



# Past, present and future of machine learning in Semiconductor Manufacturing

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Tuesday July 11<sup>th</sup> 10:30am – 12:00pm PDT

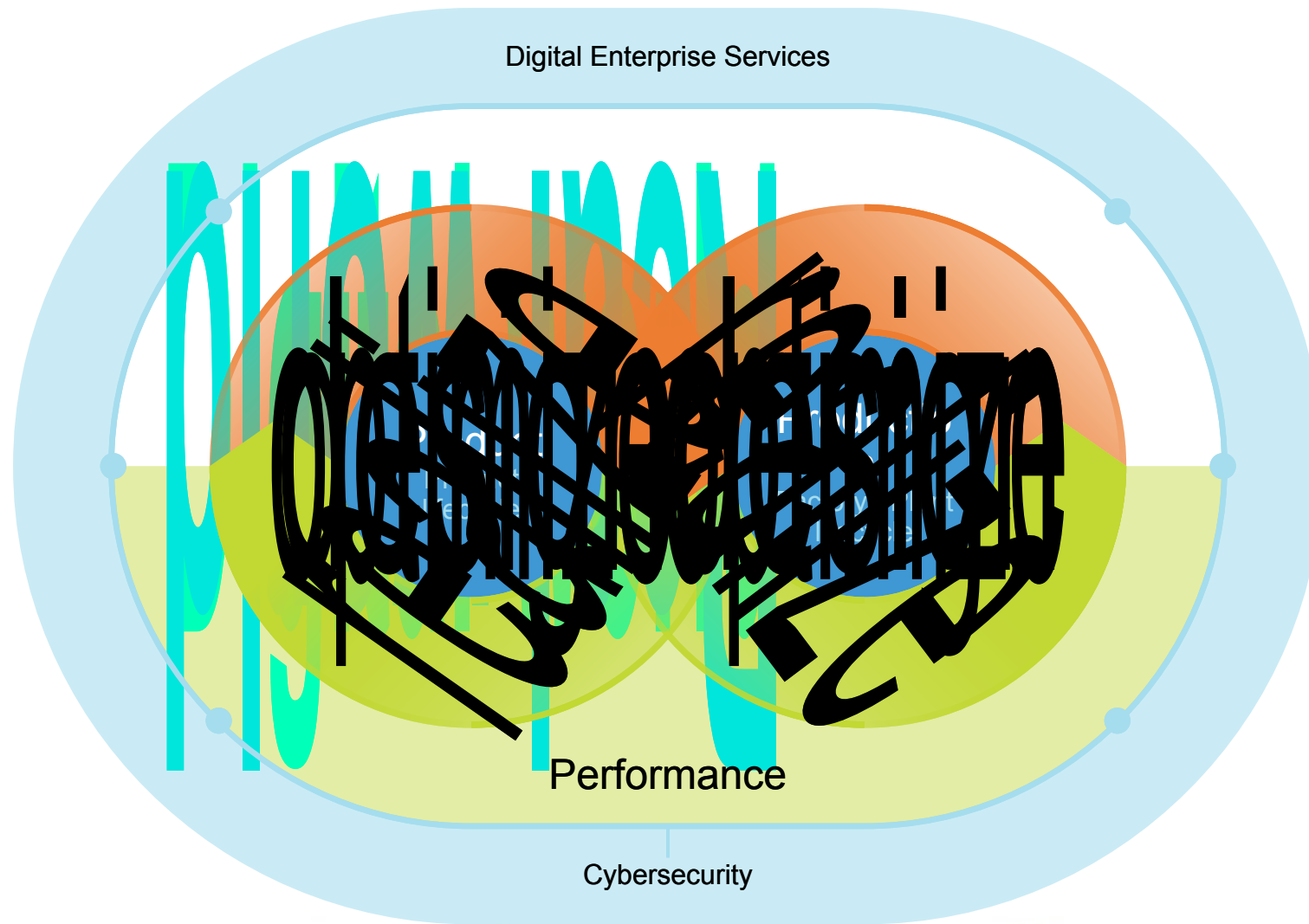
DAC 2023 San Francisco, CA

Packaging and Manufacturing Technologies Save the Day

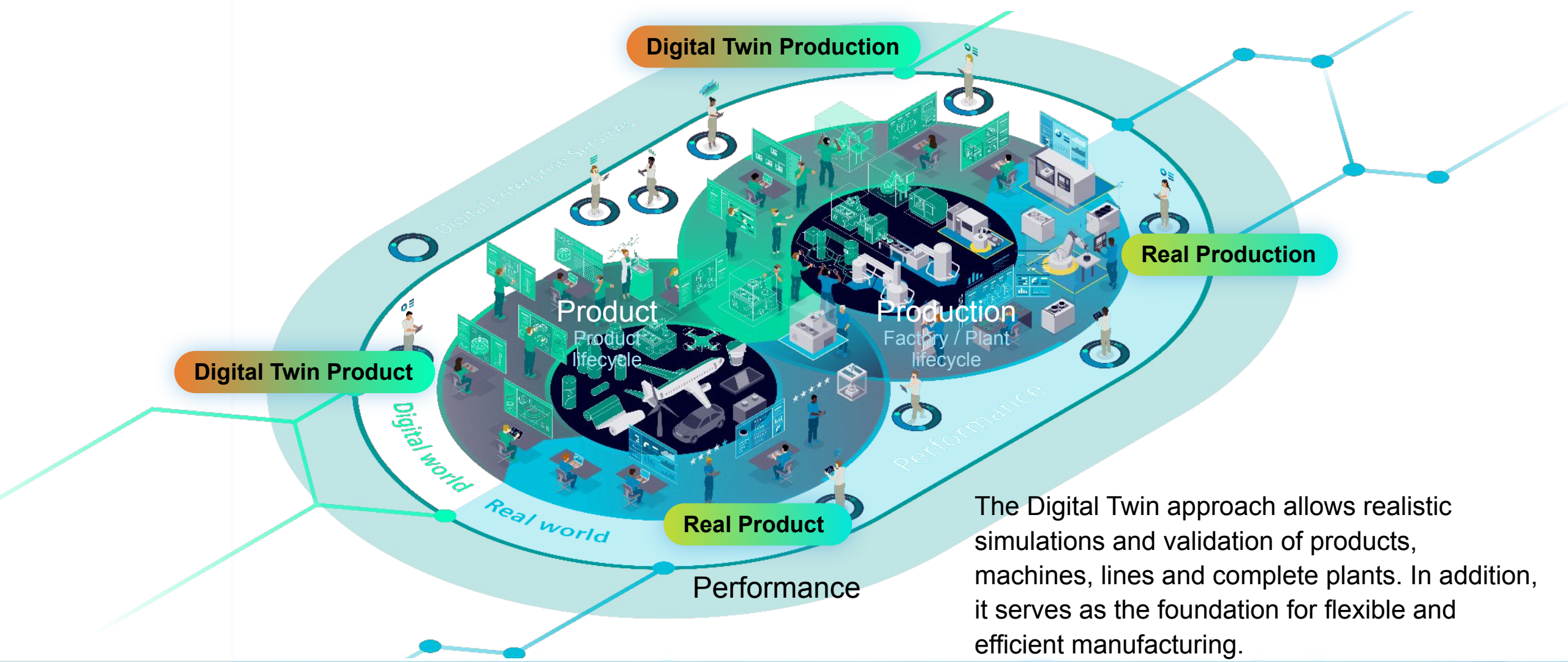


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# Comprehensive Digital Twin approach: The Goal



# Comprehensive Digital Twin approach: The execution



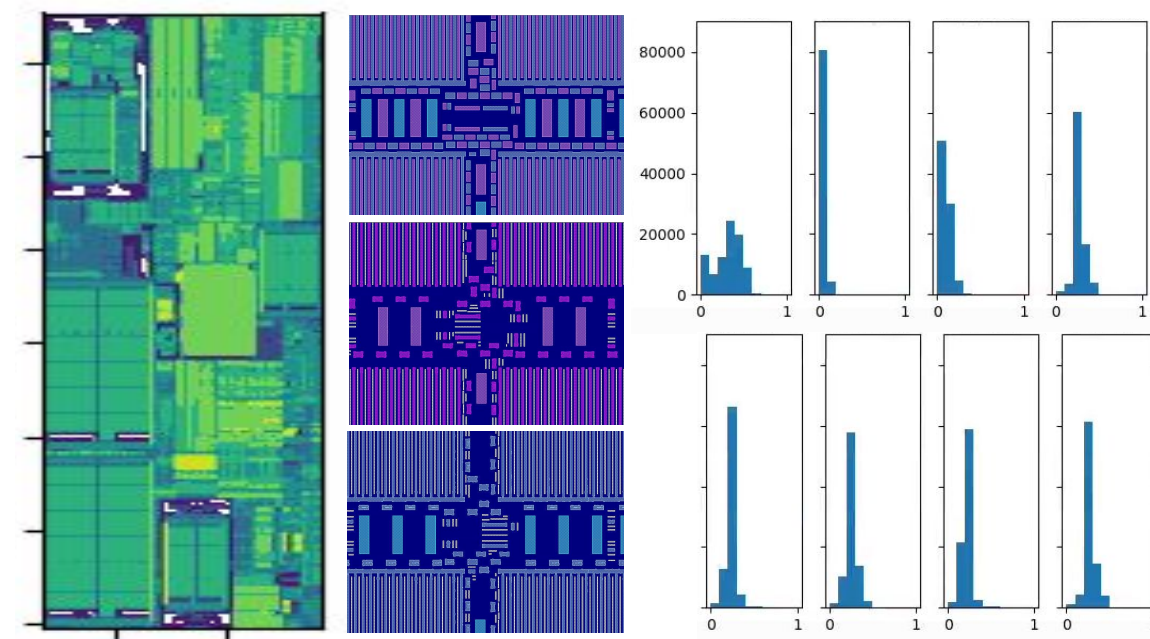
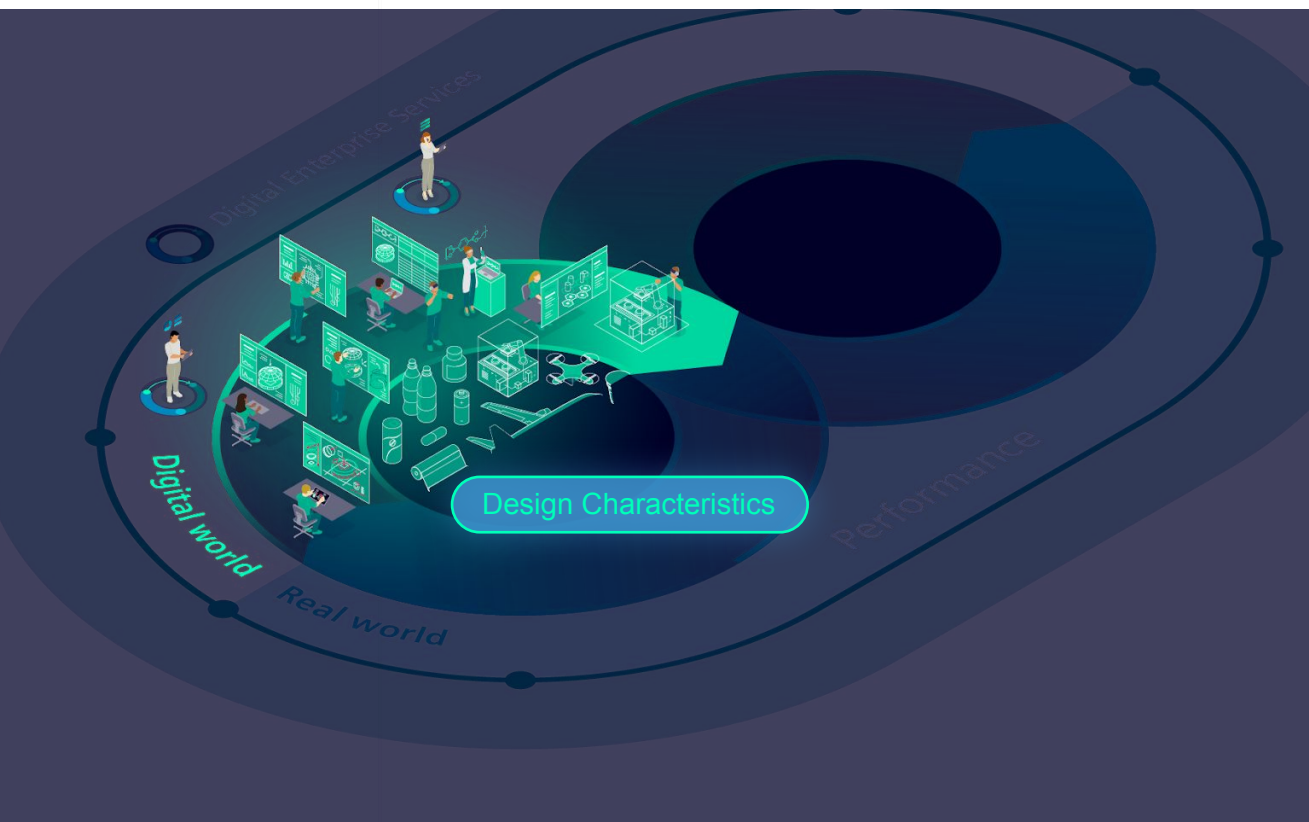
The Digital Twin approach allows realistic simulations and validation of products, machines, lines and complete plants. In addition, it serves as the foundation for flexible and efficient manufacturing.



# Building Digital Twins for Semiconductor Manufacturing



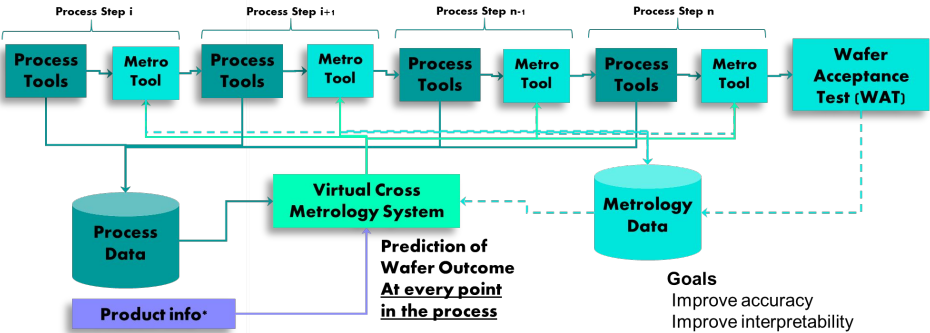
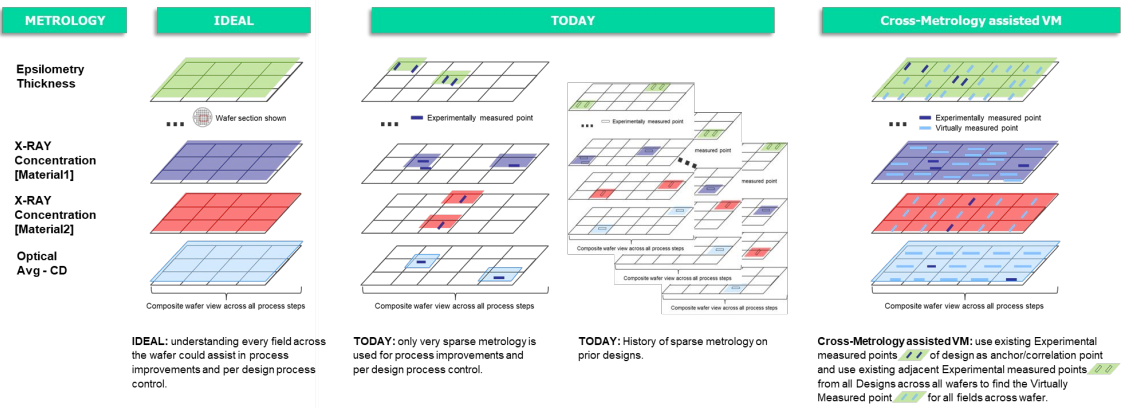
# The Digital Twin Product: Understanding Product Design



**Design, simulate, and verify products digitally.** Leverage Physical Design Understanding to capture sensitive product characteristics.

Stefan Schueler, Carsten Hartig, Andres Torres, Ivan Kissiov, Richard Gardner, Essam Mohamed, and Srividya Jayaram **"Virtual metrology: how to build the bridge between the different data sources"**. Proc. SPIE 11611, Metrology, Inspection, and Process Control for Semiconductor Manufacturing XXXV, 116112D (22 February 2021)

# The Digital Twin Production: Combining Product, Process and Metrology



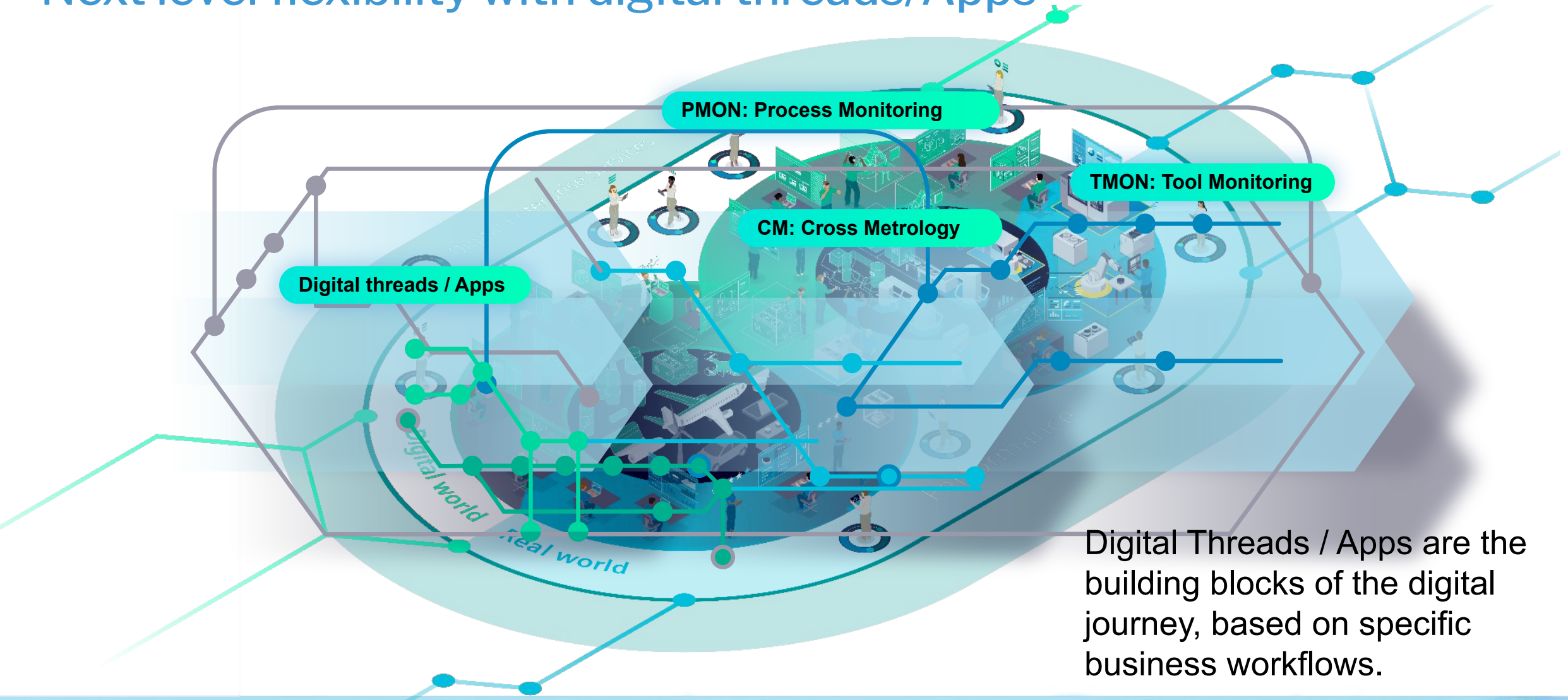
Combine Process, Product and Metrology data in a way to achieve more physical models which enable solutions to many problems like tool and process drift, as well as improved process control and wafer dispositioning



J. Andres Torres, Ivan Kissiov, Melody Tao, Graham Mueller, Stefan Schueler, Carsten Hartig, Richard Gardner, and Srividya Jayaram "Virtual cross metrology: leveraging process sequence for improved process characterization", Proc. SPIE 12053, Metrology, Inspection, and Process Control XXXVI, 120531B (26 May 2022)

Nathan G. Greeneltch, Haizhou Yin, J. Andres Torres, Melody Tao, Steven M. Lubin, Srividya Jayaram, Ivan Kissiov, Martin Niehoff, Marcus Wolf, Paul Jungmann, and Todd C. Bailey "Design-aware virtual metrology and process recipe recommendation", Proc. SPIE 12495, DTCO and Computational Patterning II, 124951V (28 April 2023)

# Next level flexibility with digital threads/Apps



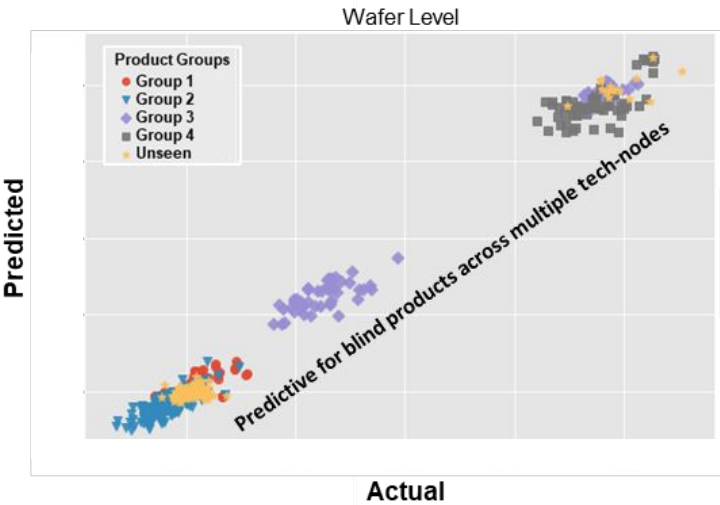


# Sample Applications Results

Monitor process drift and differentiate between different processes drift or product mix. Reduce monitoring wafers, improve wafer quality.

## Process Monitoring (PMON)

Deposition Process

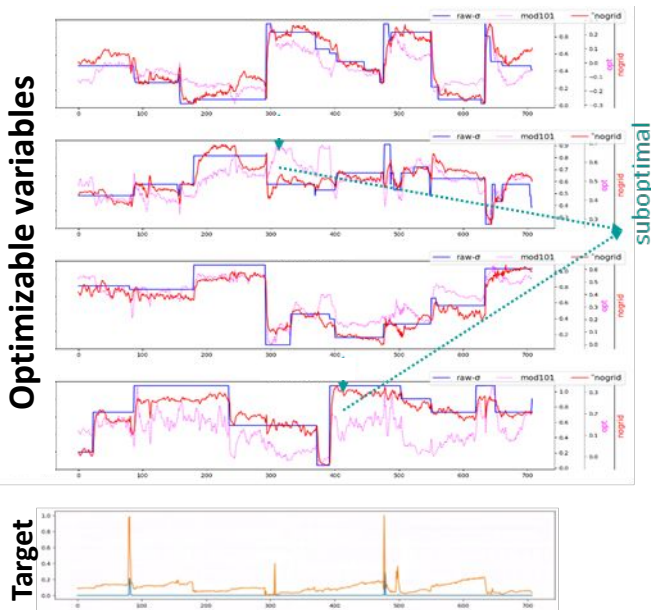


Model trained on **four different technology nodes simultaneously**

Monitor tool drift across the fleet, and restore individual nominal tool performance faster (from days to hours)

## Tool Monitoring (TMON)

CVD and Electroplating tools

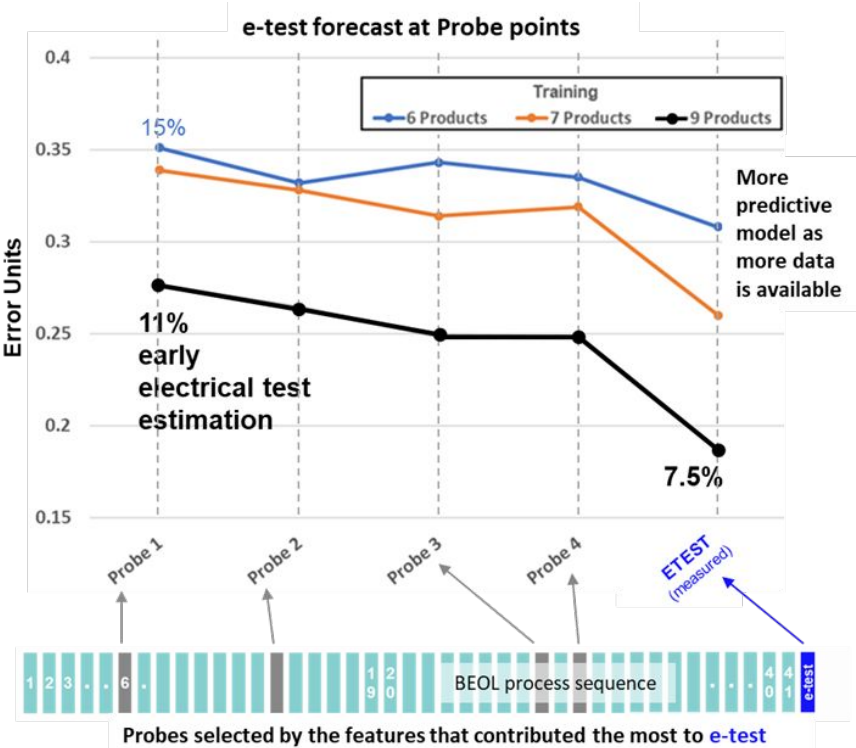


Model trained to CVD fleet with possibility to specialization, **uncovering suboptimal process parameter settings**

Forecast electrical performance earlier during processing

## Cross Metrology (CM)

BEOL: e-test target



Model a sequence of 42 individual process steps (process and metrology) and **identify most significant contributors to e-test**







# Lessons

**Data is not enough:** Data needs to be coupled with semantics describing what the data is.

**Flexible:** Solution must work in cloud and on premise

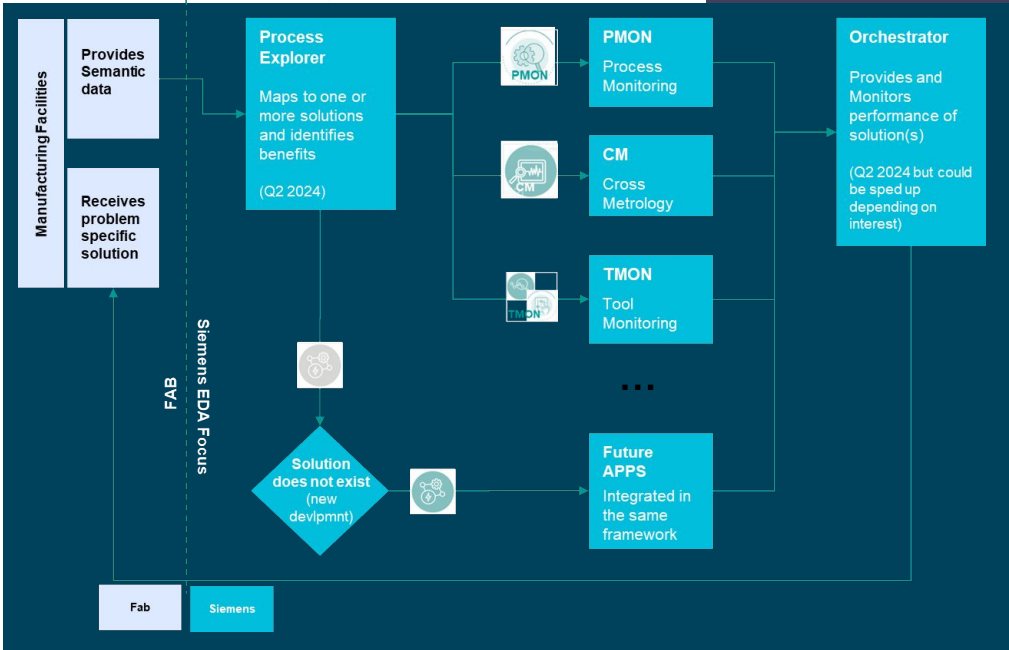
**General:** Solution must be general enough to address multiple problems

**Scalable:** Solution must be trivial to deploy at scale across all relevant manufacturing points.

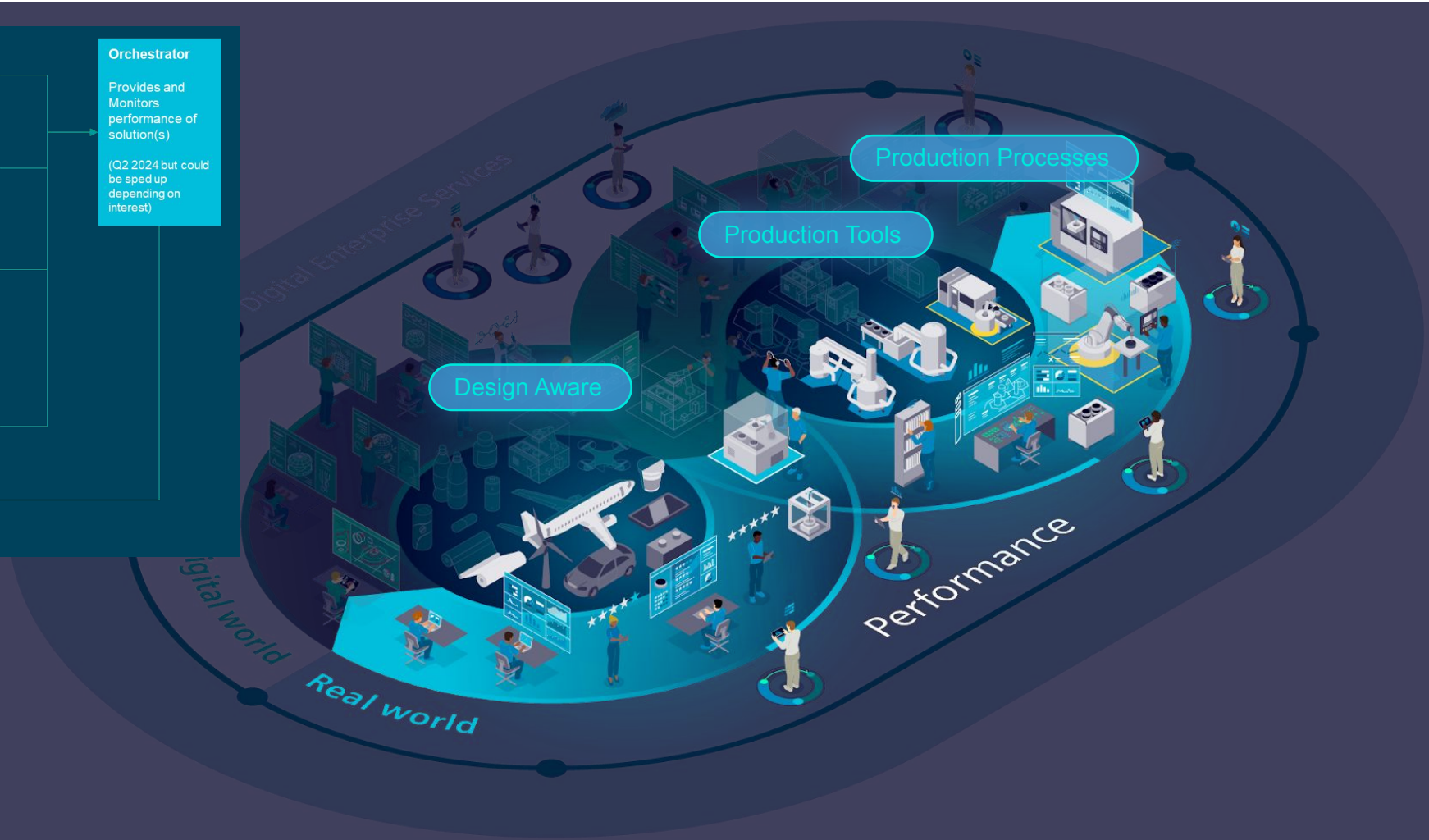
**Cost effective:** Solution must easily demonstrate significant benefits over existing processes and tools



# Realizing the full potential of a Digital Twin



Quickly and securely improve communication between design and production facilities and teams



# THANK YOU

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