Sept. 29, 2021| AKI FUJIMURA, CEO, D2S, Inc.

A general formula for deep learning success in semiconductor manufacturing

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Many Industries Have Had Deep Learning Success

So Why Does Semiconductor Manufacturing Seem Stalled?

There Have Been Many Papers

ASML

Canon

CENTER FOR DEEP LEARNING IN ELECTRONICS MANUFACTURING

D2S

Fraunhofer

HITACHI
Inspire the Next

imec

MYCRONIC

NuFlare

SIEMENS

life.augmented

SYNOPSYS®

TORAY
Innovation by Chemistry

TASMIT, Inc.

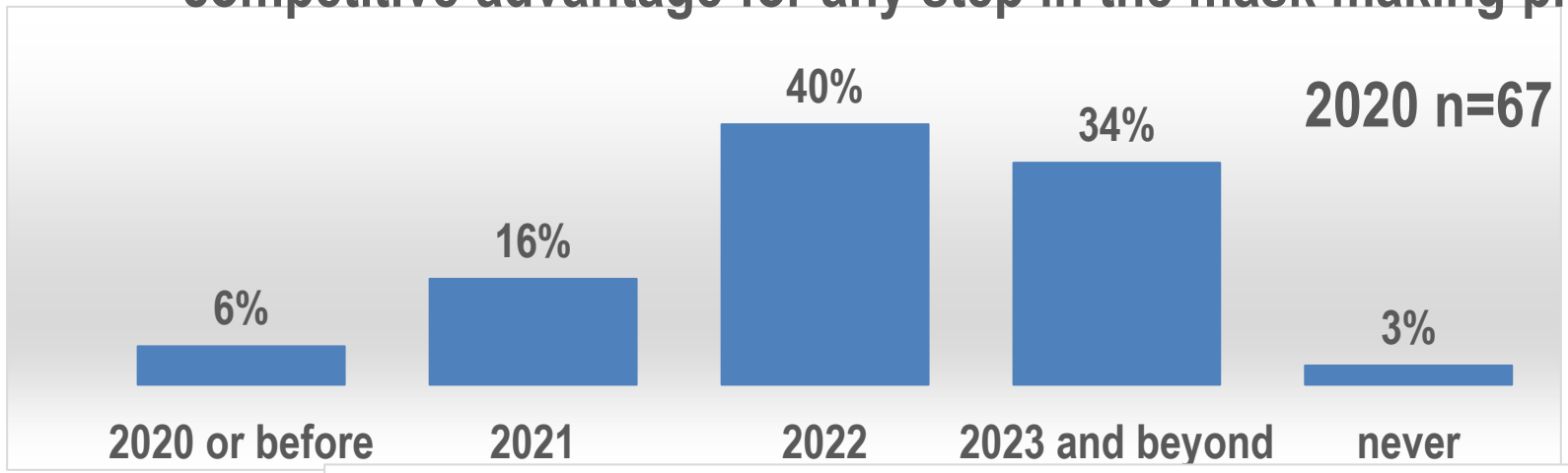
And yet…

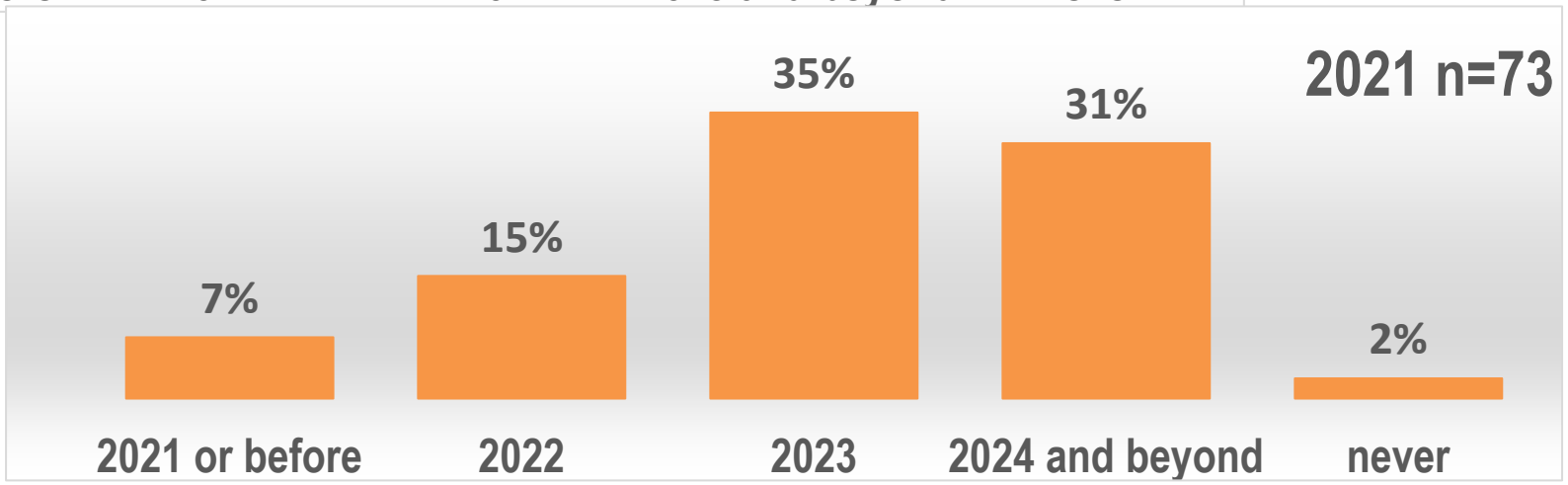
D2S

Deep Learning Predictions Shift to 2023 & Beyond

Only 22% say 2022 vs 62% in last year's survey

In the mask industry, when will capabilities based on deep learning become a competitive advantage for any step in the mask making process?

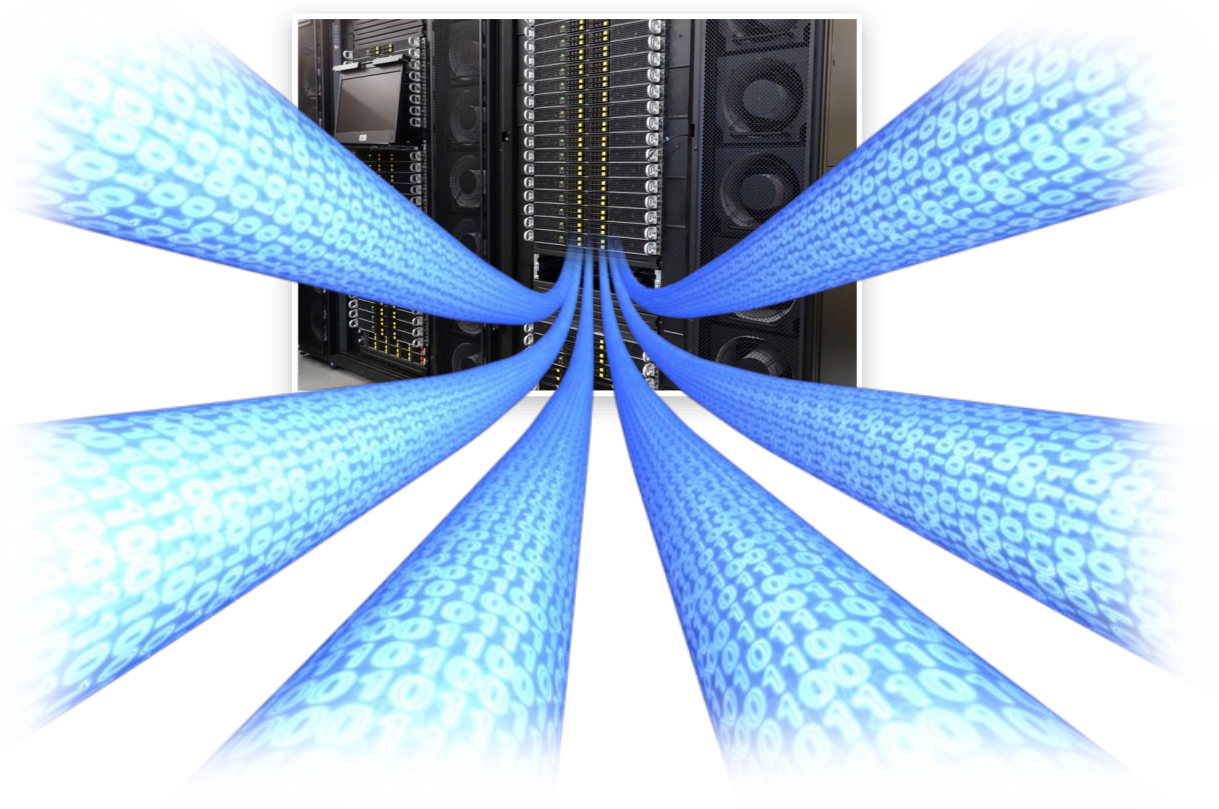




Answer choices expanded in 2021 survey – see X axis in two charts above

Prototype: Easy; Production: Hard

Doesn’t DL Need Data? We Can’t Get Data…



- DL is only as accurate as it’s trained to be = masses of data
- Data belongs to the customer
- Mask shops are good at not making too many samples of anomalous data

Simulation- and DL-based digital twins are essential!

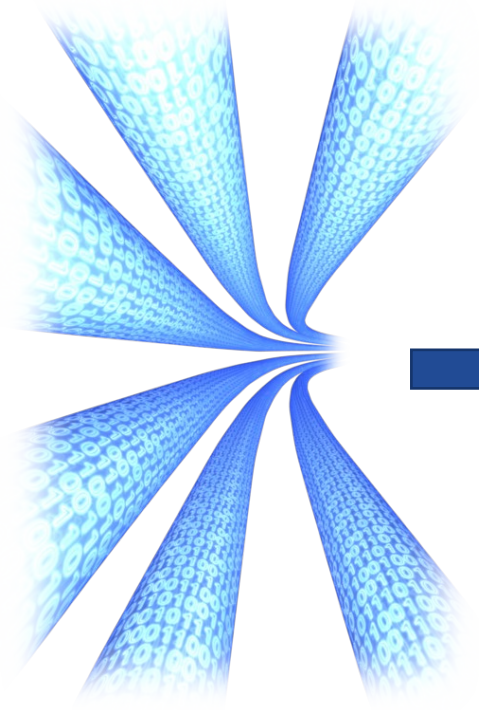
Can a Statistical Method Work for Mask Making?

Quality Target = “Better than human”

Quality Required > 7σ

The key is to apply DL carefully!

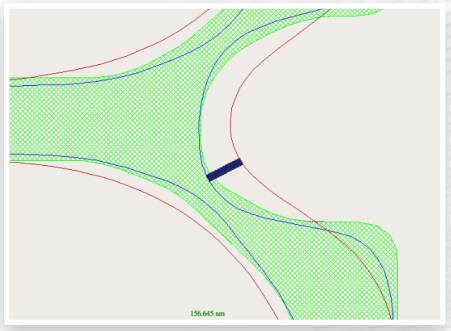
Can We Trust the Results?



Masses of data,
Including anomalous data

Properly bounded
DL network

Human experts



Analytical tools

Yes, with properly bounded networks and output checks

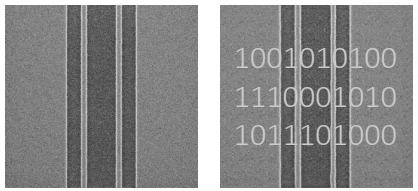
Essential Ingredients for DL Success

Executive sponsor with *long-term* commitment to DL

DL Experts

Immersion of talent

Domain Experts

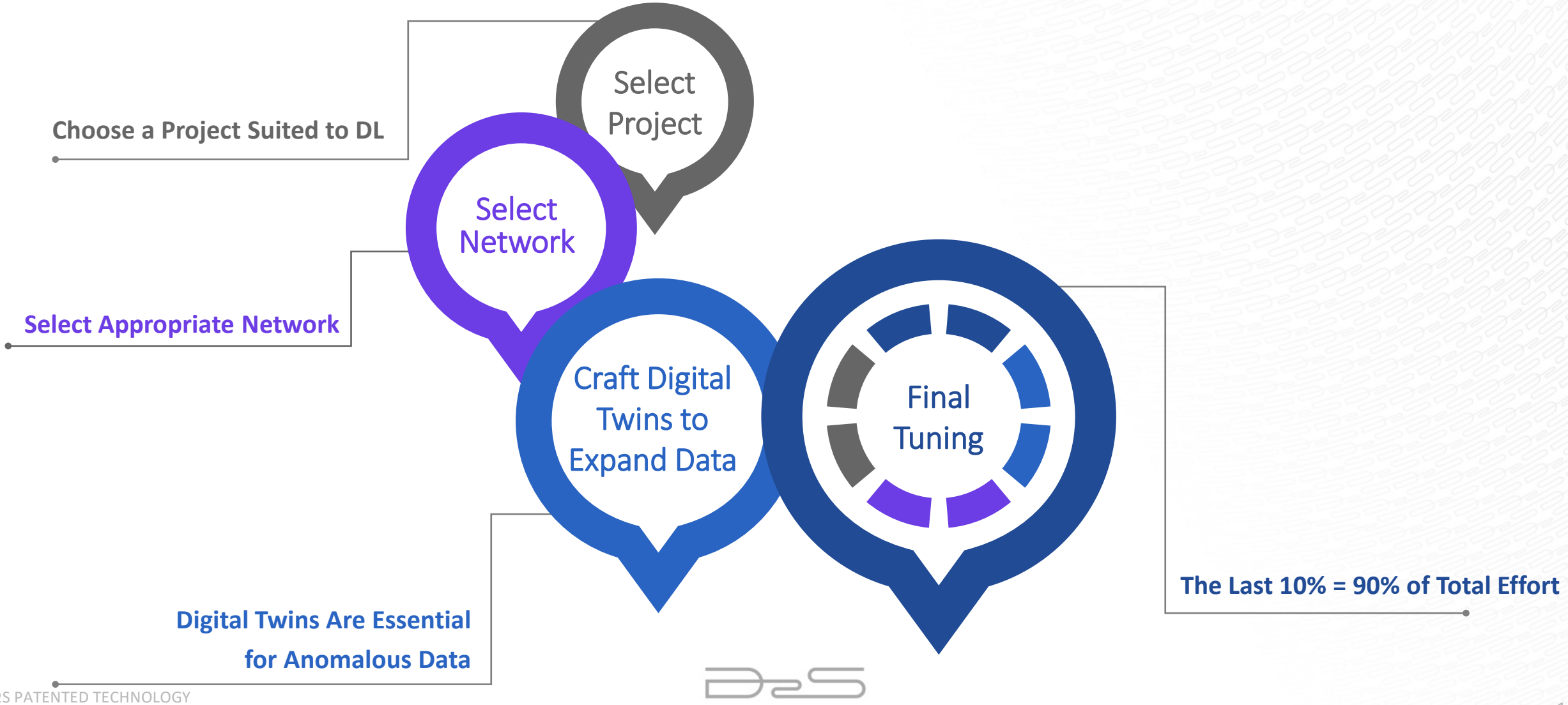


Actual SEM Digital Twin

Lots of data

PFLOPS of Computing

General Formula for DL Success in Semiconductor Manufacturing



Selecting the Right Projects

Not Suited to DL

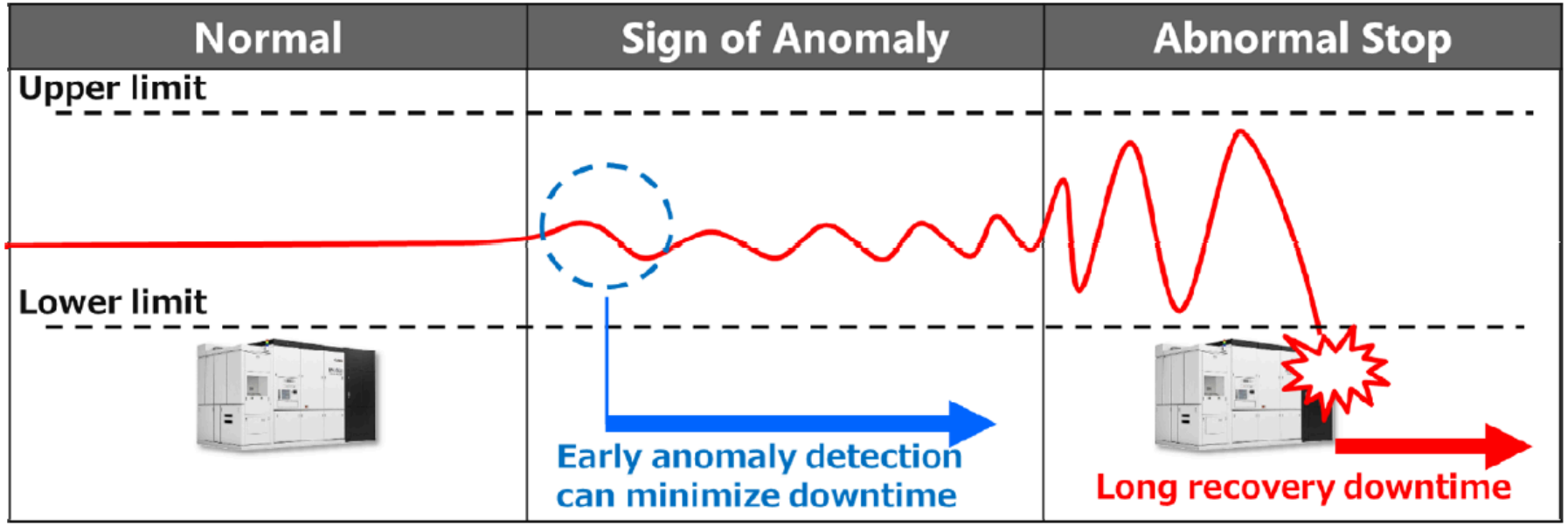
- DL-only constructive tools (ILT, MPC)
  DL is statistical: makes mistakes, though can be bounded
- eBeam or litho simulation
  Faster and more accurate analytically
- DL-only verification tools (MRC)
  DL is statistical: makes mistakes, though can be bounded

Good for DL

- Initial-condition acceleration for iterative optimization
- Estimations for other tools
- Prediction applications
- Categorization

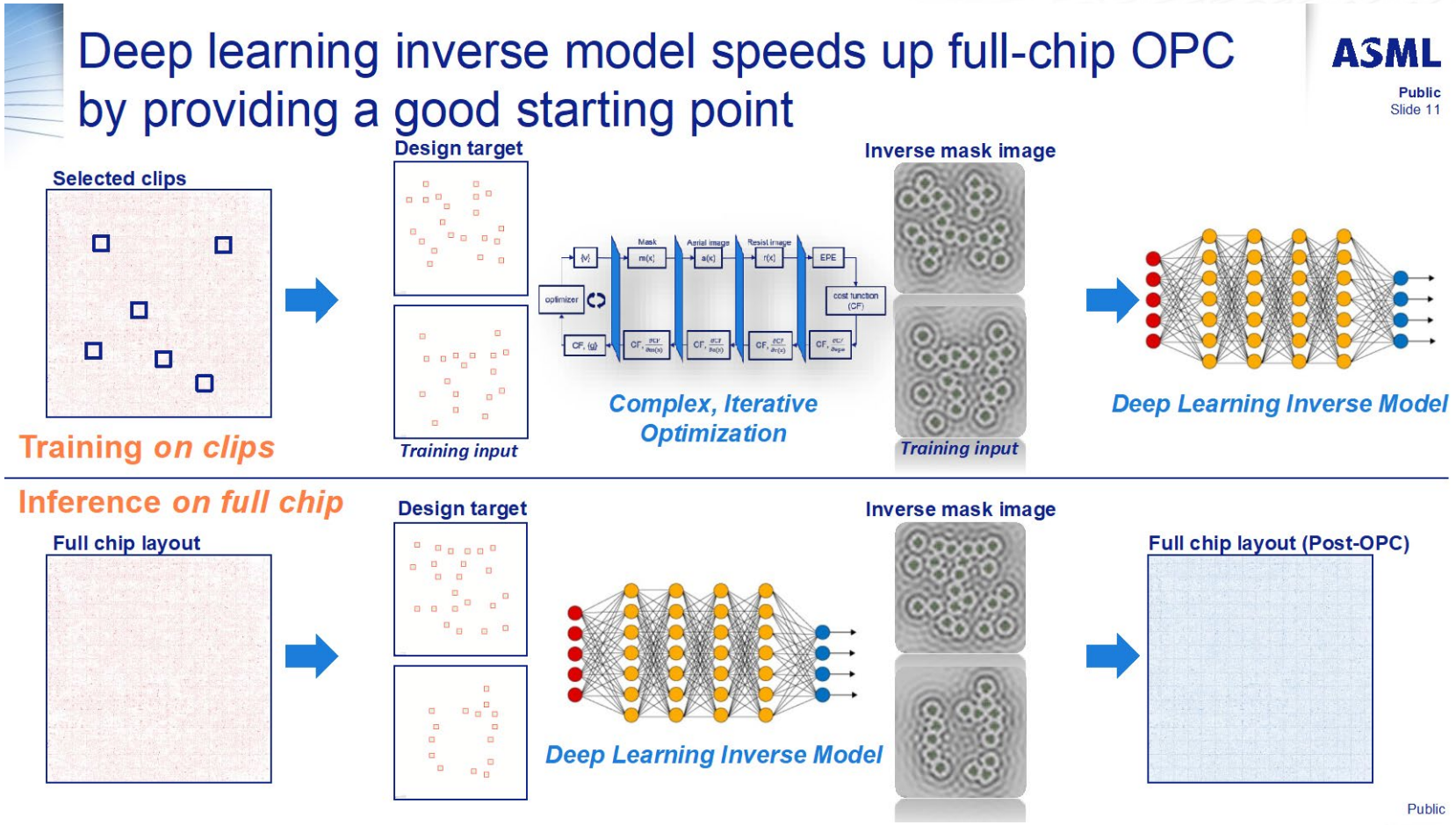
Good Choice for DL
Canon: Service Interval Prediction

Canon



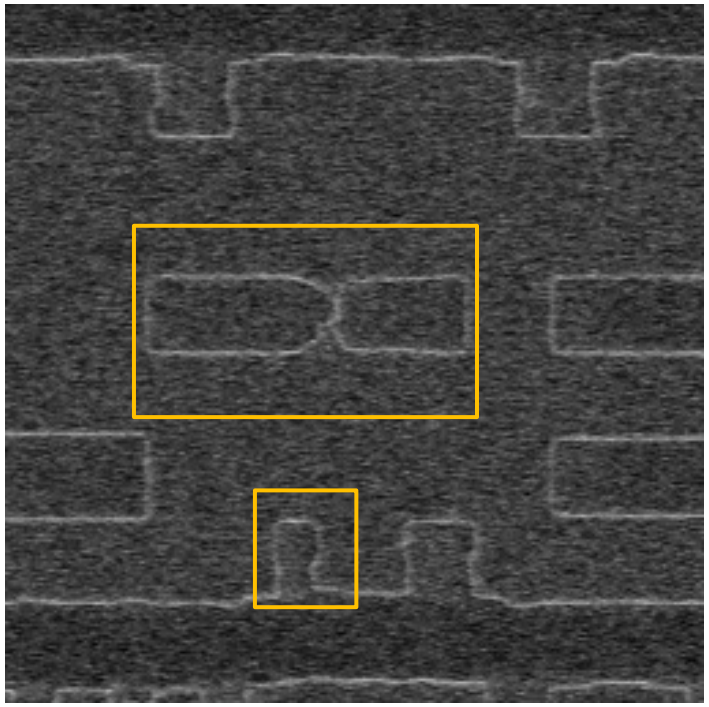
Yosuke Takarada, et al., "Lithography tool improvement at productivity and performance with data analysis and machine learning," SPIE Advanced Lithography, 2021

Good Choice for DL
ASML: Acceleration of OPC

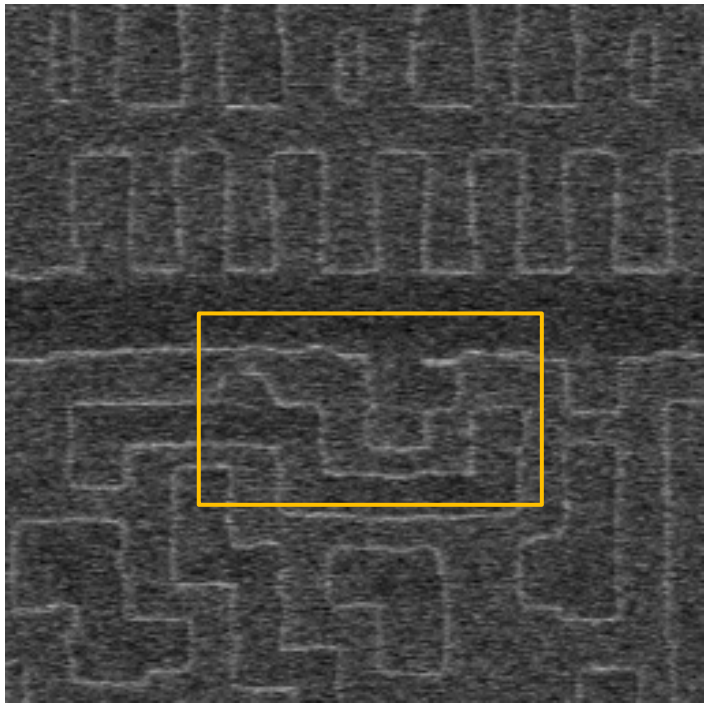


Good Choice for DL
NuFlare's VSB Writer Failure Diagnosis

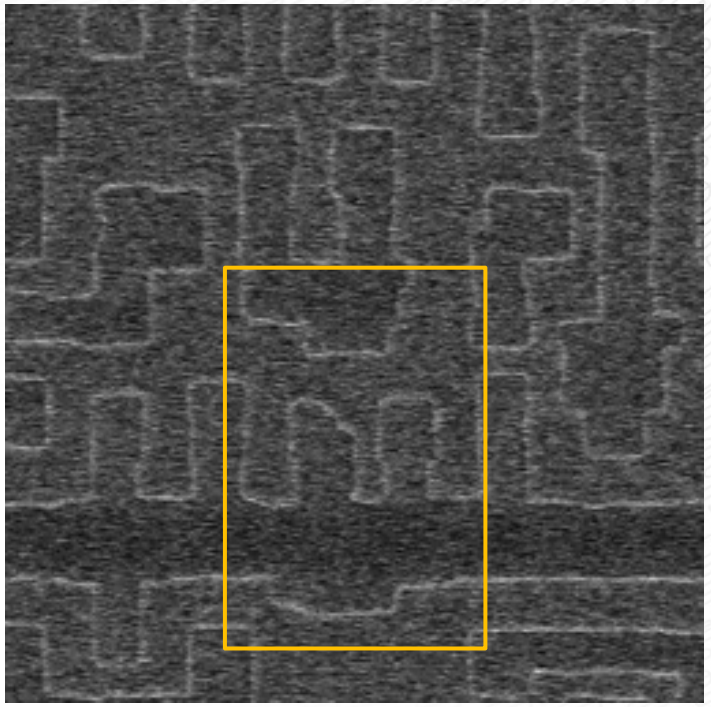
800K data points trained a 26-layer, 12 million-node network



Dose error



Shape error



Position error

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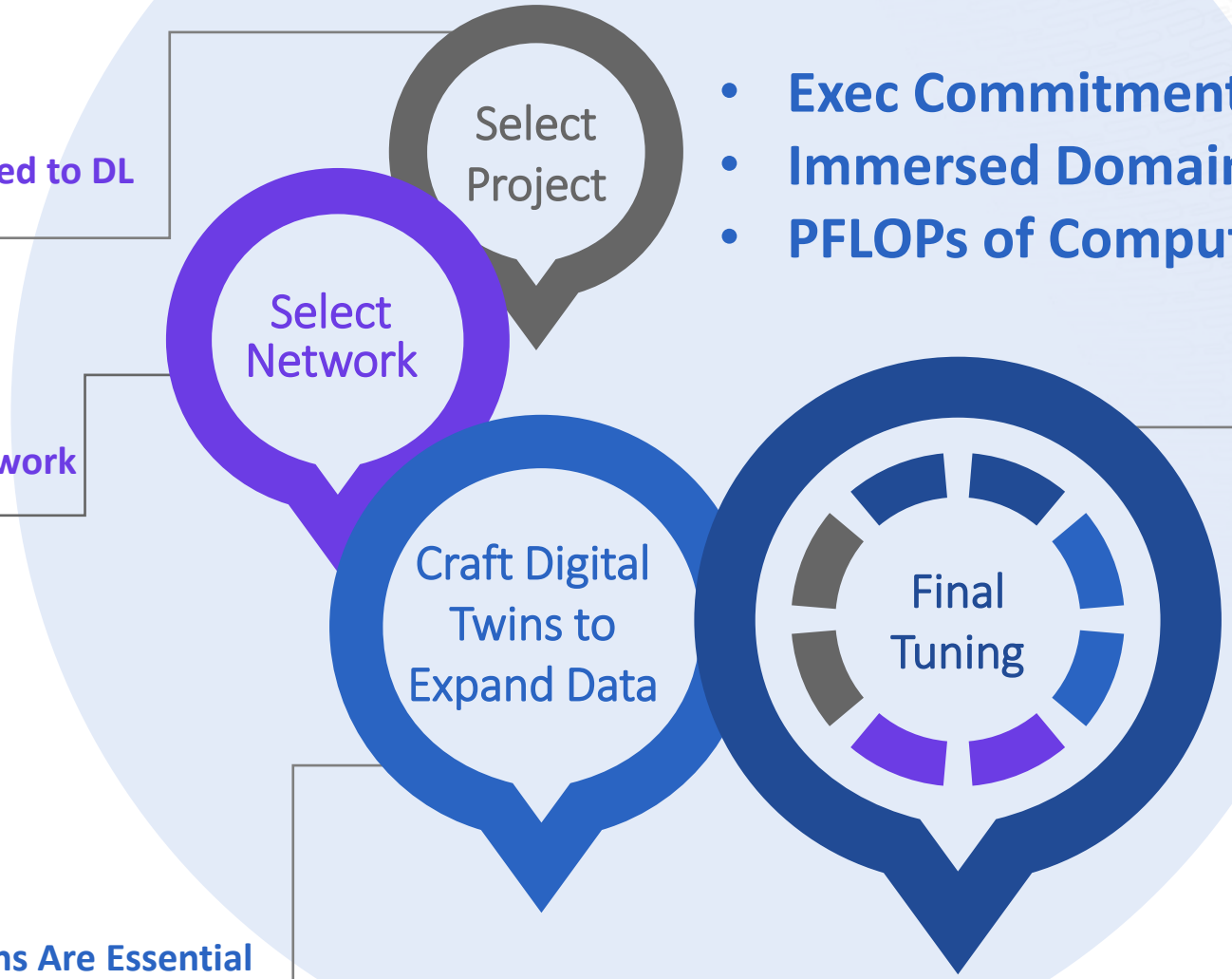
Commitment and Digital Twins Essential for DL Success

- **Exec Commitment**
- **Immersed Domain Experts with DL Experts**
- **PFLOPs of Computing**



Choose a Project Suited to DL

Select Appropriate Network

Digital Twins Are Essential

The Last 10% = 90% of Total Effort