2023 DESIGN AND VERIFICATION™ DVCON CONFERENCE AND EXHIBITION UNITED STATES

SAN JOSE, CA, USA
FEBRUARY 27-MARCH 2, 2023

Accelerate Coverage Closure from Day-1 with AI-driven Verification

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accellera SYSTEMS INITIATIVE

Agenda

- Overview [40 min]
  - Intelligent Coverage Optimization (ICO) Technology
  - ICO Values: KPI, ROI
- Real Case Studies at Qualcomm [25 min]
- Success Stories [15 min]
- Q/A [10 min]

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ICO Overview

Technology, Values

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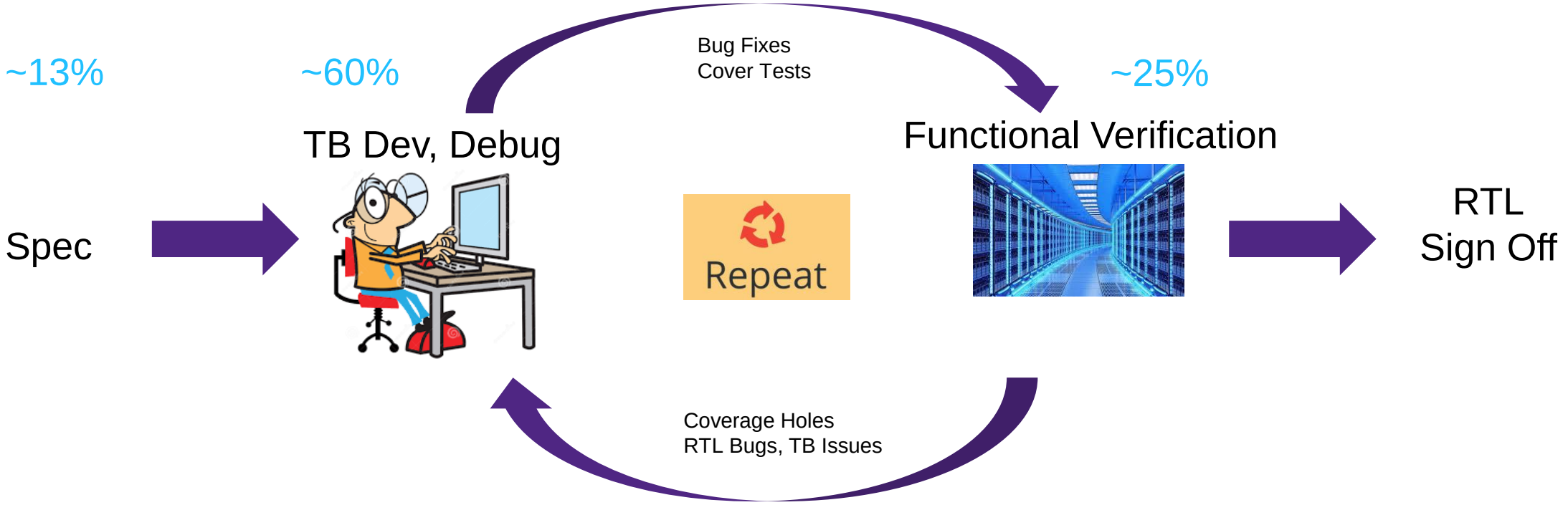
Verification Tasks



Verification Asks

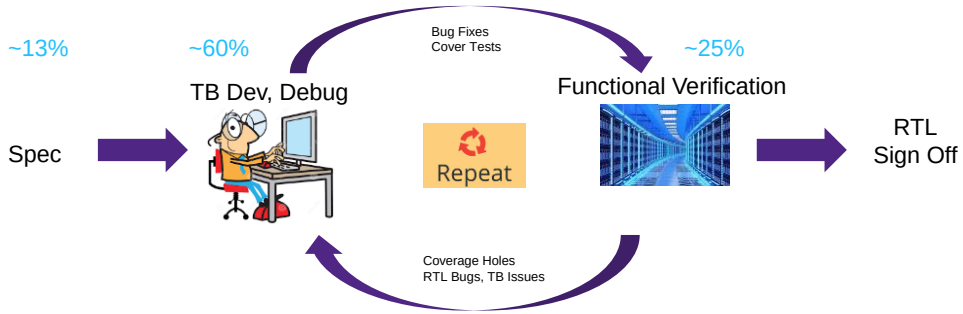
Reduce Number of Repeats ⇒ More Goals per Repeat ≡ **Productivity** Gain

More Goals Per Repeat

- TB Issues – inefficiency, under/over constraints, missing scenarios, illegal stimuli
- DUT Bugs – easy & hard-to-hits
- Cover group hits – easy & hard-to-hit
- Code Coverage, Assertions, Cover Properties
- Spec/Checker issues, …

ICO

Reduce Resource per Repeat ⇒ Less Cost per Repeat ≡ **Efficiency** Gain

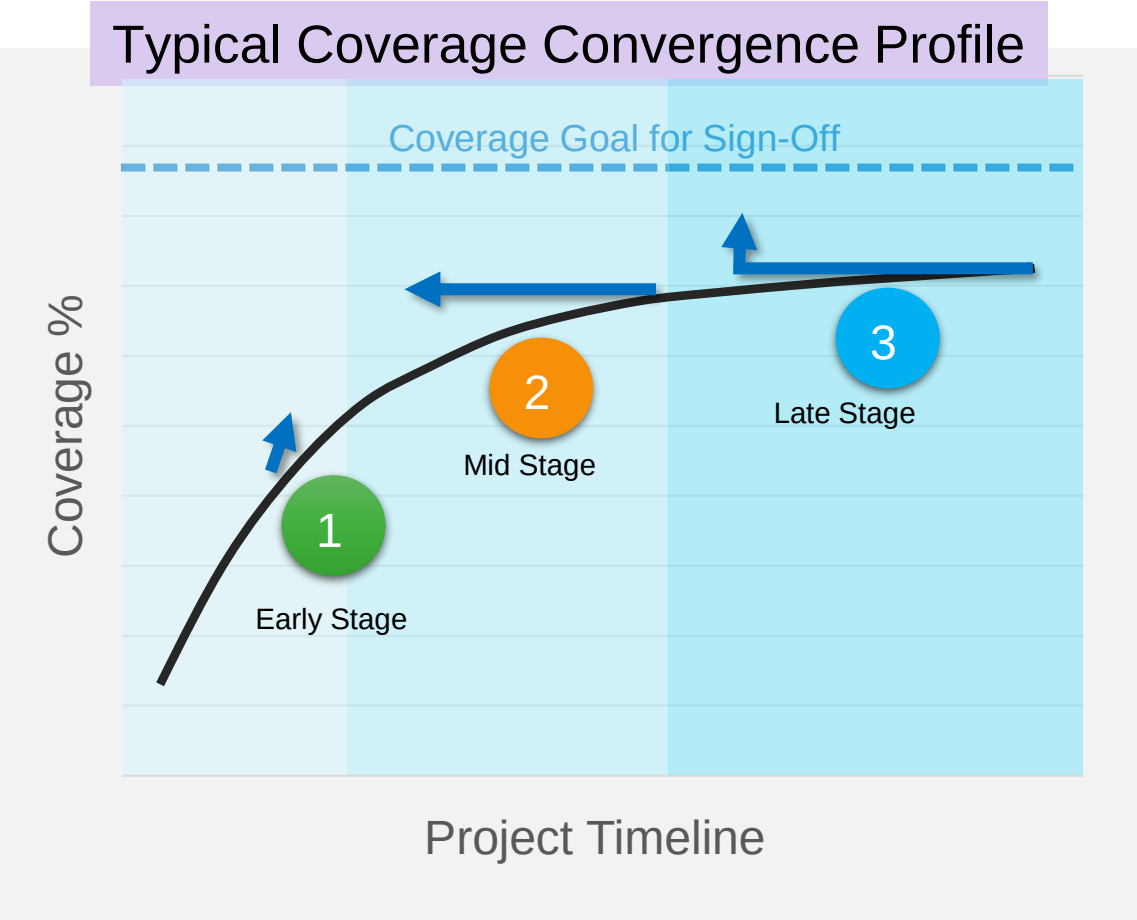


Less Cost Per Repeat

- Faster Performance
- Smaller Regression Size
- Fewer Grid Resource
- Easy deployment, Quality/Robustness
- Better debugging, Auto RCA
- Faster Bug Validation, …

FGP ||COMP UNR DTL ICO

ASK #1: Shift-Left Functional Coverage



1 TB Development

Ask – Stabilize and Mature TB faster

2 Optimize Regression, Achieve Coverage Goals

Ask – Accelerate Coverage and Bug rate

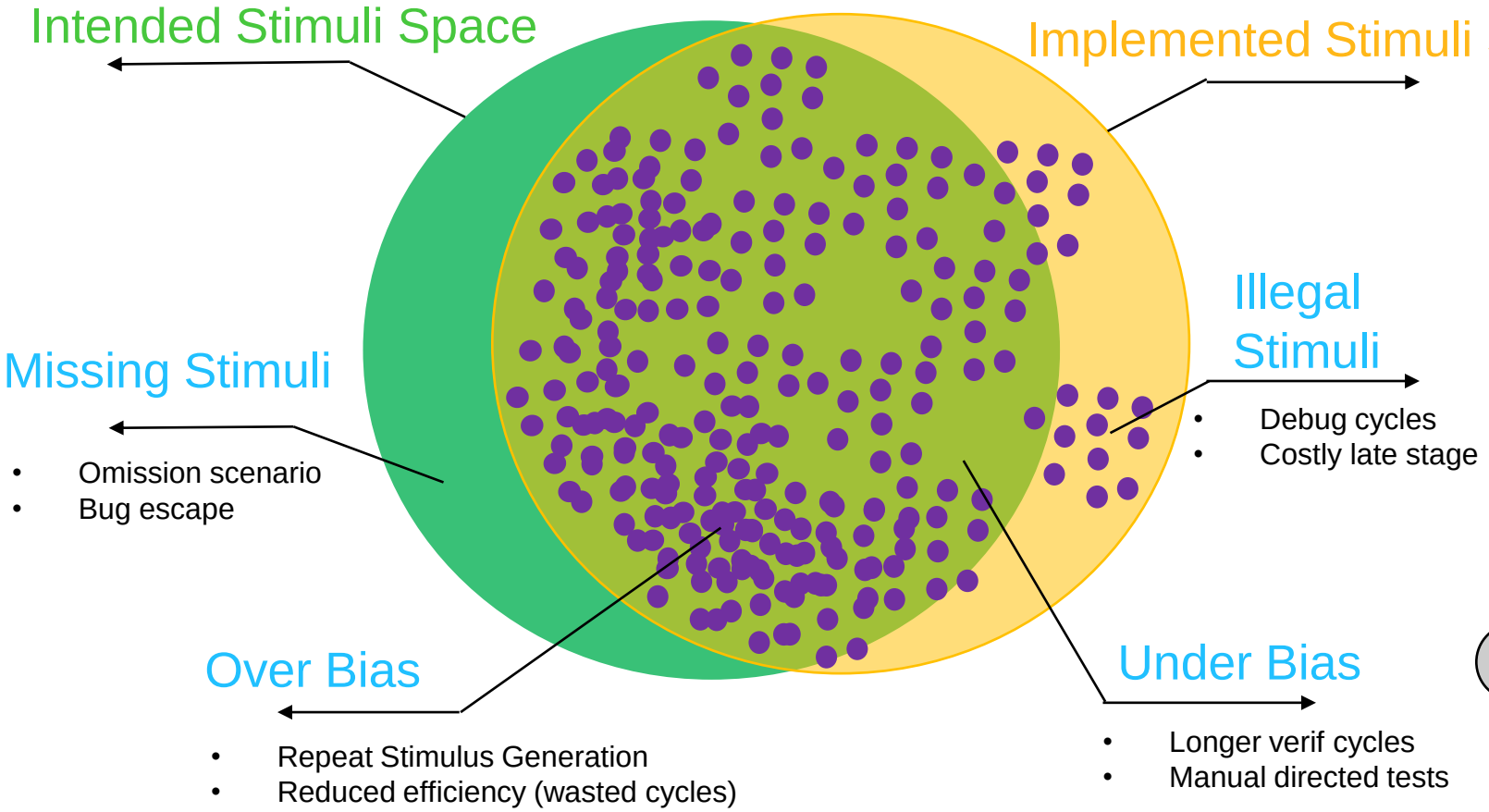
3 Coverage Convergence & Closure

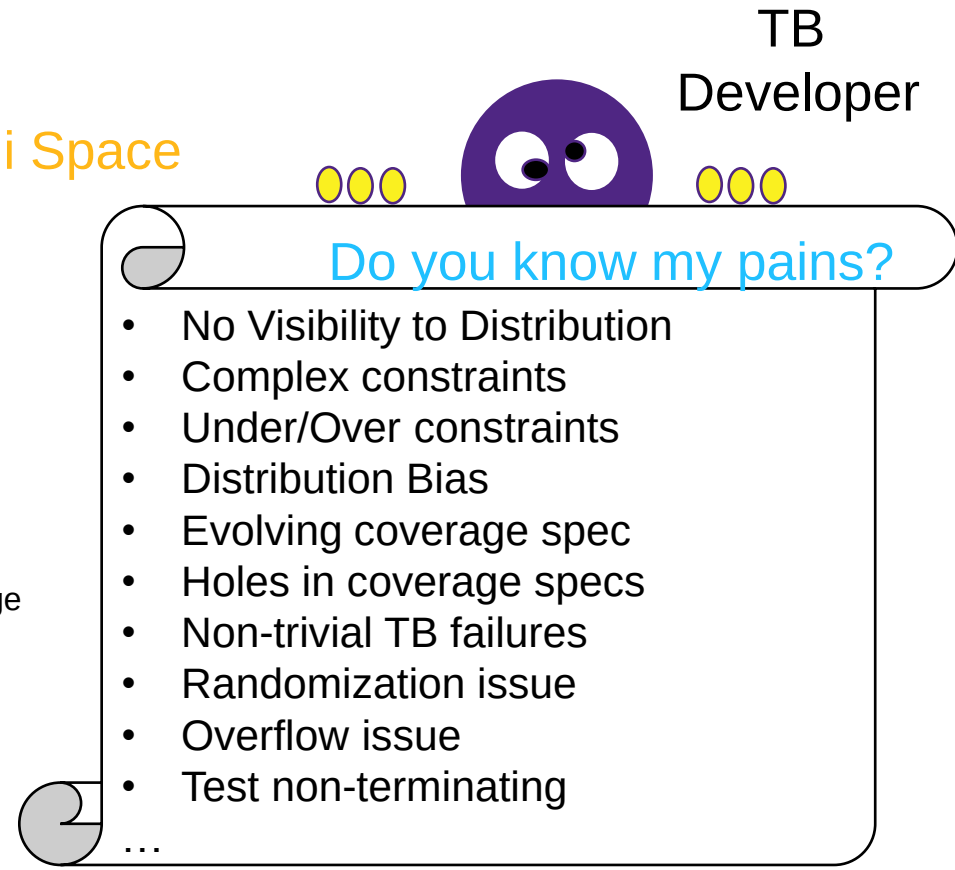
Ask – Faster closure, Save writing directed tests

“ICO can help from Day 1”

ASK #2: TB is the key for verification signoff, but …

Tuning TB is non-trivial, laborious, and risk prone





“ICO can help from Day 1”

Intelligent Coverage Optimization (ICO): Key Differentiators

1 Enhances Stimulus Quality using Reinforcement Learning

- Exposes more bugs including TB latent issues
- Reduce regress TAT with boosted grading
- Faster and Better code and functional coverage

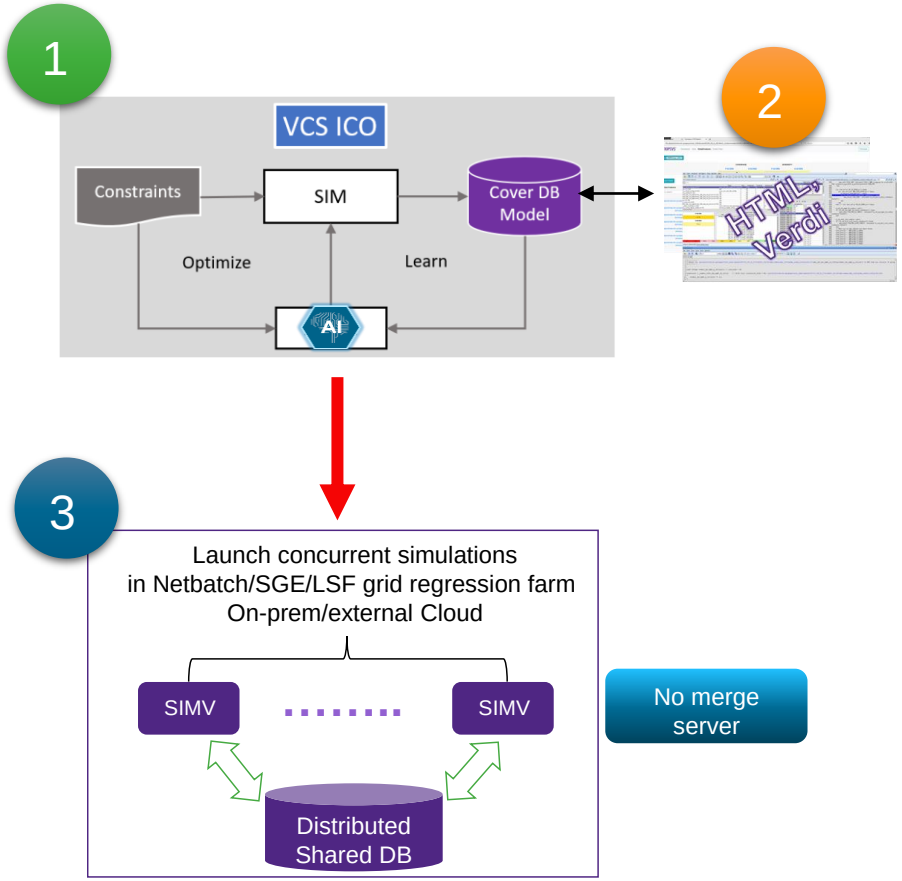
Synopsys VCS Availability:
2020.03, 2020.12, 2021.09, 2022.06, 2023.03

2 Provides TB Visibility & Analytics

- Stimuli distribution: diversity metric, histogram
- RCA to Low coverage, Skewed distribution, Under/Over-Constraints

3 Deployable at all stages of TB development

- Early (no user-coverage), Intermediate, Stable (rare issues)
- Ease of use and deployment (fits seamlessly in Synopsys VCS user environment)
- No need to rewrite/change functional coverage model



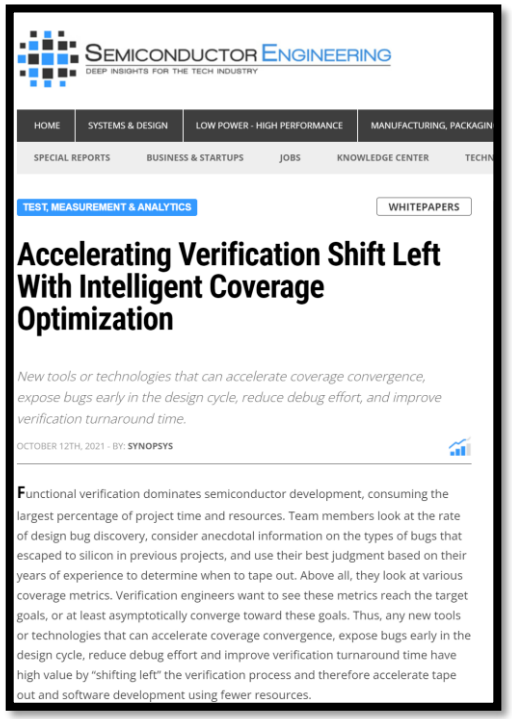
ICO KPIs

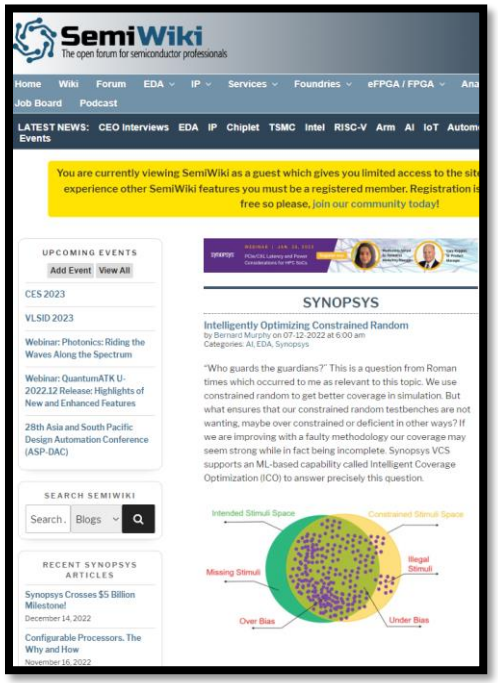

Easy Use Model
Save Writing Tests, Grid Usage
Improve Stimuli Diversity
Blocked Value Analysis
Accelerate Functional Coverage Rate
ICO
Expose TB issues
Shift-left Bug Rate
TB Insights
Boost Grading
Cover Hard-to-Hit Targets

ICO: KPI ⇒ ROI

- Measuring ICO Values & Impacts
  - `ICO KPI := Func(TB Constraint complexity, TB Randomness, TB Maturity)`
  - When used in early/mid stages
    - Higher volume of bugs => faster TB stabilization [User1: weekly bug rate up 2X]
    - More coverage => write fewer directed tests, grid savings [User2: 64% after 7 vs 15 runs, speedup 2x]
    - TB insights => missing scenarios, incorrect constraints [User3: help revise TB to reach bins 100%, cross @ 99%]
  - When used in late stage
    - Hard-to-hit, latent, omission bugs => reduce repeat [User4: spec bug, deadlock]
- Cost of Results
    - Ease of Use, Low Overhead, Runtime On/Off flexibility, Product robustness => reduce cost

ICO: Blogs, Pubs, Presentations





Many ICO Successful Deployment Stories from SNUG

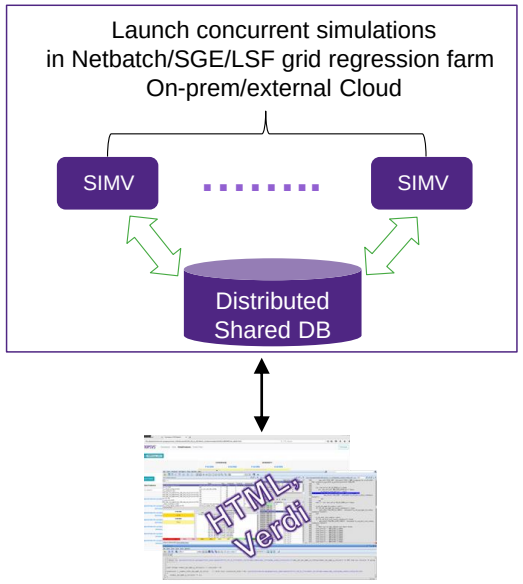
Visit: https://training.synopsys.com/learn

ICO Value #1: Easy Use Model

No need to rewrite / change func model

No need for a merge server

Deployable on-prem / external cloud



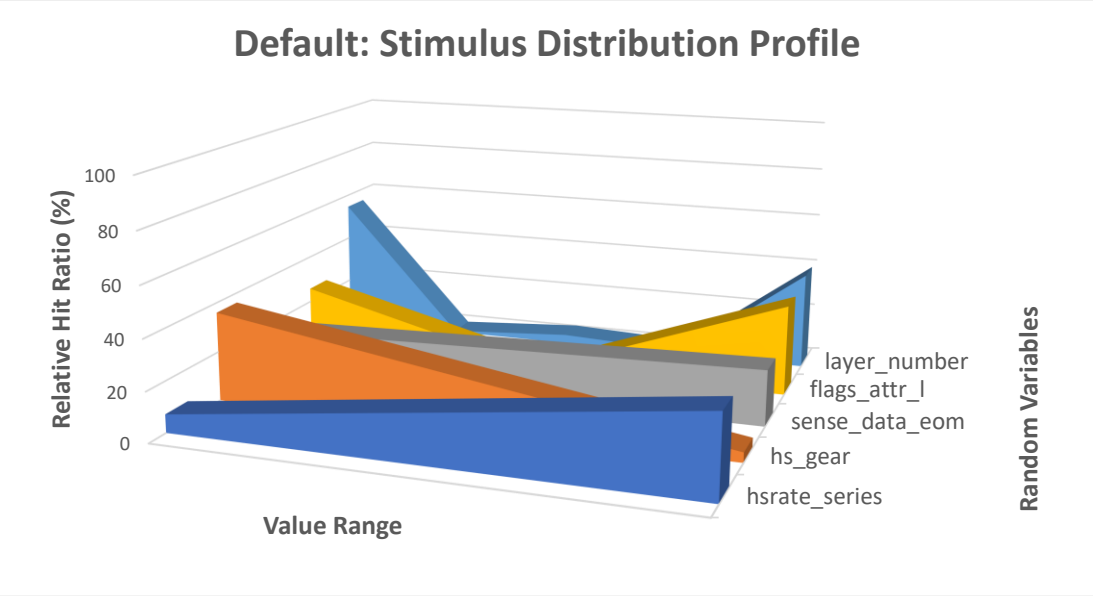

```
% vcs ... //nothing needs to be changed

% crg -dir <shared_cdb> -shared init

// run regression in parallel
% simv <ico_run_opt> <other run_opts>

% crg -dir <shared_cdb> -report crgReport
```

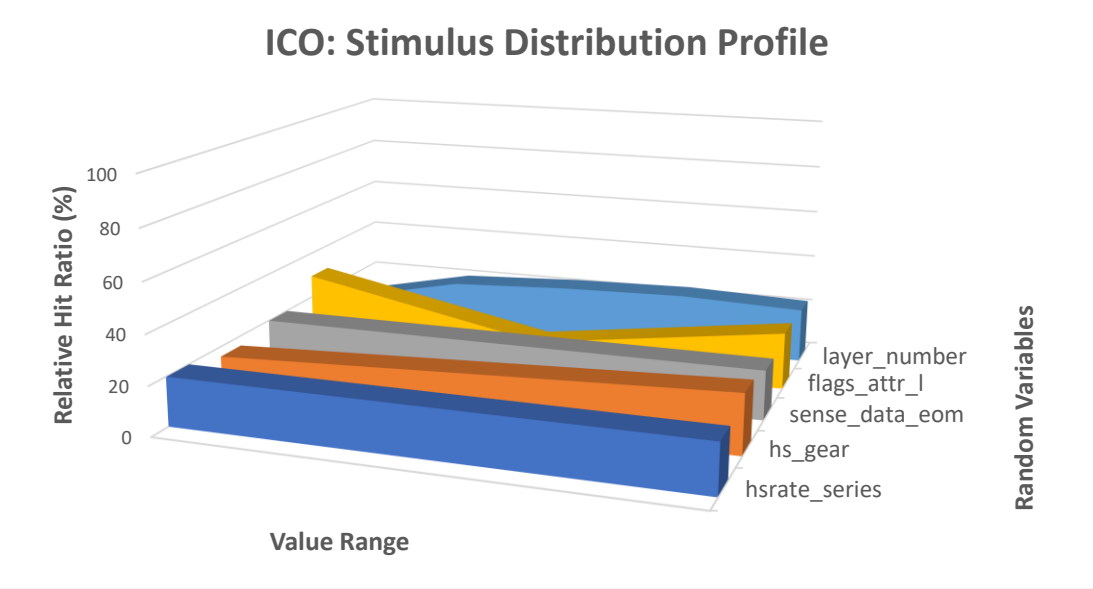
Initialize/Reuse Shared cdb

Launch ICO Regression

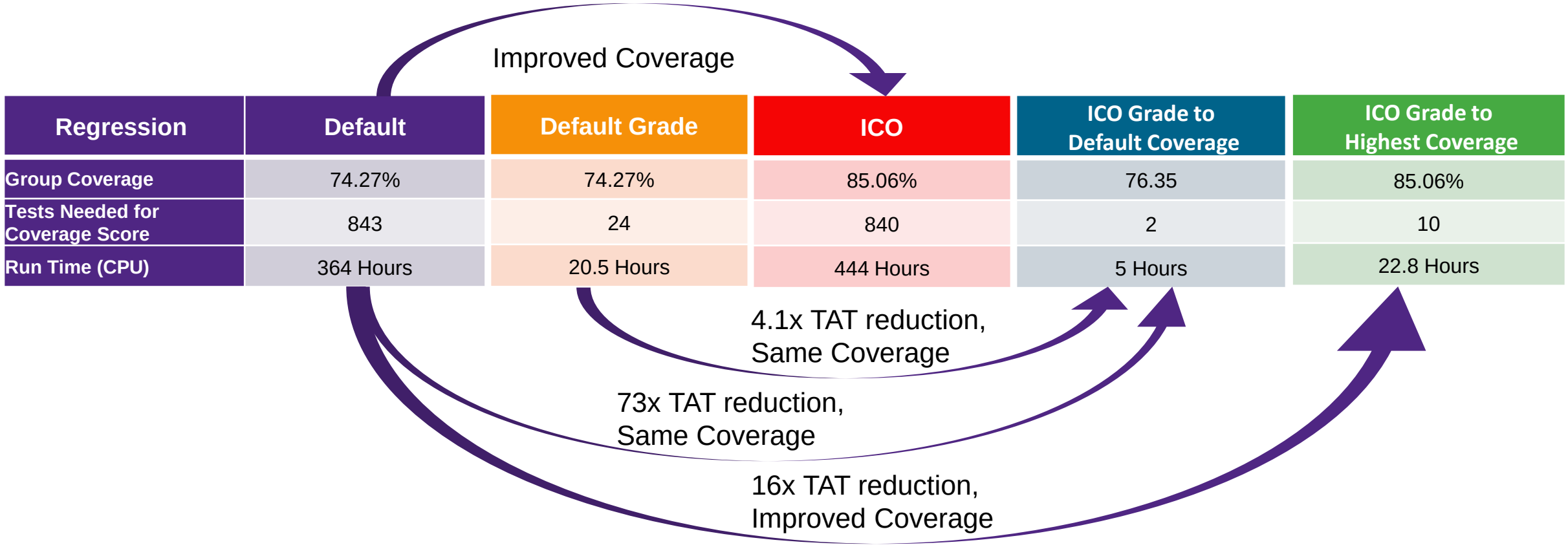
Generate CRG reports

ICO Value #2: Improve Stimuli Diversity



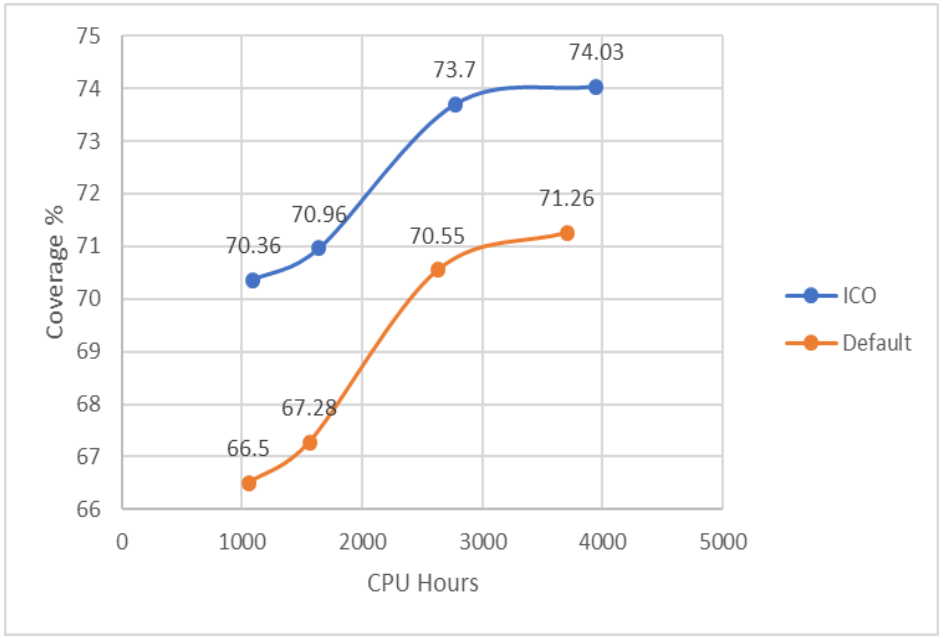


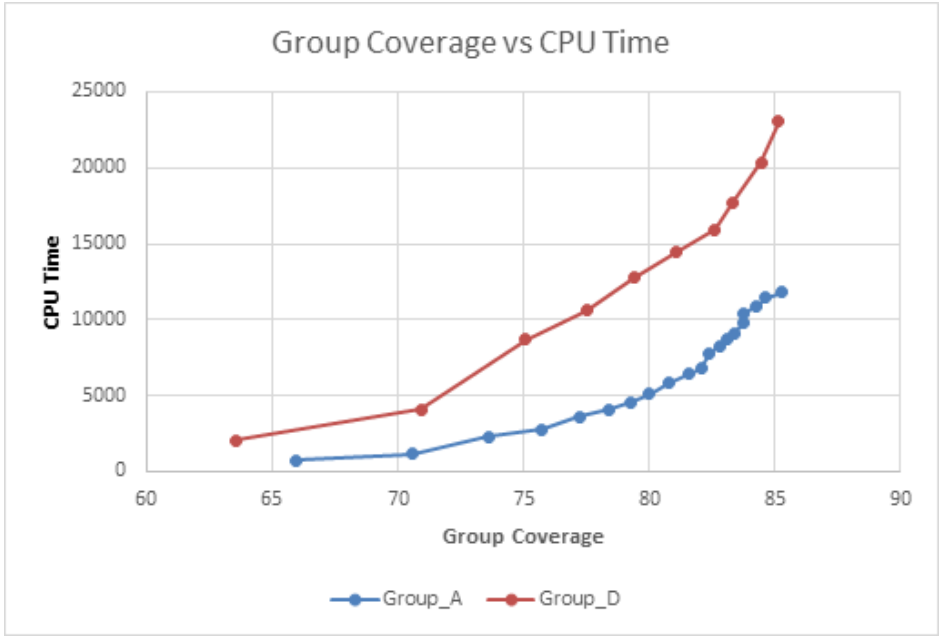
ICO Value #3: Boost (URG) Grading



Regression	Default	Default Grade	ICO	ICO Grade to Default Coverage	ICO Grade to Highest Coverage
Group Coverage	74.27%	74.27%	85.06%	76.35	85.06%
Tests Needed for Coverage Score	843	24	840	2	10
Run Time (CPU)	364 Hours	20.5 Hours	444 Hours	5 Hours	22.8 Hours

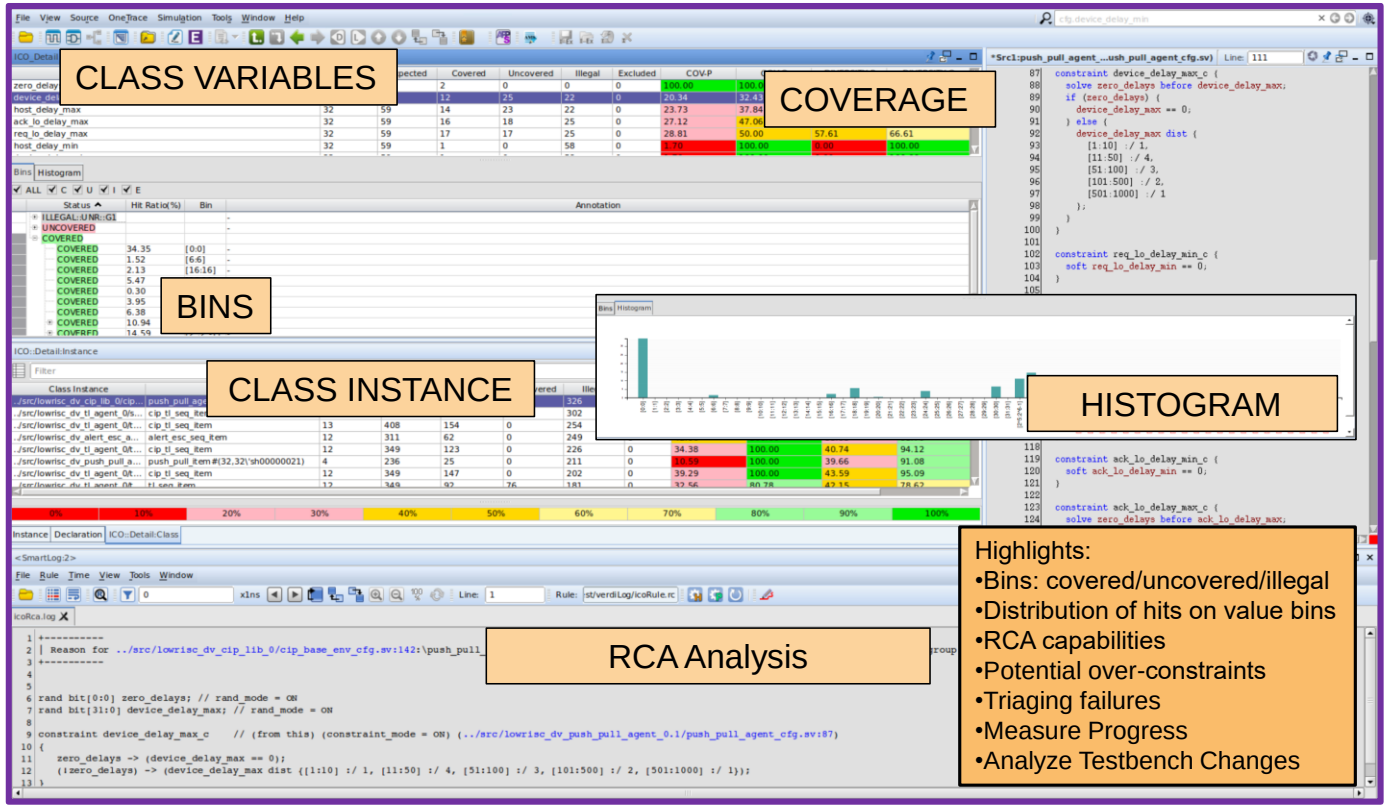
ICO Value #4: Accelerate Functional Coverage Rate





Early Mid Stage

ICO Value #5 & #6: Provide TB Insights, RCA



ICO Value #7: Expose TB issues

Early Stage

- Found incorrect random distribution

```
std::randomize(num_zero_bytes) with { num_zero_bytes dist { [0:14] :/ 0, 15:= 1 };  }
```

- Changed many variables from int to bit vector to limit the boundary of legal values

```
int pkt_len; // Need to declare as bit[7:0]
std::randomize(pkt_len) with {pkt_len > 0; pkt_len <=256;};
```

- Found unwanted randomization of variables/constraint blocks

```
if(err_en == 1) begin // This condition was missing
  for(int k =0; k < 1000; k++) begin
     scan_frames[k] = new();
     scan_frames[k].randomize();
```

- Over constraint issues

```
constraint abc {
   abc inside {[0:2**n-1]} // Should be 0 : 2**n
 }
```

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Real Case Studies at Qualcomm

ICO values at Early, Mid, Late Stage of Projects

"Accelerating Functional Verification Through Stabilization of Testbench Using AI/ML" – DVCON'23

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Requirements

- GPU architecture is intricate
  - Parallelism, complex logic
  - Challenging to find corner case bug, to achieve full functional coverage
- Manual effort is required for test creation
  - Semi-directed test cases to hit corner cases at the block level and cluster level
- Need for a productive approach with automation that
  - Does not require rewrite/change in functional coverage model
  - Helps shift-level verification – accelerate bug finding, coverage rate
  - Ideally, fits seamless in our regression environment

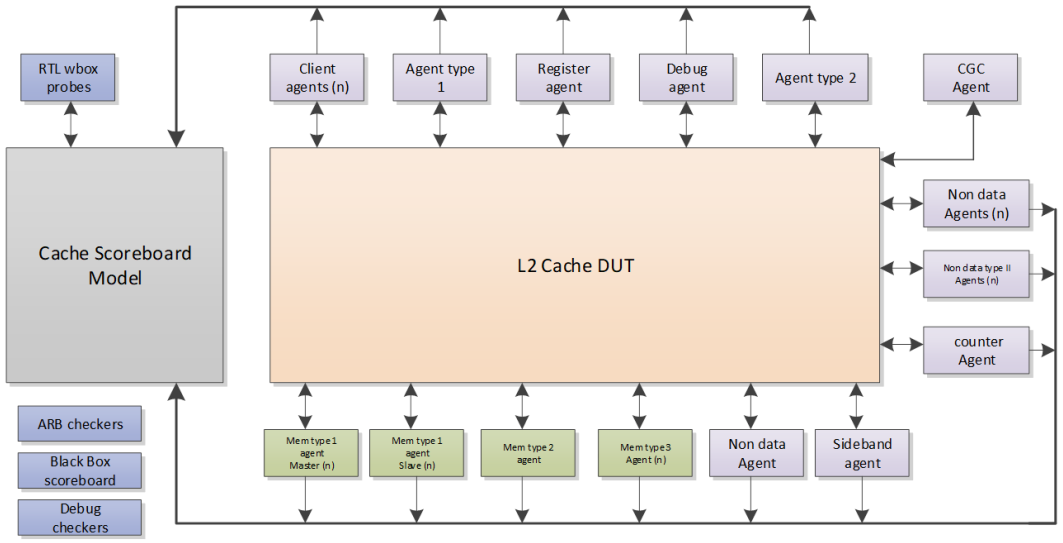
Overview of Case Studies

- Demonstrate how we leveraged ICO
  - Deployed ICO in multiple real-life scenarios across multiple blocks
- Collected, analyzed data over a period of 2+ years (2019-2022)
- We present our observation across 3 projects at different stages
  - Project A @ Late Stage
  - Project B @ Early-Mid Stage
  - Project C @ Mid Stage
- Compare ICO vs. Non-ICO (status quo)
  - Key Performance Indicators: Bug rate, Coverage rate
  - ROI: productivity, efficiency

Project A:
Late Stage

ICO Value #8: Cover Hard-to-Hit Targets

- The L2 cache TB was stable
  - pass rate of 98% with a coverage rate of 95% over 10 regression cycles.
- Full insight into stimulus types with ICO
  - Uncovered 30% more bugs despite TB being stable.



Improved testbench, expose rare scenarios

- 30% more TB Issues uncovered: Constraint inconsistency failures, Design SVA failures due to issue in TB UVM driver, Scoreboard issues related to checker
- RTL Issue uncovered: Design deadlock scenarios
- Full visibility into TB (over-constrained, distributions, RCA)
- 6 regressions with ICO vs. 10 regressions with Default to hit 95% functional coverage (each regression takes 1 day, 4 days of savings)

	Default simulation UVM error count per regression	ICO simulation UVM error count per regression
Regression 1	67	84
Regression 2	64	86
Regression 3	70	79
Regression 4	72	111
TOTAL	**TOTAL=273**	**TOTAL=360**

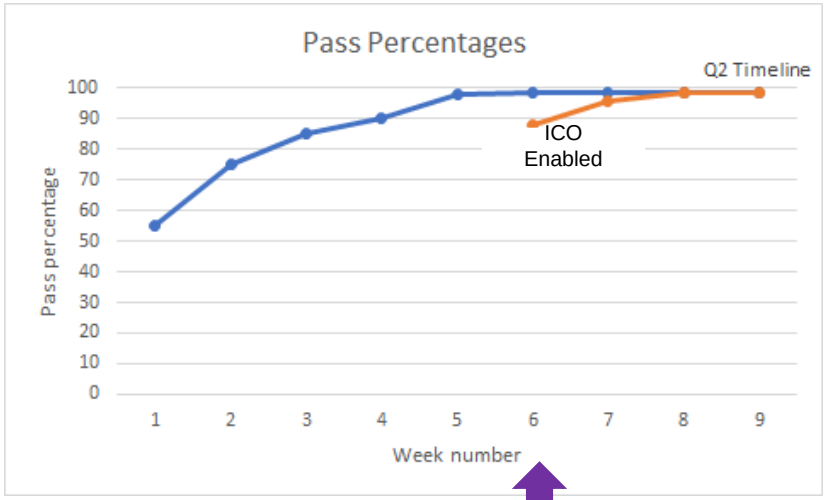
Inconsistent constraints: **0**
Scoreboard mismatch errors: **0**

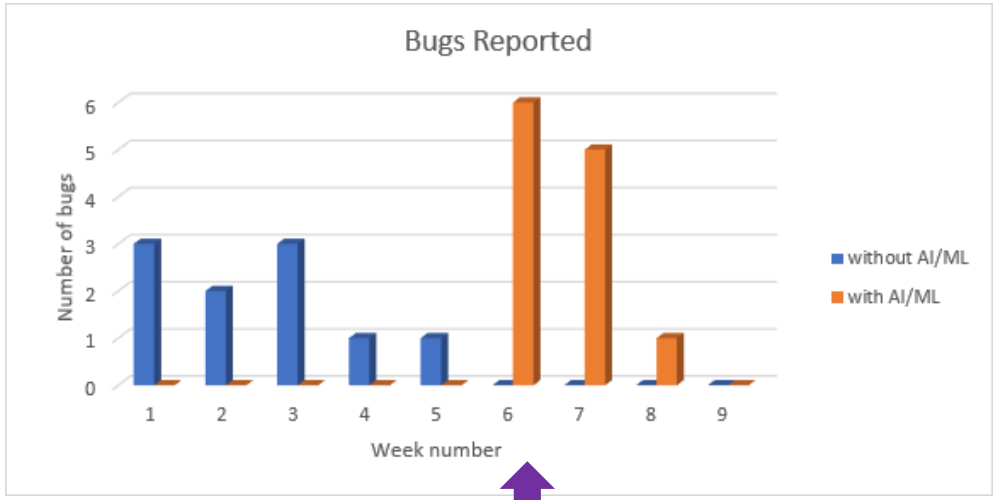
Inconsistent constraints: **89#**
Scoreboard mismatch errors: **7***

ICO Value #9: Shift-left Bug Rate

More Goals Per Repeat => Higher Productivity

Week #	Pass %	ICO Enabled?	# TB bugs	# RTL bugs
Week 1	55%	no	13	3
Week 2	75%	no	10	2
Week 3	85%	no	11	3
Week 4	90%	no	11	1
Week 5	98%	no	7	1
Week 6	88%	Yes	18	6
Week 7	96%	Yes	7	5
Week 8	98.50%	Yes	5	1
Week 9	98.50%	Yes	5	0





ICO enabled

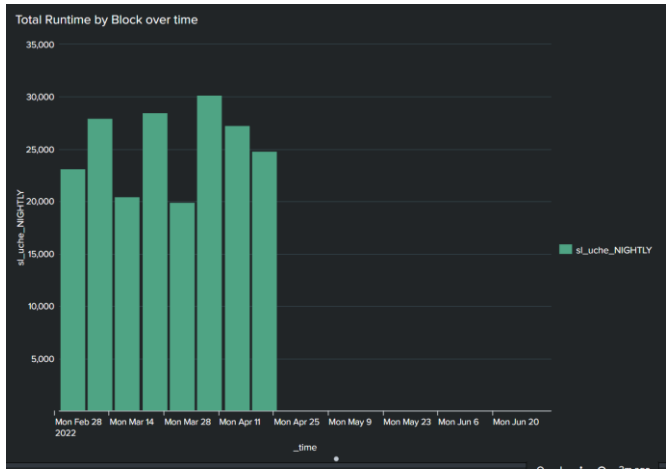
ICO enabled

- ICO was enabled on Week 6th when pass rate was ~98%
- A big surge in both TB and DUT was observed even when TB/DUT was deemed stable
- In subsequent fewer iterations all DUT bugs were exposed

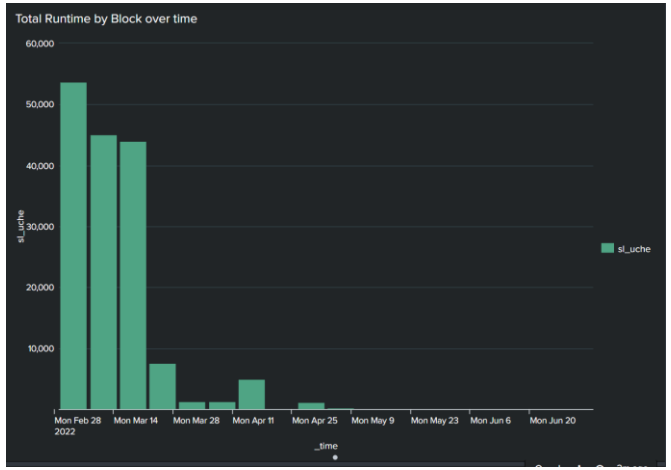
Project C: Mid Stage

ICO Value #10: Save Writing Directed Tests, Grid Usage

Coverage	Metric	Default	ICO Enabled	Improvement with ICO
Code	Line	88064	89231	1167
	FSM	855	885	30
	Condition	356836	359019	2183
	Branch	66888	69931	3043
Functional	Cover Points	1757	1804	47
	Coverpoint bins	39628	39969	341
	Cross Coverage bins	305445	306859	1414
	Total Bins	347984	349661	1677



Default: 198k time units



ICO: 162k time units

Render Block has ~350K coverage bins

- Combinations of color/depth formats, tile packings
- Required months of back-to-back regressions

10-15% reduction in grid usage per block (Project B)

"*After enabling ICO in random regression for this block, we witnessed dramatic improvement or left shift in functional coverage closure by 1.5 weeks. We observed that most of complex bins which needs tweaking of constraints or delay profile automatically are now getting hit quickly. Consequently, we now need to spend very minimal effort (maybe for less than 100 bins instead of 200 to 500 bins) on directed /constraint tweaking or delay profile tweaking.*

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ICO Success Stories

ICO values at various design houses

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ICO Success Stories

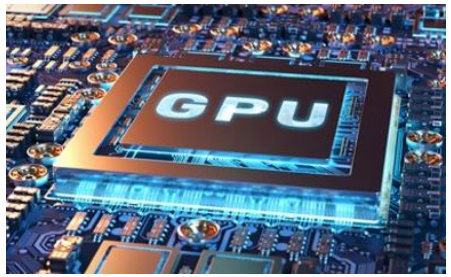
HYPER SCALERS

RESULTS

- Exposed 51 Testbench bugs
- 10% increased coverage with hard to hit bugs exposed

RESULTS

- >10% coverage improvement
- Exposed rare scenarios
- Production use in IP/SoC blocks



RESULTS

- Upto 3X faster TAT
- Regression Count reduced by 2X
- Exposed DUT bugs

Early and Additional Bugs Found on a Mobile Design

1.67X faster coverage closure and 30% more issues uncovered

Application	Graphics

Customer Goals	**Results with VCS ICO**
Insight into stimulus coverage	• Full visibility into testbench (over-constrained, distributions, RCA)
Shift left in bug hunting	• **30% more** TB Issues uncovered • RTL issue uncovered: design deadlock scenarios
Verification completeness	• **1.67X** faster coverage closure • **6** regressions with ICO vs.**10** regressions with default to hit **95%** functional coverage

Faster and Improved Coverage at a 5G Design

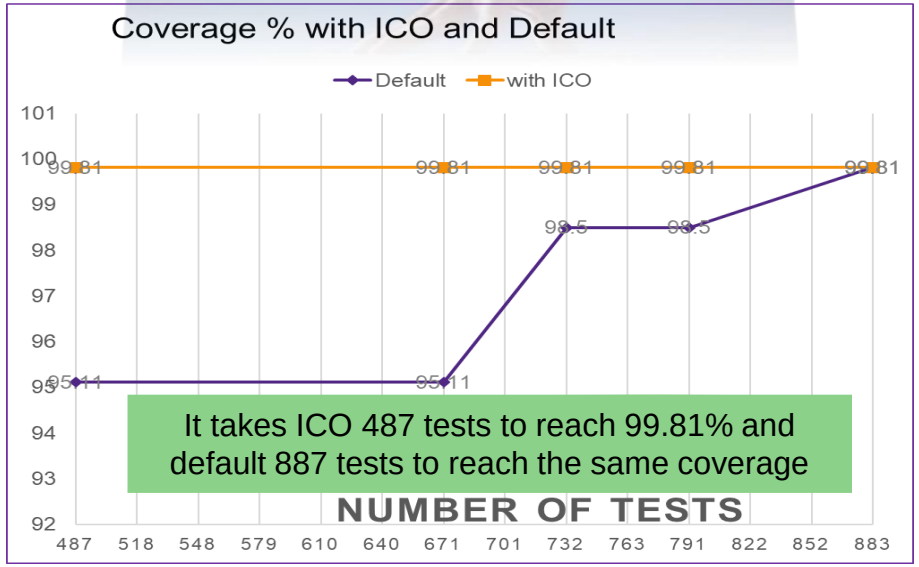
1.5X faster coverage closure, 5% higher coverage compared to default regression

Application	5G, IoT, mission critical systems

Customer Goals	Results with VCS ICO
Testbench visibility and find more bugs	• Visibility to stimulus coverage, diversity and distribution • Exposed one TB issue
Increase coverage and faster coverage	• **5%** higher coverage and **1.5X** faster to reach complete coverage closure

Regression	Default	VCS ICO
Group Coverage	99.81%	99.81%
Tests Needed for Coverage Score	911	507
Run Time (CPU)	36.76 Hours	23.79 Hours

1.5x

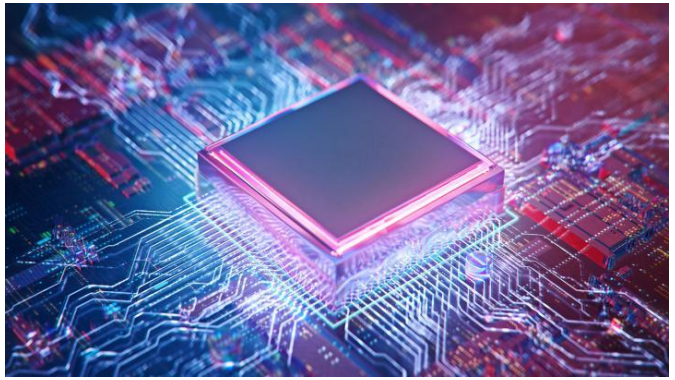


Improved Quality and Compute Efficiency on a CPU Design

Exposed 2X failure buckets, 4% higher coverage with <30% runtime overhead

Application	Microprocessor

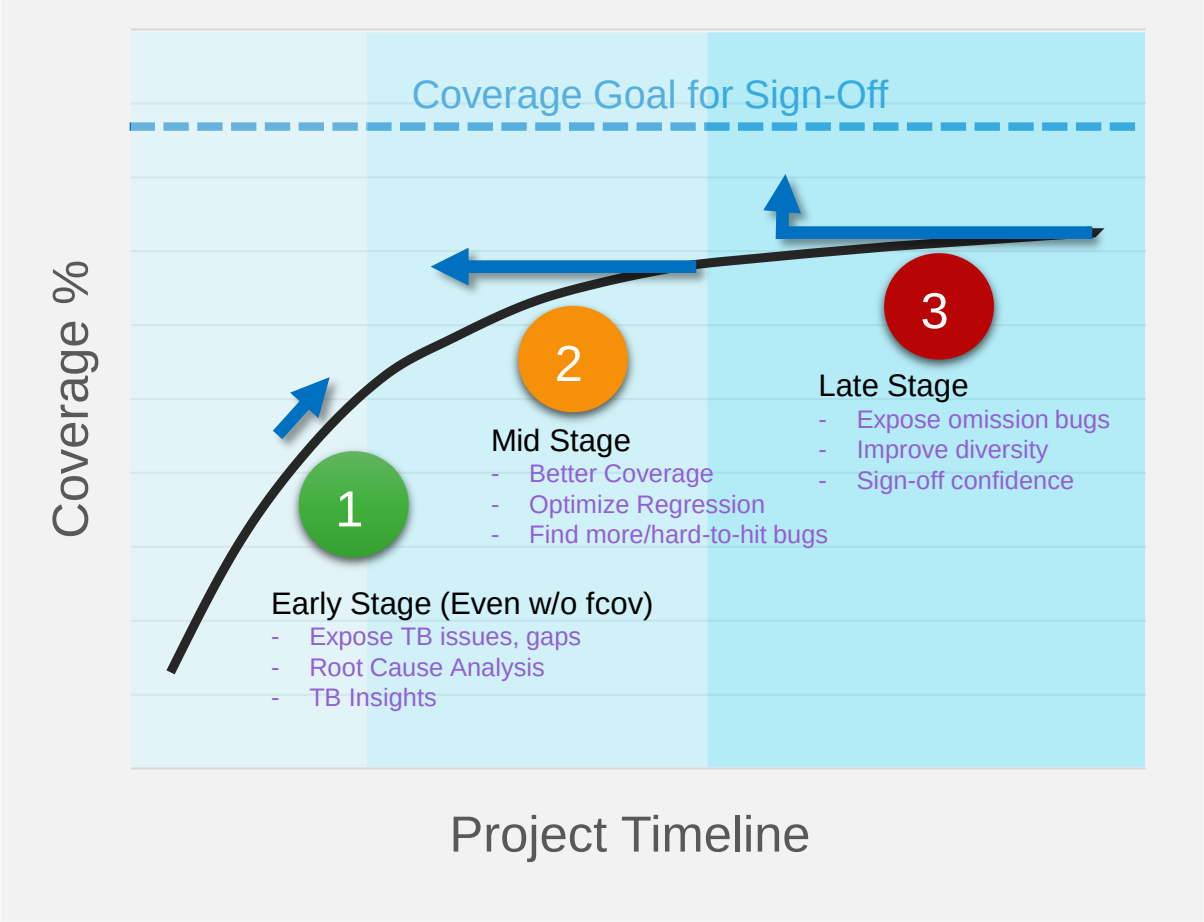
Customer Goals	**Results with VCS ICO**
Improve verification quality	• Found 2X buckets of failures with the same seeds • Reports provide interesting insights on efficacy of stimulus
Increase Compute Efficiency	• **<30%** runtime overhead • Comparable cycle per second
Increase Verification Efficiency	• Cover Group score per regression seems to be 4% higher on average



Metric	Default	VCS ICO
Failure Buckets	17	32
Run time (CPS)	67 Hz	69Hz
Coverage	71%	75%
Stimulus Quality	Cov: 9.44% Diversity: 2.74%	Cov: 26.75% Diversity: 12.78%

Summary: ICO Helps Shift-Left Verification From Day-1

Verification Productivity



Verification Efficiency

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Q&A

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Thank You

Contact Synopsys AE's for More Information

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