	Sel mode 2	cross: tb::a.sel_mode_2	Base	Y
ERR.CAP_Y.1	Bad sel	cross: tb::a.sel_err	EnErrs	

Testplan Score

- Only includes functional coverage metrics *indicated* in the testplan
  - Functional coverage collected outside of testplan is ignored
  - Can include VIP or other external functional coverage
- Only includes run tests *indicated* in the testplan
  - Simulated tests run but not listed in the testplan is ignored
- Is this the best way to calculate testplan score?
  - I don’t really know – let’s discuss

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Conclusions

- Holistic approach requires buy-in from whole team and management
- Our method can accurately pinpoint scenarios:
  - Verified
  - Failing
  - Missing
- Our method can manage multiple active programs simultaneously
- We have employed this approach on two major projects
  - >5 simultaneous customer programs

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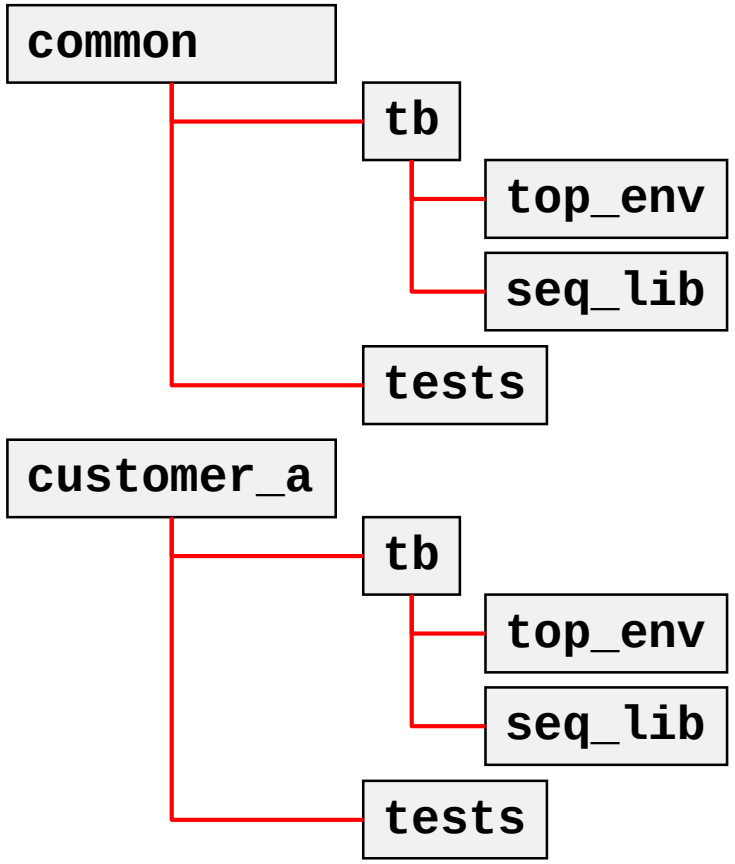
THANK YOU!

Questions Please

Extra Slides

Testbench Structure

- Common components / objects
- Extend to customer-specific
- Standard directory Structure
  - Common
  - Extended to customer-specific
- Class Inheritance Tree
  - Common
  - Extended to customer-specific



- Target the general case – common should be most heavily weighted