



ChinaTM

Virtual Event

November 1 – 4, 2022

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How Machine learning can help customer in PSV/Production process

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Virtual ▪ November 1-4, 2022

ADVANTEST

Contents

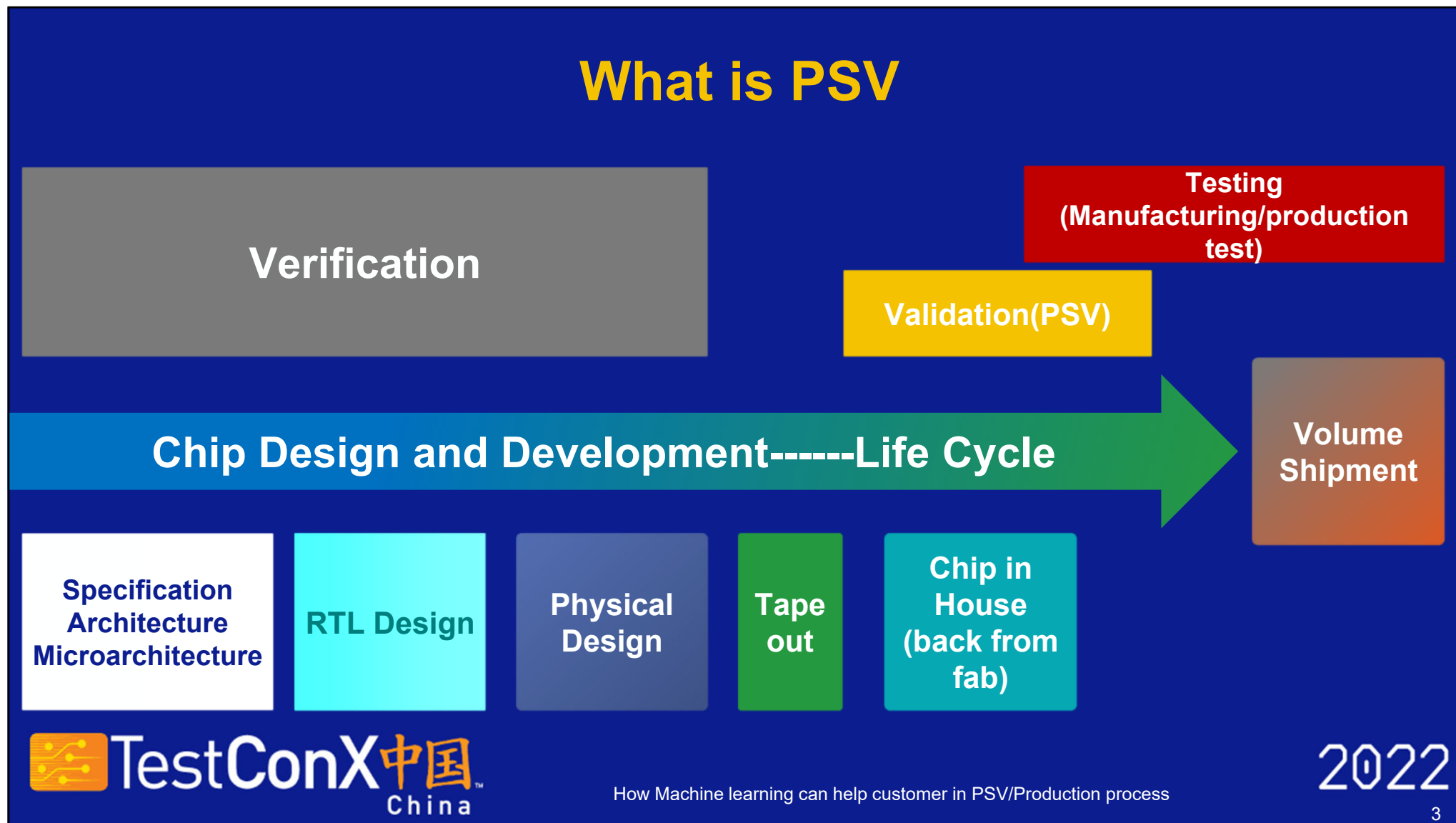
- PSV and it's challenge
- Our Methodology
- Function overview
- Introduction of key functions
- Practice in PSV & Production
- Summary



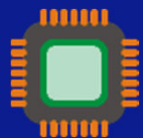
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2022

2



How is Challenges



- Process variations, design complexity and black-box IP blocks lead to unexpected, hard to debug problems under peculiar conditions



- Schedule pressure



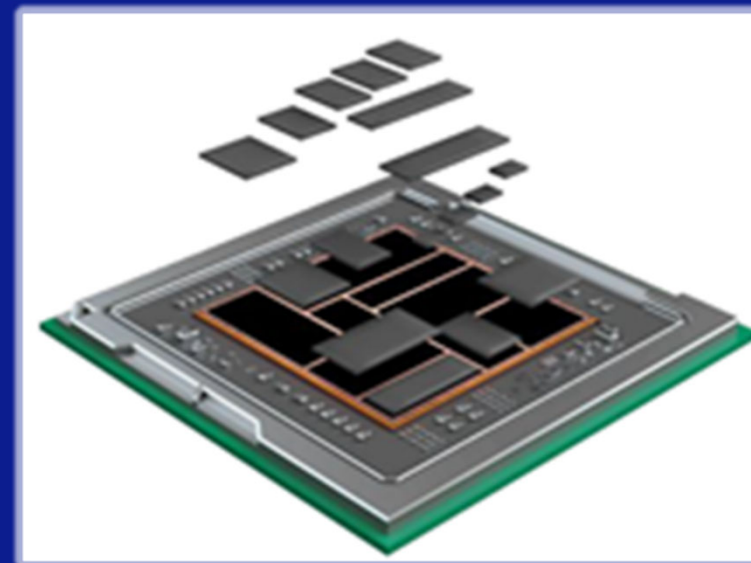
- Increasing quality expectations



- Tuning becomes too complex



- Experts are sparse

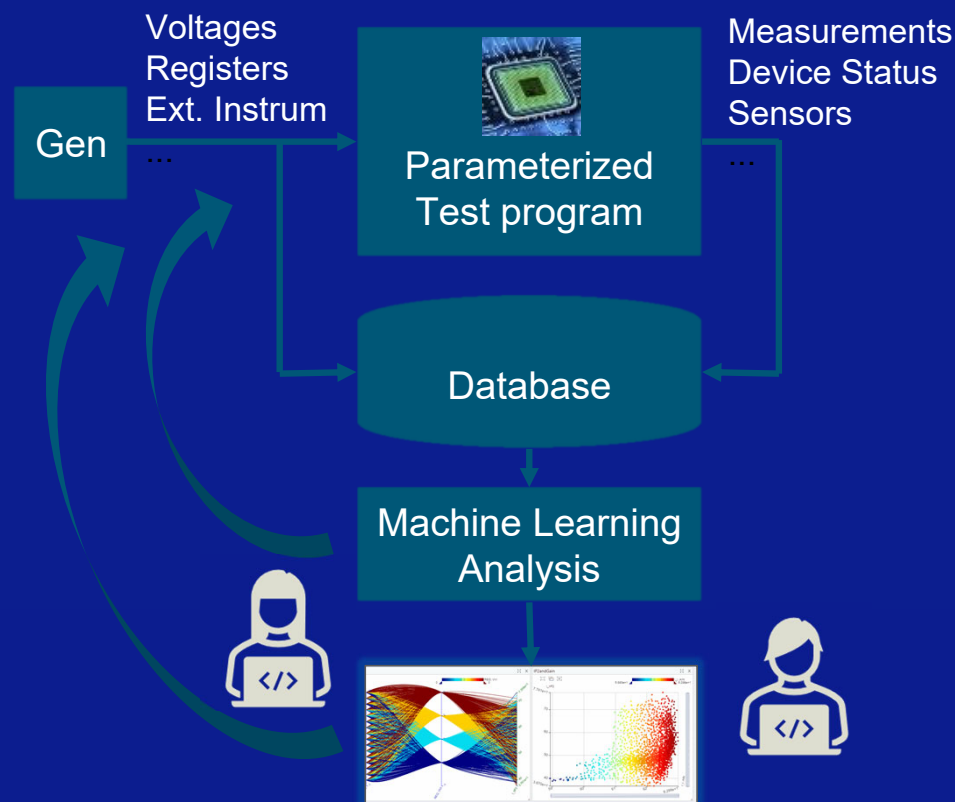


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4

Our Methodology



Parameterized Functional Test

- Validates chip + FW + test program

Optimizing Func. test Set

- Scans parameter space (10k~100k parameterizations)
- optimizes Functional test set (reduce runtime)

Quality through black-box coverage

- No assumptions → Constrained random tests

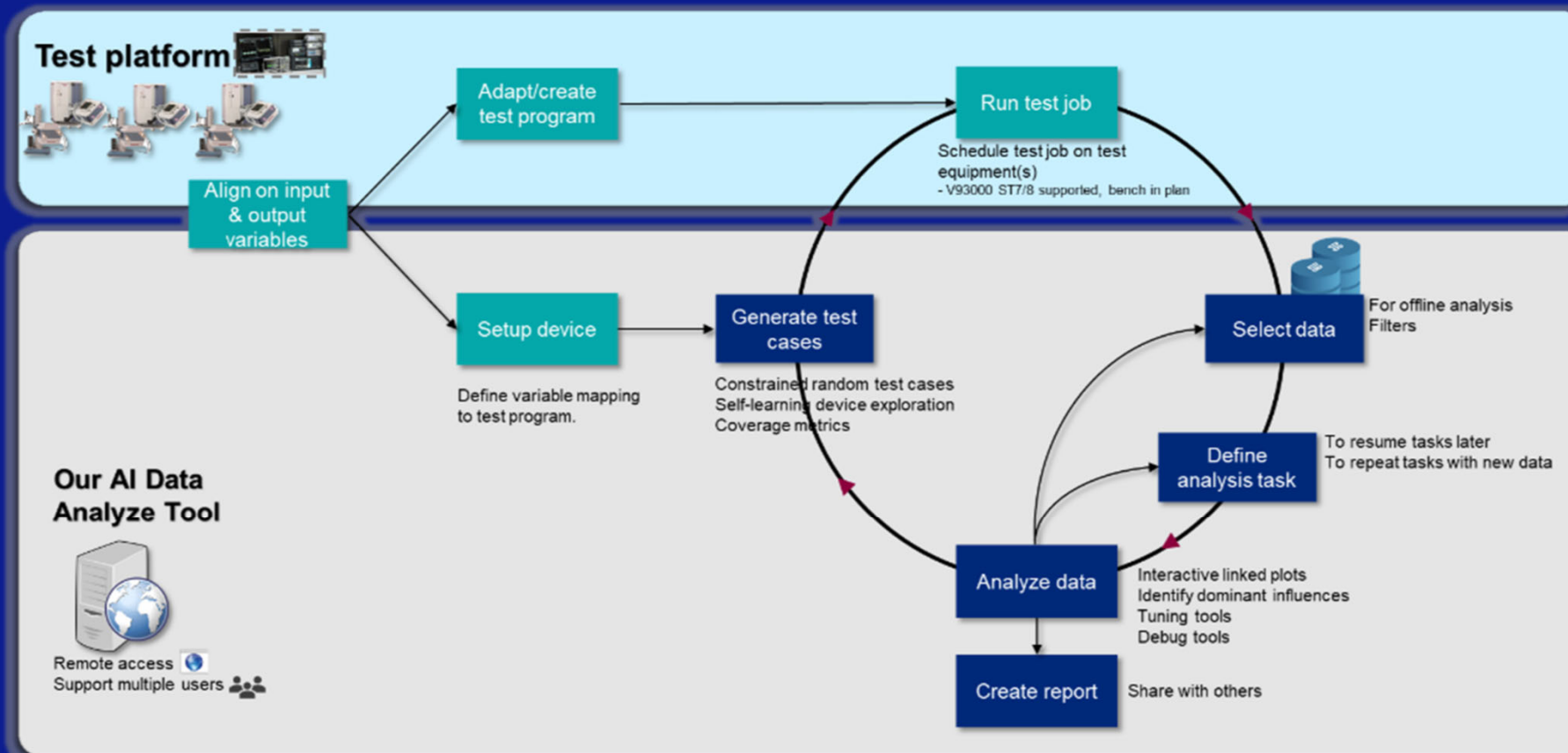
Relate inputs to outputs

- Identify important influences

Interactive post-processing analysis

- Based on comprehensive data
- Generate more data from within plots

Our Workflow



Function overview

Notes: some functions are still under development

Basic Function

- I. Support 93K&Bench
- II. Variable selection finds most important dependencies
- III. Automatically generate test conditions
- IV. High coverage through constrained random tests

AI Tuning

- I. Automatic AI-based multi-dimensional tuning
- II. Adaptive Test Generation collects relevant data faster

General Debug

- I. Split multiple problems for easier debugging
- II. Model-based what-if analysis
- III. Peel-the-onion tool reveals subtle effects

Advanced Debug

- I. Self-Learning Debugging
- II. Multicores Debugging

Various Plots

- I. Interactive, linked plots highlight selected data in all plots(9 types currently), Interactively run tests from within plots
- II. Automatic plot type selection
- III. Highlight statistically significant (small) deviations
- IV. Linked plots of spectra & waveforms

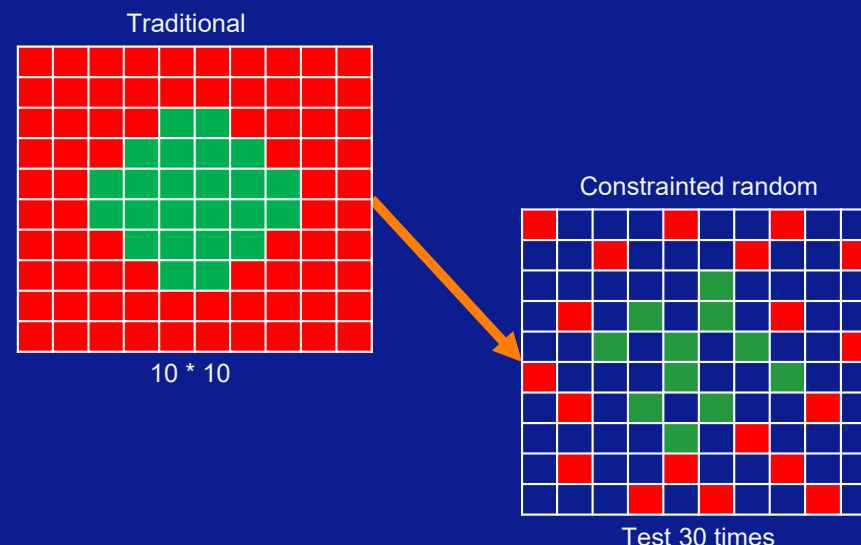
Production Test

- I. Find suitable spec settings automatically by AI to make the scan tests pass under special conditions
- II. Improve test program quality

Better coverage through constrained random testing

Sample device module:

- Parameterizable inputs: 8 channels, each has 3 register (5 bits each), 3 devices
- Test execution time: 100ms / case



$$\text{Total test time} = 8 * \underbrace{2^5 * 2^5}_{\text{registers}} * 2^5 * 3 * 100\text{ms}$$

channels devices

= 22hours

Gain basic profile through 30% coverage

—————> 8 hours



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8

Better coverage through constrained random testing

Scenario: 25 inputs, want to cover all 10% value intervals, budget of 10k test cases. There are 300 pairs of 25 variables, and 2300 triples.

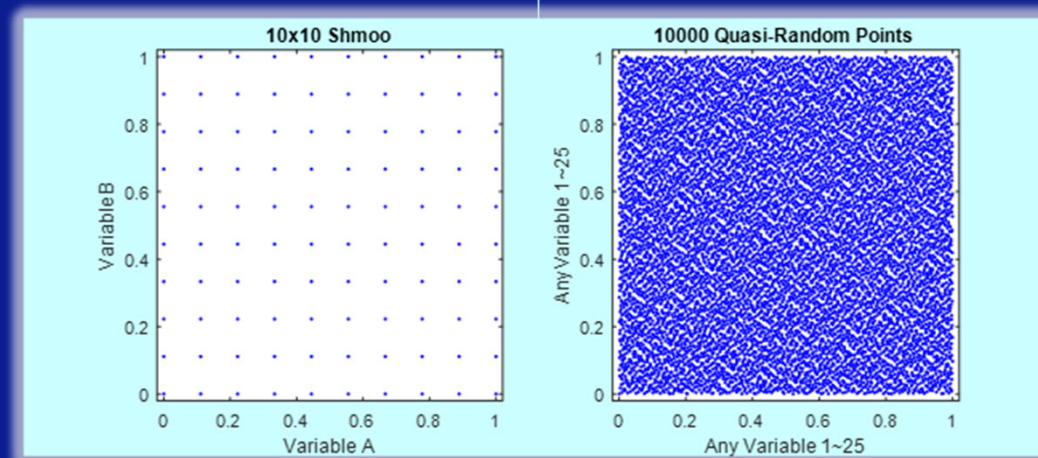
Shmoo: Select 100 suspected most relevant input pairs, run 10x10 Shmoo for each pair.

Pair Coverage: 40 % Triple Coverage: < 10 %

Random Test: Randomize all input variables simultaneously. Make no assumption!

Pair Coverage: 100 % Triple Coverage: 100 %

Shmoo tests find only expected problems.



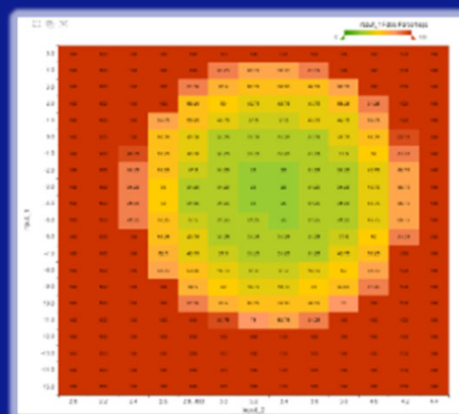
Random tests find also unexpected problems.

3D Shmoo

1. Define Shmoo generation method for Shmoo (axis) variables

- All numeric input variables can be used as Shmoo axis
- Support up to 5 variables

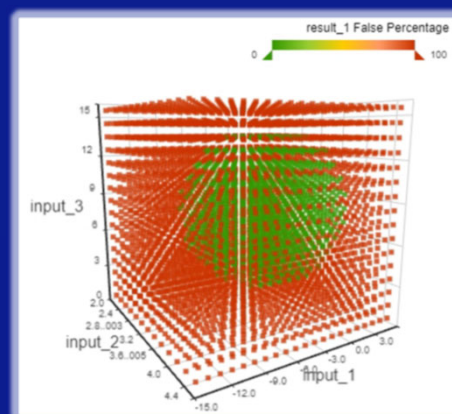
2. Create test job to execute the test conditions



2D Shmoo

(result_1 vs input_1, input_2)

+ input_3



3D Shmoo

(result_1 vs input_1, input_2, input_3)

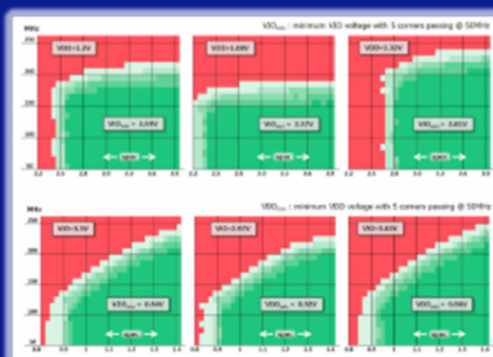
Analysis result with Shmoo plot

- Support 2D and 3D
- Support overlay
- Support result filter

Variable Selection

• Traditional way

Read lots of Shmoo plots



- Require a lot of effort
- Hard to find high dimensional dependency

• Variable Selection

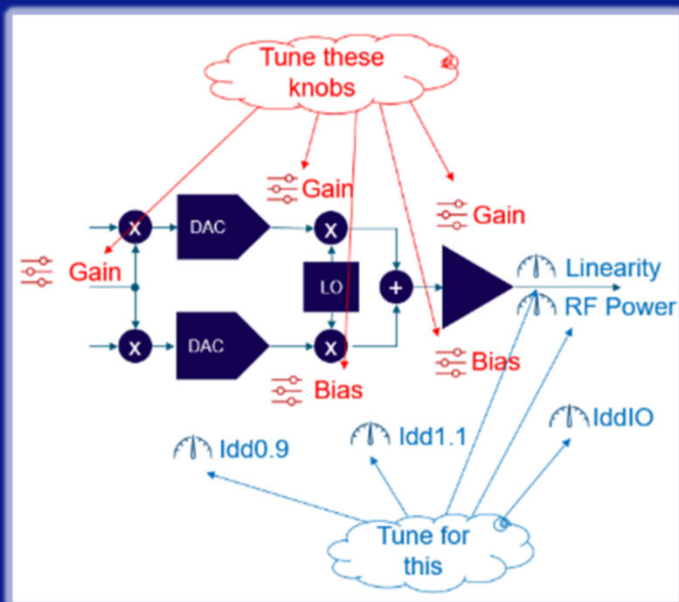
For a given target variable

... and a list of candidate variables

... find the most influential subset

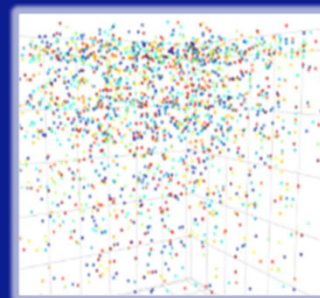


Automatic Tuning

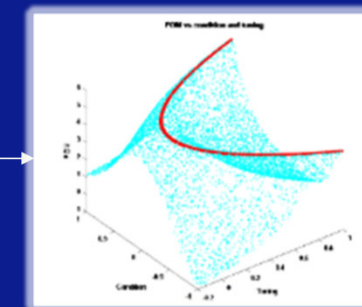


Balance between multiple tasks:

- Tradeoff between multiple goals
- Tuning multiple knobs in one time
- Fit for all allowed operating conditions

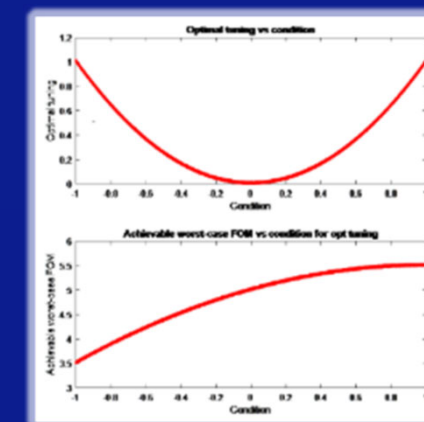


Multi-dim training data



Performance model

1. Transform goals to measurable data
2. Build model with maximized margin
3. Evaluate achievable performance
4. Predict best tuning law



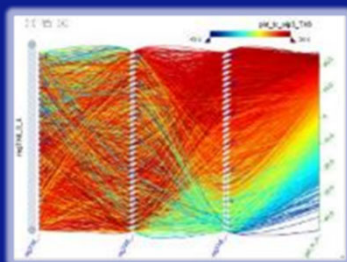
Predicted tuning law + achievable figure of merit

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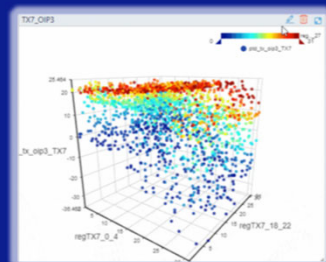
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Visual analytics

Over 20 types of plots



Parallel Coordinates Plot



3D Scatter



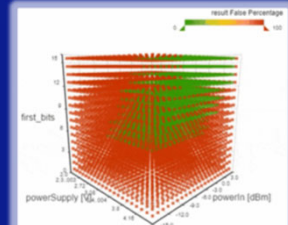
Box Plot



Results Distribution



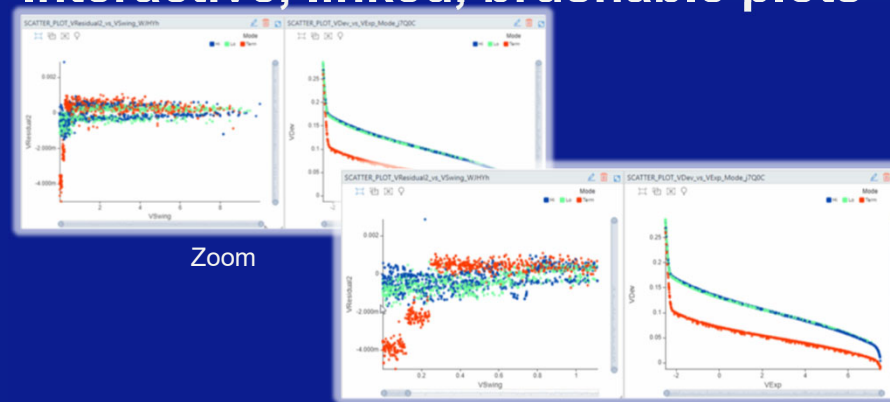
Error Bar Matrix



3D Shmoo



Interactive, linked, brushable plots



Zoom

Brush over plots

Large data support

Common plot rendering solution:

- 10k points > 3s
- 100k points: out of memory

Our rendering solution:

- ✓ 10 times faster
- ✓ Feature optimized aggregation



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Result verification & report

Verify if the tuning prediction matches to reality

Tune with the collected test results

Visualize tuning prediction

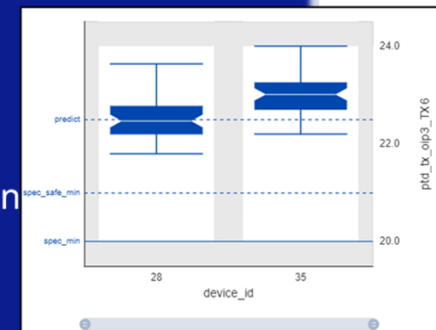
Generate new inputs from prediction

Execute on multiple devices

Compare new results with prediction

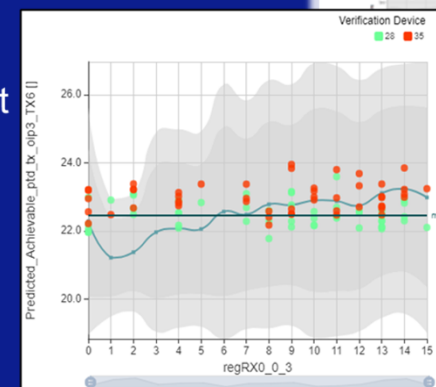
Summary view:

- Per device result statistic box
- Marker line of prediction
- Marker line of user expectation



Detail view:

- Frontend dots: verification test results
- Backend band: prediction (y axis) vs condition (x axis)



Tuning Report
2022-07-22

Device: [Device ID]

Number of tested devices: 2 device_id: 28, 35

By finding the best settings of [param, value, unit, range, unit, range]

Param	Value	Unit	Range
param1	1.0	1.0	1.0
param2	1.0	1.0	1.0

Number of tested devices: 2 device_id: 28, 35

Param	Value	Unit	Range
param1	1.0	1.0	1.0
param2	1.0	1.0	1.0

Practice in PSV

- TX independent 8 channels, each 3 vars
RX independent 4 channels, each 2 vars

- 1 Voltage

Expect:

- Max IIP3 and OIP3 for each channel
- Determine whether the voltage has impact on the IP3 or not

(TX)
45 hours later

9 hours later
(RX)

- Provide best setting for TX 8 Chan and RX 4 Chan

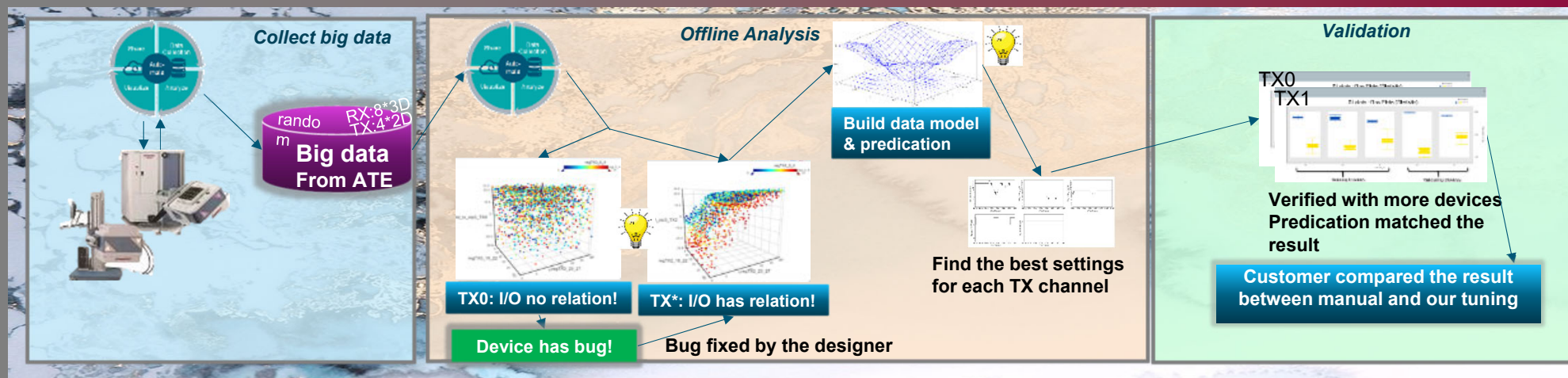
- Improved OIP3 by **0.68~2.44 dB** for TX 8 channels

- RX: Found devices bugs for RX0

Different from designer's information, the actual results cannot find the correlation.

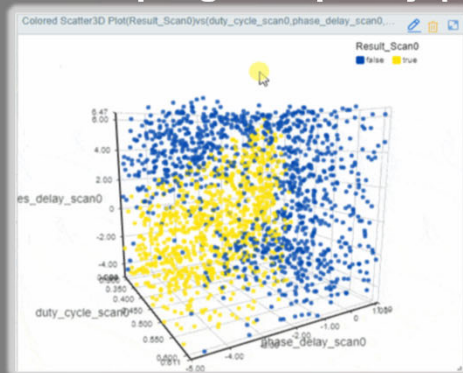
Improve IIP3 by **1.04dB** for RX other 3 channels

- Help customer to understand their devices



Practice in Production

Product Test program quality (High Speed)

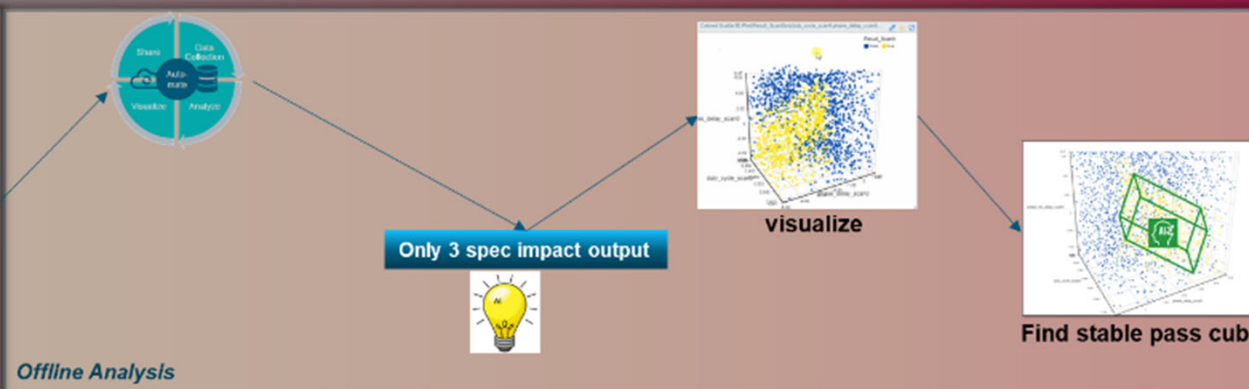


5 adjustable timing/level specs

Always fail on a Scan test suite >80MHz

8 hours later

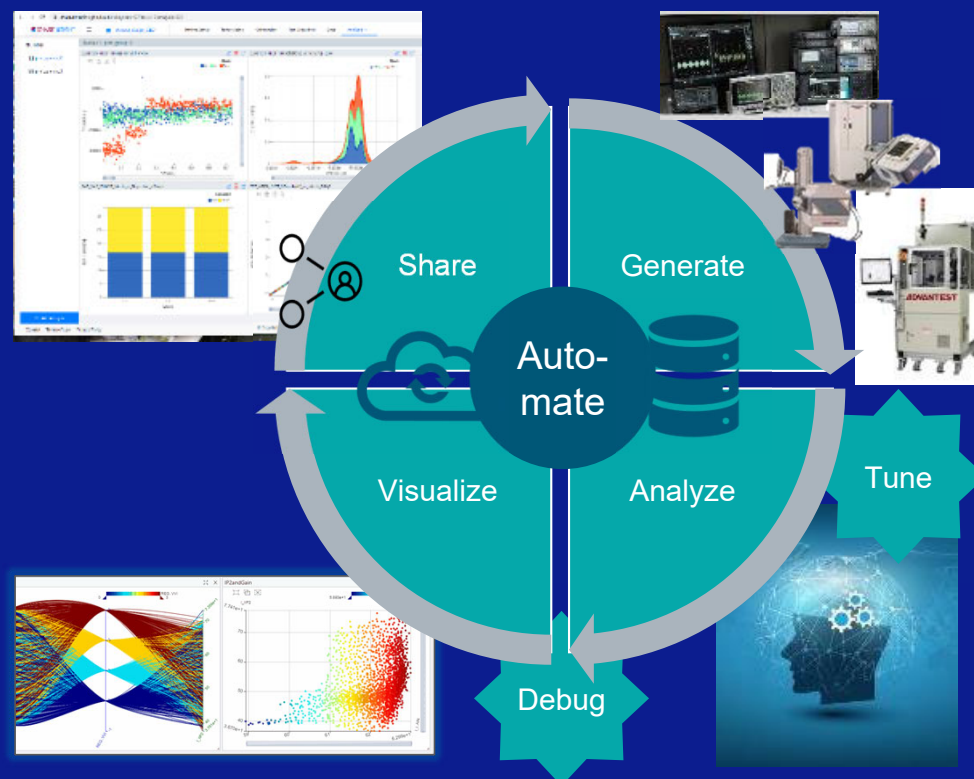
Find most important spec var and optimally set them
Stable pass on that test suite even >100MHz



8 hours to make TP stable pass on high frequency

Summary

For RF / mixed-signal / HSIO / PLL, system-level digital, ...



TTM

- Automate tedious tasks
- Faster insight / debug
- Efficient communication



Quality

- Comprehensive, quantified coverage



Yield

- AI-based tuning improves yield or performance / power consumption

Integrated workflow automation based on data-driven, AI-powered analysis methodology



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17

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