Solido
Machine Learning for Engineering

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EDPS 2017

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Solido Overview

Founded: 2005

Focus: Variation-Aware Design and Characterization Software

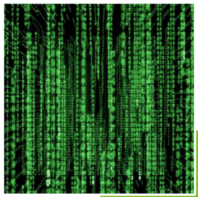
Application Areas:

Memory – Standard Cell – Custom Digital – Analog/RF

- Solido's machine learning technologies provide disruptive customer benefits
- Integration with all major software tools and PDKs
- Trusted by top semiconductor companies

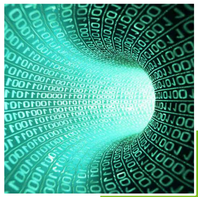
Published customer case studies from:

Machine Learning for Engineering Applications
Challenges and Solutions



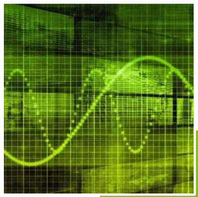
Massive data

- Optimized streaming parsers
- Parallelizable algorithms
- Massively scalable solutions



Complexity

- Advanced supervised learning
- Big toolbox of modeling technologies
- Smart filtering



Correctness

- Accuracy-aware modeling
- Active learning
- Self-verifying algorithms

Machine Learning for Engineering Applications: Massive Data

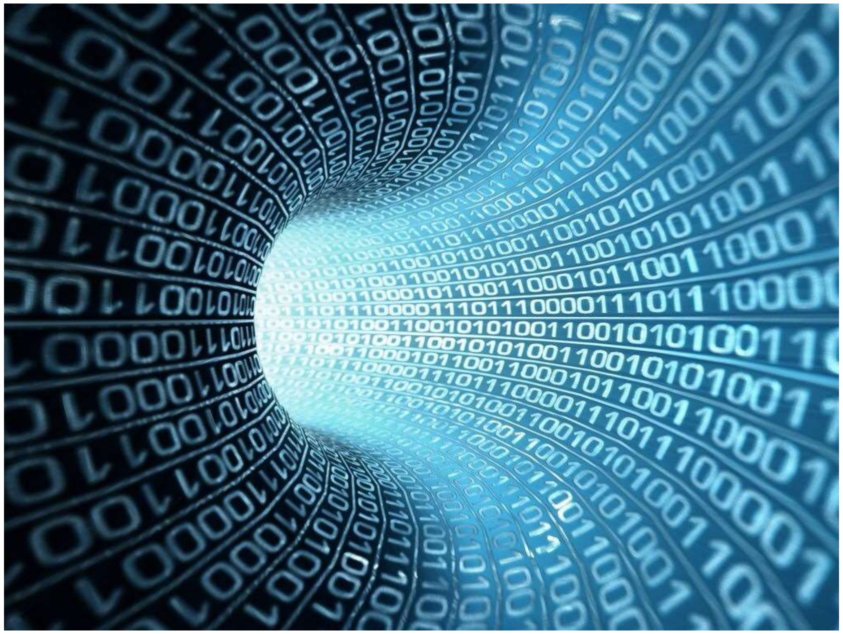
- Challenge:
  → High streaming data rates and massive data archives

- Key technologies:
  → *Optimized streaming parsers*
  → *Parallelizable algorithms*
  → *Efficient and scalable cluster management*
  → *Automated recovery and repair*
  → *Big data debugging*

Machine Learning for Engineering Applications: Data Complexity

- Challenge:
  - → High dimensionality, high-order interactions, discontinuities, non-linearities

- Key technologies:
  - → *Design of experiments tech*
  - → *Advanced supervised learning*
  - → *Intelligent screening and filtering*
  - → *Outstanding benchmarking infrastructure*
  - → *Big toolbox with lots of experience with tools*



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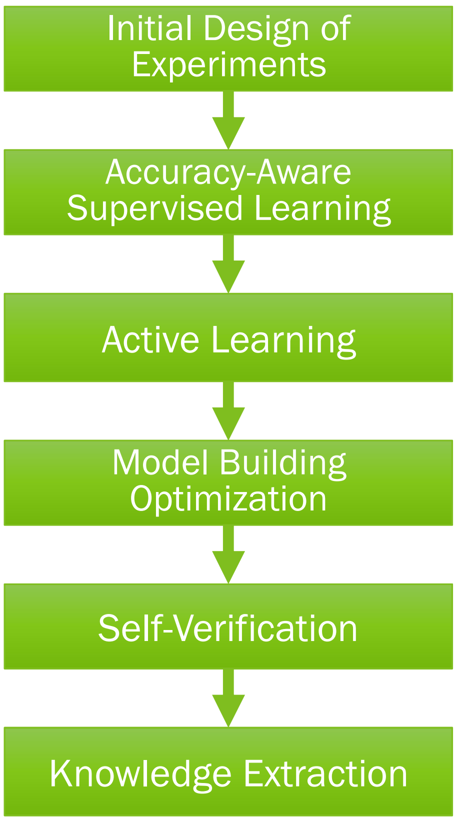
Machine Learning for Engineering Applications: Correctness

- Challenge:
  → Engineering problems require the *right* answer

- Key technologies:
  → *Accuracy-aware modeling*
  → *Active learning*
  → *Self-verifying algorithms*
  → *Extensive internal benchmarking infrastructure*
  → *Customer-side benchmarking infrastructure*

Solido’s ML for Engineering Technology: Overview



- Solido’s generic ML for engineering flow
- Used for solving a variety of different problems
- Basis for many of Solido’s tools in the simulation space:
  - → Fast PVT
  - → Statistical PVT
  - → High-Sigma Monte Carlo
  - → Hierarchical Monte Carlo
  - → PVTMC Verifier
  - → Cell Optimizer

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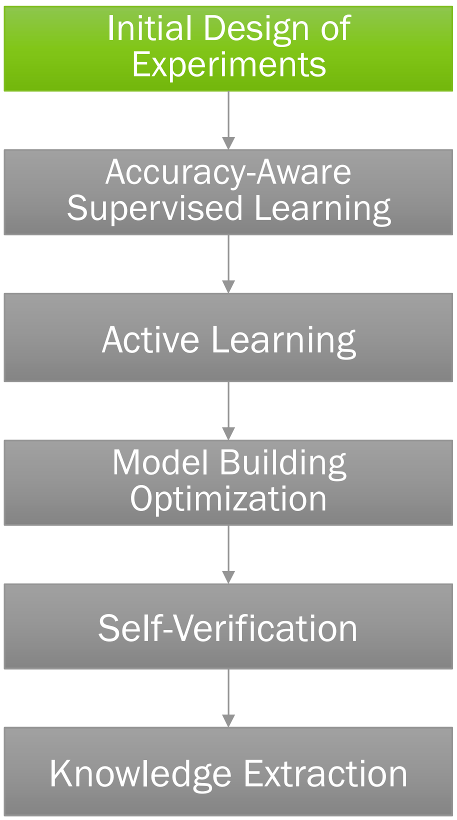
Solido's ML for Engineering Technology: Basic Fast PVT Example



- We know nothing about the circuit – need some data
- We have a set of conditions to explore; e.g.:
  - → Temp: -40, 25, 80, 125, 150
  - → Vdd: 0.52, 0.65, 0.8, 0.92, 1.1, 1.3
  - → Process: FF, SS, TT, FS, SF
  - → 150 combinations
- We want to cover the space as efficiently as possible; we use design of experiments to figure that out; e.g.:
  - → Independent sweeps: 14 simulations
    - Gives detailed main effects
  - → Fractional factorial: 11 simulations
    - Reveals interaction effects between variables
- E.g. simulated just 25/150 simulations, and we have a good basis for model building

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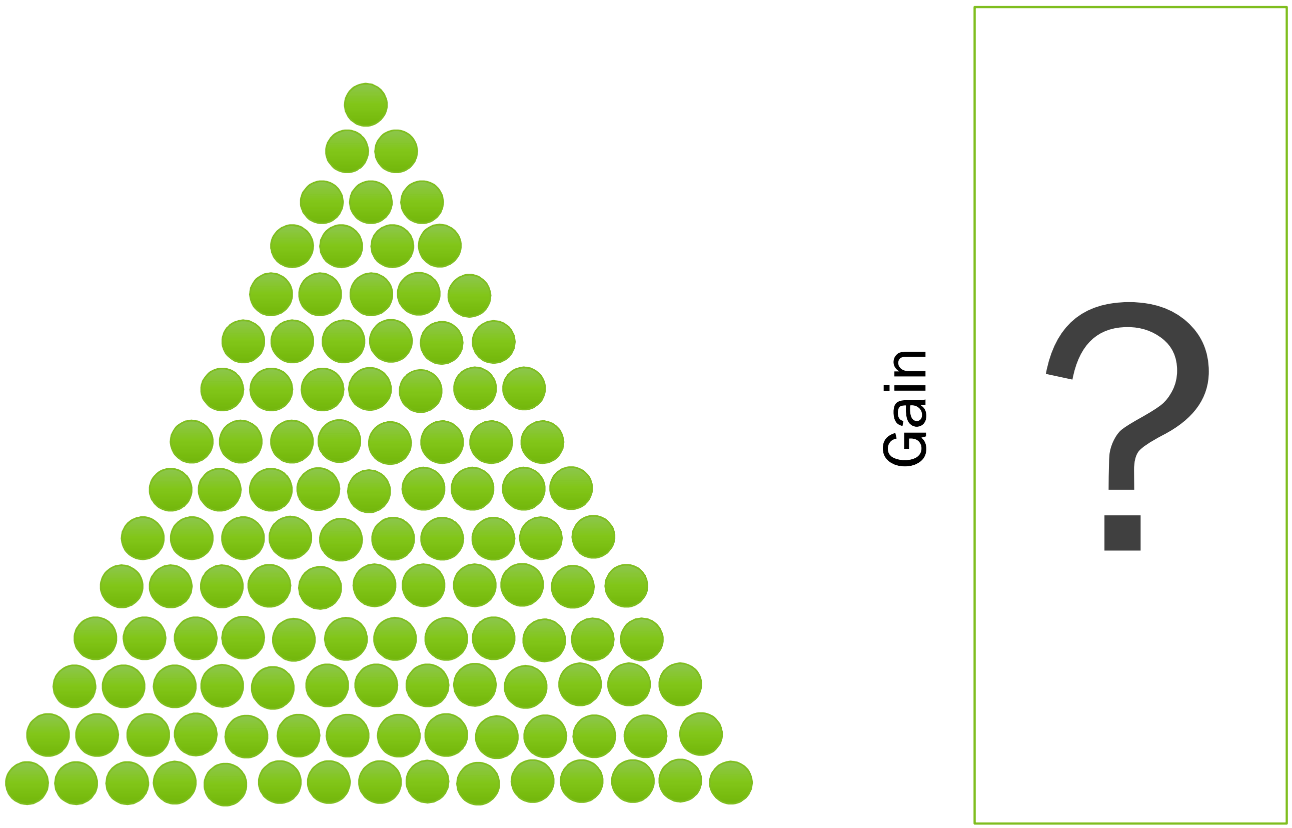
Solido's ML for Engineering Technology: Basic Fast PVT Example

- Initial Design of Experiments
- Accuracy-Aware Supervised Learning
- Active Learning
- Model Building Optimization
- Self-Verification
- Knowledge Extraction



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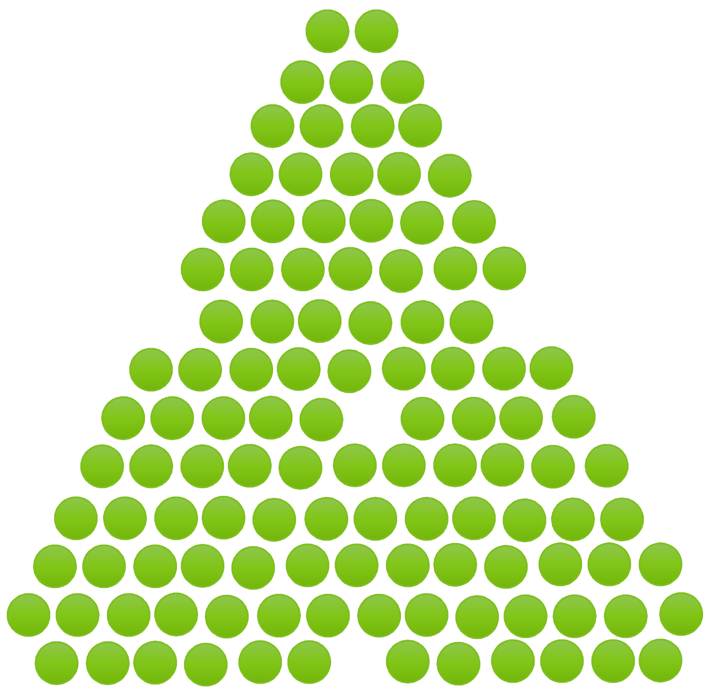

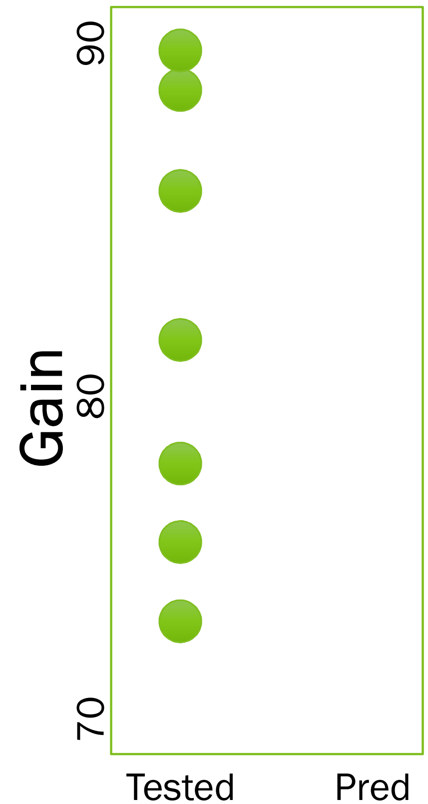

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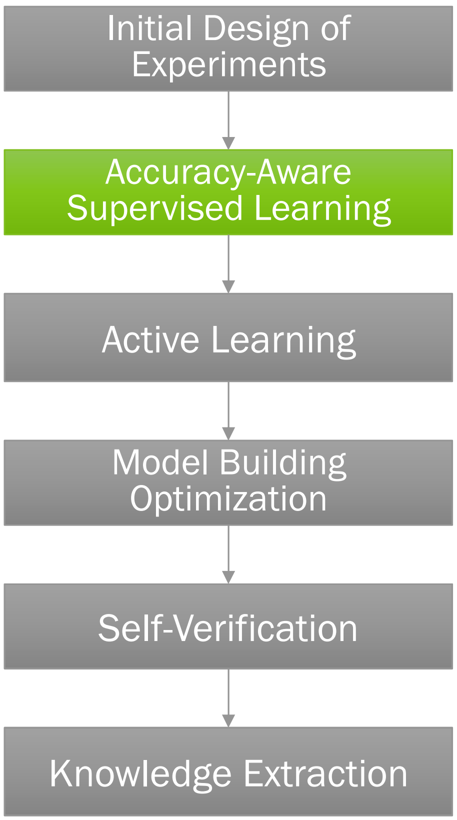

- Build an accuracy-aware model the full space; e.g.:
  - → Use the 25 simulated points that cover independent effects and interaction effects
  - → For each measurement (e.g. gain, bw), build a regression model
  - → Model must capture:
    - Non-linearities
    - Discontinuities
    - Interactions (e.g. temp * vdd effect)
    - Accuracy (i.e. the +/- on the estimated values)
- Use that model to predict the remainder of the values
  - → E.g. From 25 simulated values, predict the remaining 100
- Now we have accuracy-aware predictions for all values

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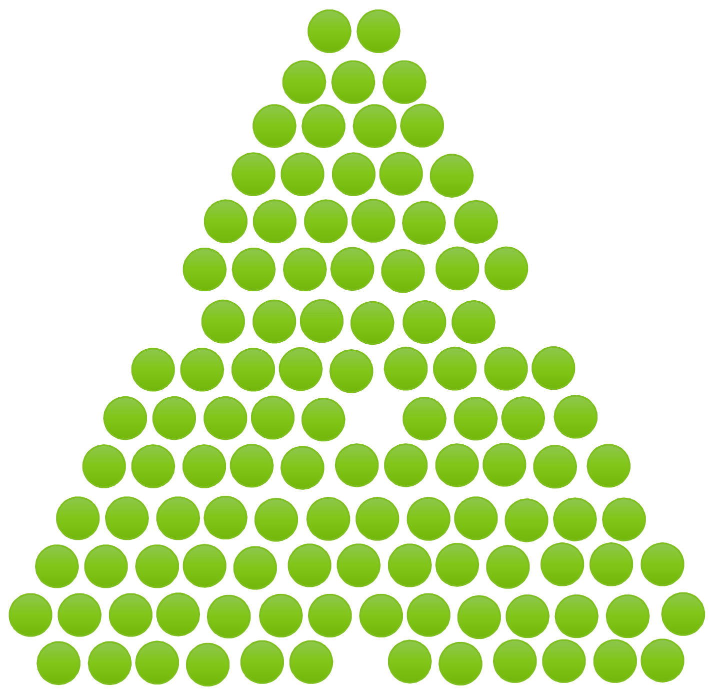
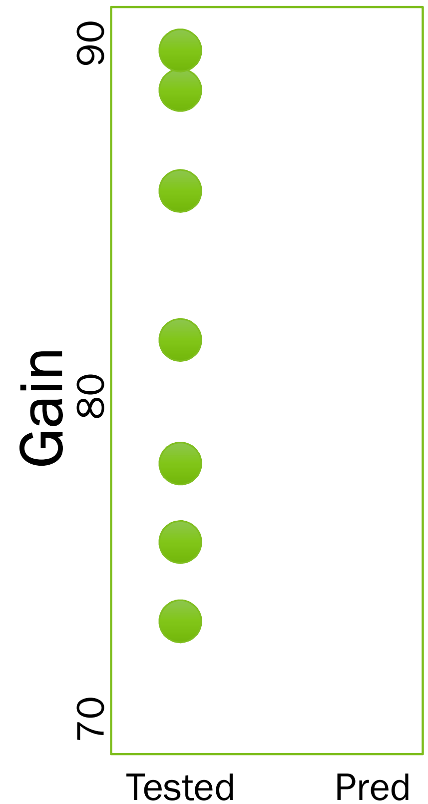
Solido's ML for Engineering Technology: Basic Fast PVT Example

- Initial Design of Experiments
- **Accuracy-Aware Supervised Learning**
- Active Learning
- Model Building Optimization
- Self-Verification
- Knowledge Extraction





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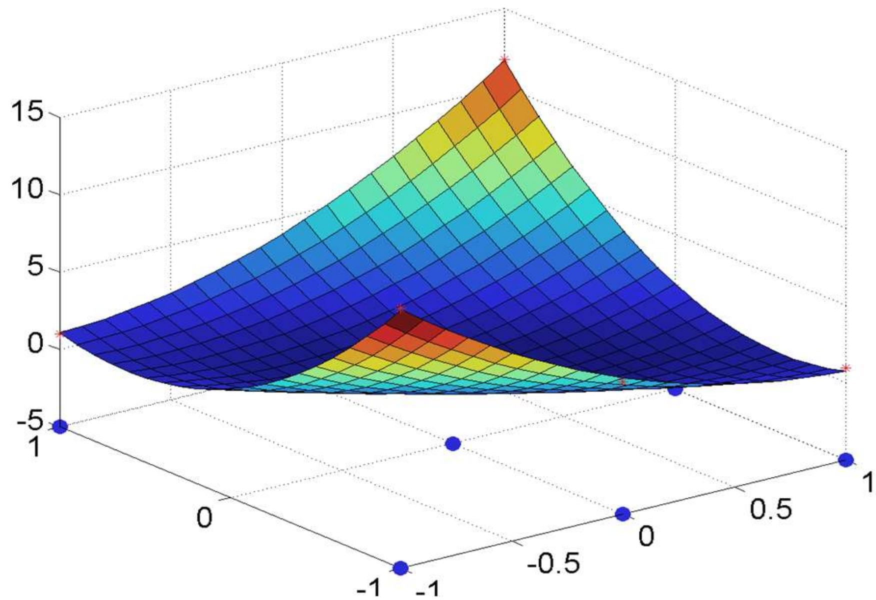

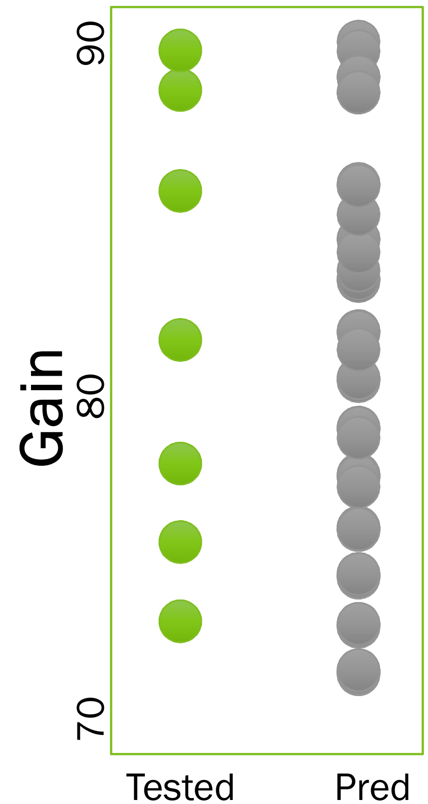

Solido's ML for Engineering Technology: Basic Fast PVT Example

Initial Design of Experiments ↓ Accuracy-Aware Supervised Learning ↓ **Active Learning** ↓ Model Building Optimization ↓ Self-Verification ↓ Knowledge Extraction

- We want to now focus on the area of interest and get perfect results there
- E.g. For gain, we want to simulate the lowest gains
- Since the model is accuracy-aware, we can simulate any gain that might have the lowest value
- We can also rebuild models after every result comes in to tighten accuracy on other estimates – this saves simulation
- E.g.: We may simulate another 5/125 worst case gain candidates
- The result is perfect SPICE accuracy in the worst case

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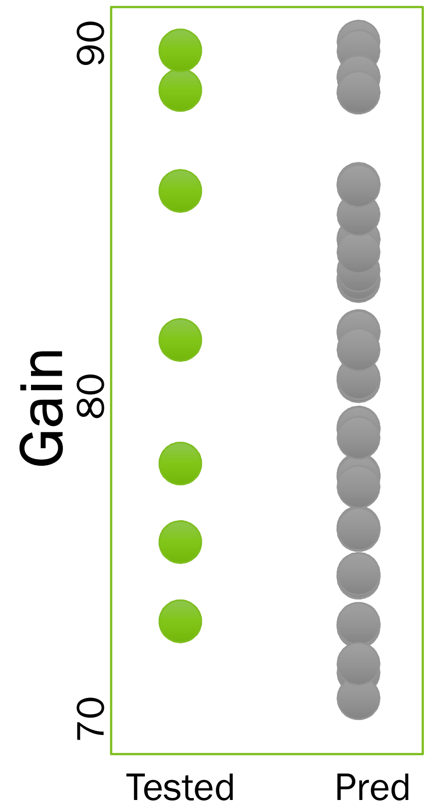
Solido's ML for Engineering Technology: Basic Fast PVT Example

1. Initial Design of Experiments
2. Accuracy-Aware Supervised Learning
3. **Active Learning**
4. Model Building Optimization
5. Self-Verification
6. Knowledge Extraction

Goal:
Perfect accuracy for worst cases
Simulate those!



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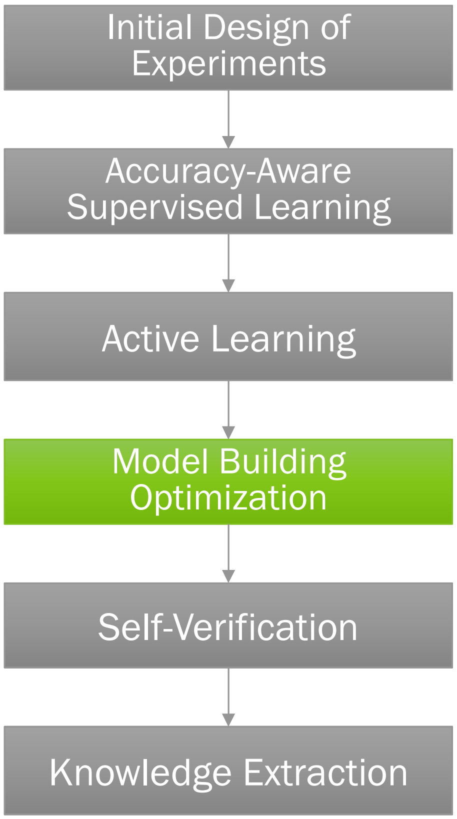
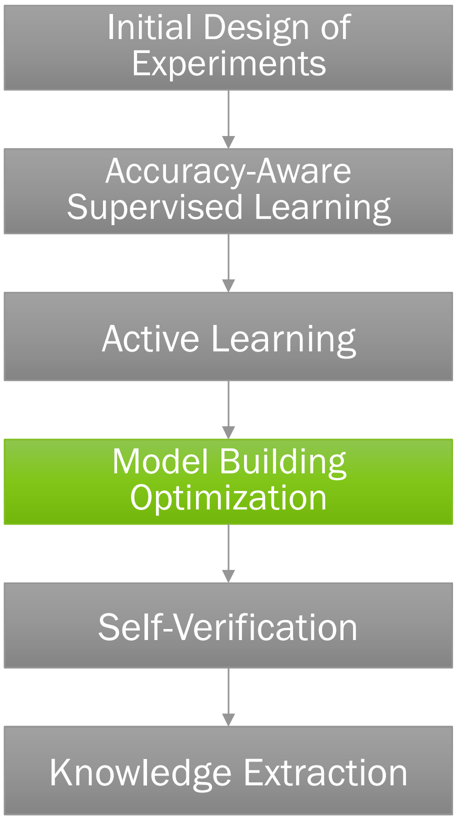
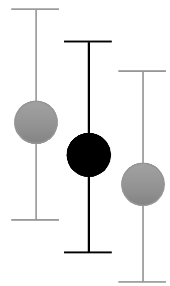
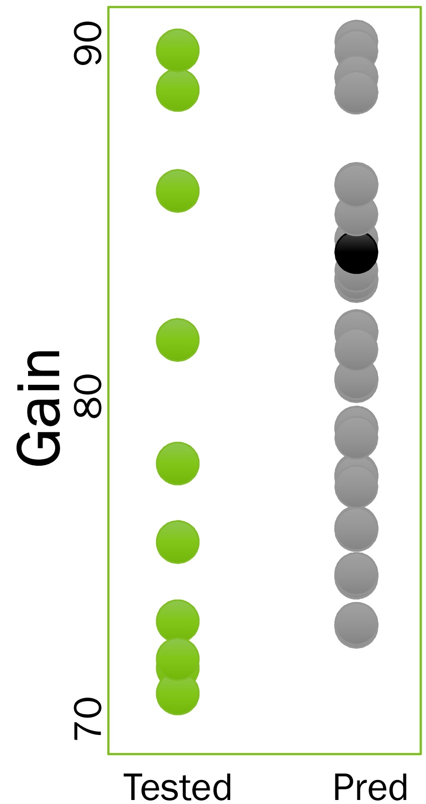


- We now have perfect results for worst cases, but we also want to ensure high-quality estimates through the rest of the range
- Since the model is accuracy-aware, we can simulate anywhere the model is too loose:
  - → Target sparseness
  - → Target areas where there is a lot of change
- This tightens up all predictions
- E.g. we might run another 5/125 simulations at areas with the loosest model accuracy to tighten up the space

Solido's ML for Engineering Technology: Basic Fast PVT Example







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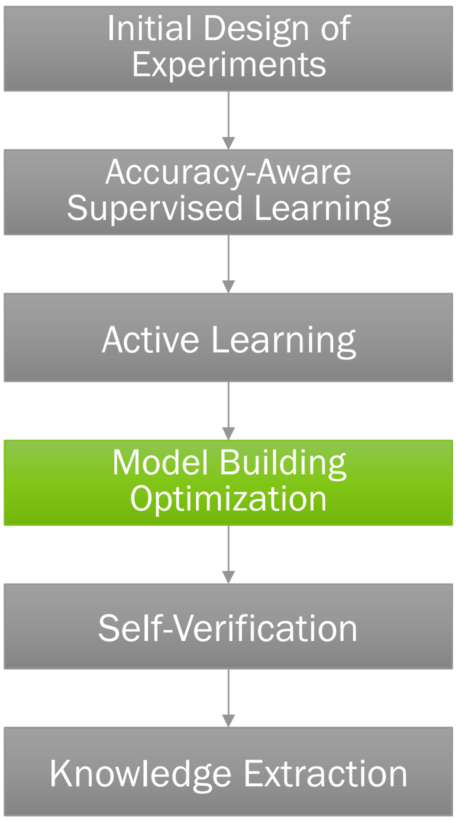

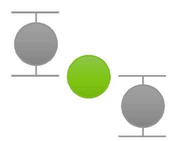

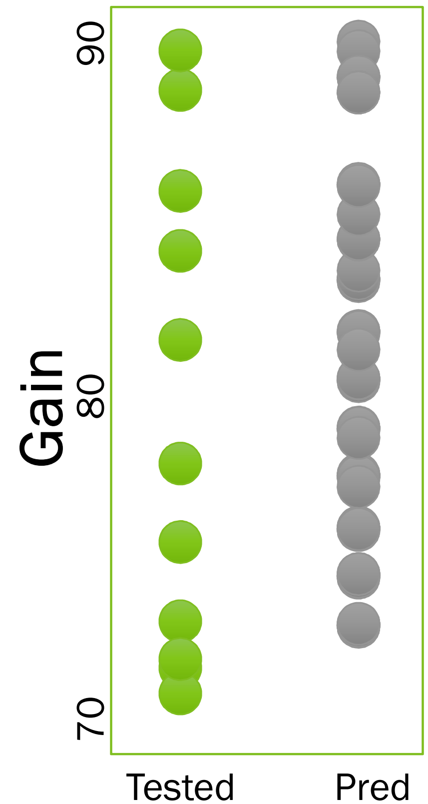

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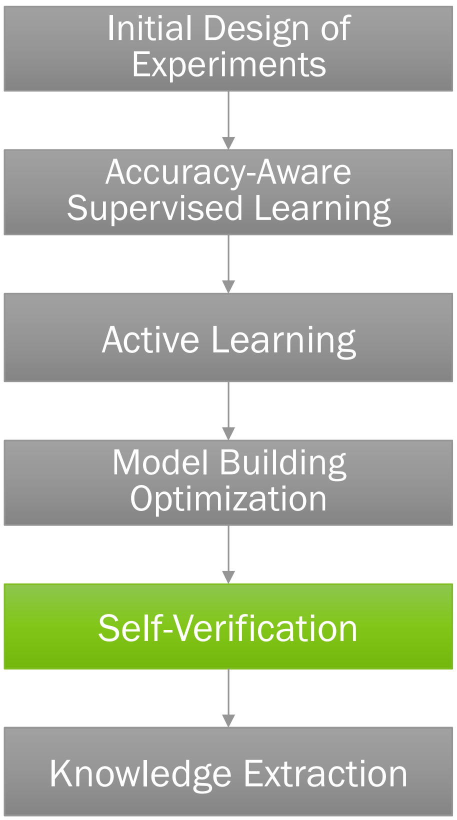
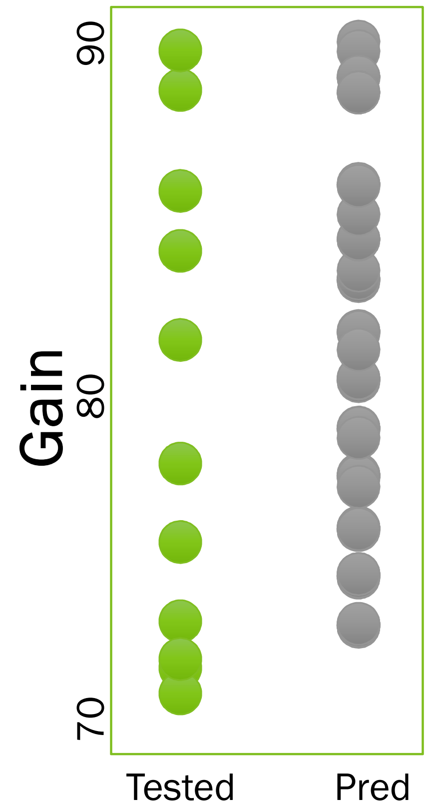


- We now have:
  - → Perfect SPICE accuracy in the tail
  - → Good estimates through the rest of the space
- …and now we need to prove it to the engineer
- We show clearly that the model's predictions and the actual simulation results line up
- We can also run additional verification simulations to prove that the model is accurate throughout the remainder of the space
  - → E.g. run 5 more worst-case gain predicted samples and show that the predicted value and the actual value are very close, and that the values are no worse than the estimated worst case
- In the end, we run 40/150 simulations, have perfect accuracy in the worst cases, have good accuracy throughout, and we have given the designer confidence in the rigor of the approach.

Solido's ML for Engineering Technology: Overview

- Initial Design of Experiments
- Accuracy-Aware Supervised Learning
- Active Learning
- Model Building Optimization
- **Self-Verification**
- Knowledge Extraction



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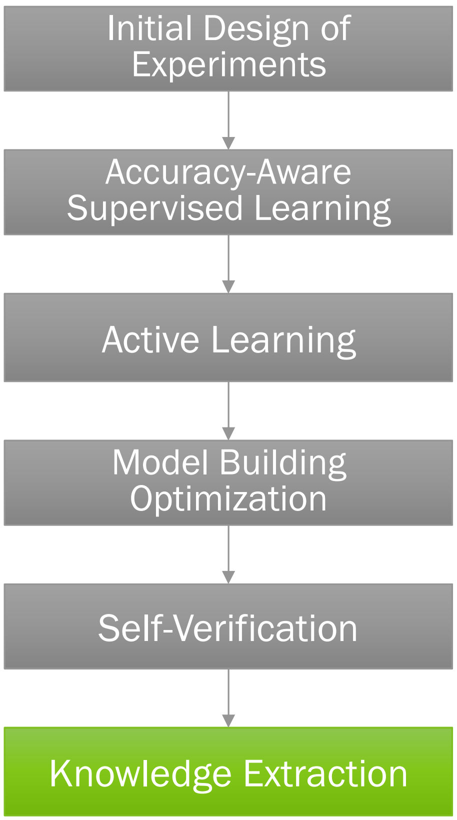

- Next, the designer may want to know exactly what caused performance shifts:
  - → Temperature?
  - → Vdd?
  - → Process corner?
  - → A combination?
- The knowledge extraction phase pulls out useful information for the designer about what caused shifts
  - → E.g. Show that the interaction of temp*vdd was the dominant cause of shifts, and let designers surf the response surface to understand exactly how they interact

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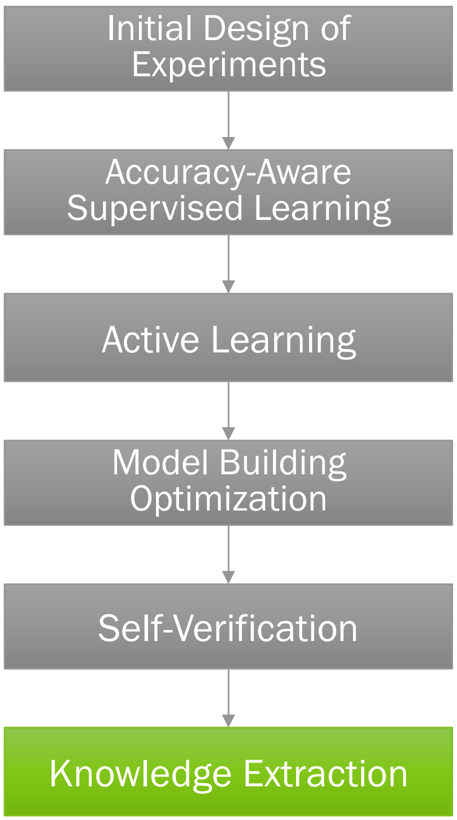

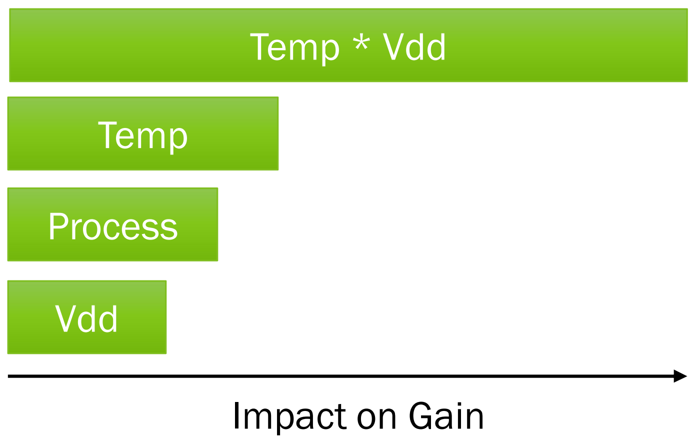

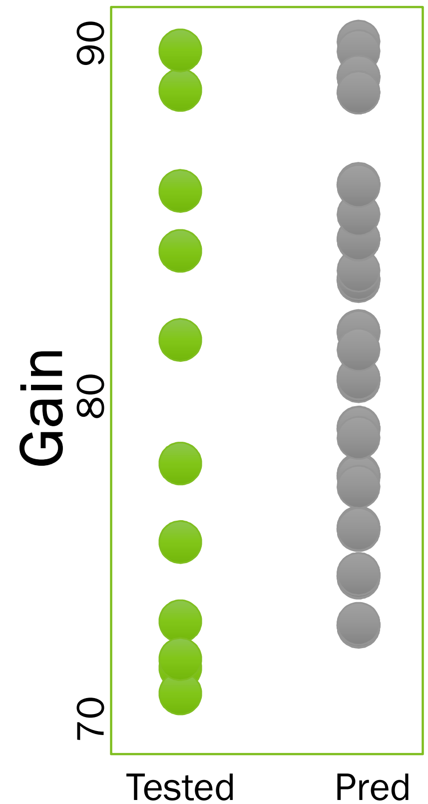

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Solido ML Techniques:
Key Benefits

- Solido has been applying ML to simulation and characterization for 12 years
- Key benefits:
  - → Full coverage of worst-case PVT conditions 2-50X faster than brute-force
  - → Accurate 3-sigma coverage 10X faster at 1 PVT condition, and >100X faster across multiple PVT conditions at once
  - → Accurate high-sigma verification with the same accuracy as millions or billions of Monte Carlo samples in just 1000s of simulations
  - → Fully automated cell-level variation-aware circuit optimization
  - → Knowledge extraction pinpointing causes of variation
  - → 50% faster timing model (.lib) characterization
  - → Monte Carlo accurate statistical timing model generation, >1000X faster than Monte Carlo

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Solido Product Families
Disruptive Solutions Built On Solido's ML For Engineering Tech

Solido Variation Designer

Accurate & fast variation-aware design and verification of memory, standard cell, and analog/RF

Solido ML Characterization Suite

Accelerates characterization of Standard Cells, Memory, and I/O with Machine Learning

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Solido Variation Designer – Product Overview

Solido Variation Designer

High-Sigma Monte Carlo
MC & SPICE accurate high-sigma verification

Hierarchical Monte Carlo
Full-chip memory statistical verification

PVTMC Verifier
Unprecedented coverage and speed for PVT & MC

Fast PVT
2-50X faster verification across corners

Fast Monte Carlo
Fast and accurate 3σ verification & design

Cell Optimizer
Fast and accurate optimization of std. cells

DesignSense
Variation-aware design sensitivity

Run Corners
Fast design iteration & debugging

PDK Interface ↕ TSMC, GLOBALFOUNDRIES, Samsung, UMC, TowerJazz, Custom Internal PDKs, Others

Parallel Analysis Interface ↕ HSPICE®, CustomSim™, FineSim™, Spectre®/APS/XPS/RF, Eldo®, Analog FastSPICE™, GoldenGate, SmartSpice, Custom simulators

Design & Test Interface ↕ Netlist or Virtuoso® ADE

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Solido ML Characterization Suite – Product Overview

Solido ML Characterization Suite

Predictor
Reduces characterization runtimes by 30-70%

Statistical Characterizer
Fast, Monte Carlo accurate LVF/AOCV/POCV generation

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Solido ML Techniques Per Product

	Design of experiments	Supervised learning	Active learning	Knowledge extraction	Parameter filtering	Clustering	Density estimation	Deep learning	Solido proprietary
Variation Designer									
Fast PVT	✓	✓	✓	✓					✓
Fast Monte Carlo				✓			✓		✓
Cell Optimizer	✓	✓	✓		✓				✓
Fast DesignSense	✓	✓		✓					✓
Statistical PVT	✓	✓	✓	✓					✓
PVTMC Verifier	✓	✓	✓	✓	✓	✓	✓		✓
High-Sigma Monte Carlo	✓	✓	✓	✓	✓		✓	✓	✓
Hierarchical Monte Carlo	✓	✓	✓	✓	✓		✓	✓	✓
ML Characterization Suite									
Predictor	✓	✓	✓	✓					✓
Statistical Characterizer	✓	✓	✓		✓	✓			✓

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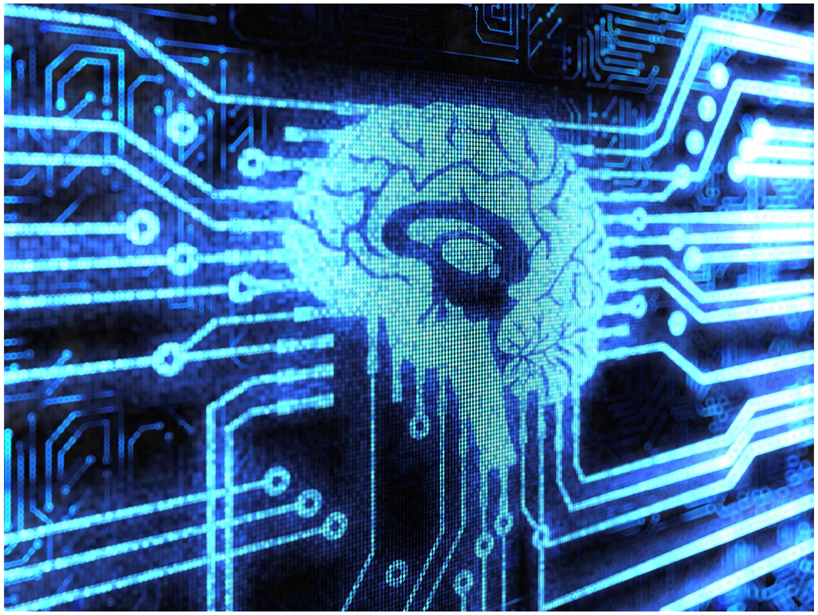
Solido ML Labs

- Opportunity:
  - → Many EDA problems can be solved with ML based approaches
  - → Solido ML Labs is a platform for bringing up new ML based technologies to solve new problems
- Approach:
  - → *Solido partners with lead customer*
  - → *Solido+partner carefully define the problem*
  - → *Solido prototypes a solution and runs a proof-of-concept study using partner production data*
  - → *If successful, Solido productizes the solution working with partner company*



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