

# ASML

## Integration of a Fab Cyber Physical System *The marriage of two digital twins*

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ASML, System Engineering

SASG, Eindhoven  
June 4th, 2019 v1

## Summary

ASML is a patterning/lithography company

## Topics

Chips are made with data

Two digital twins are horizontally  
and vertically integrated

Horizontal integration is the most challenging

## Summary



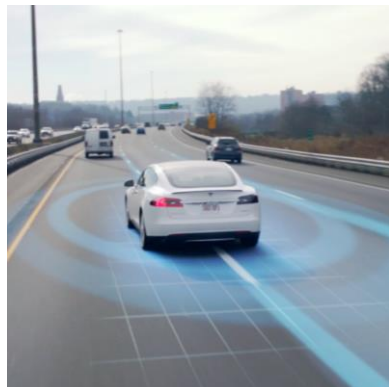
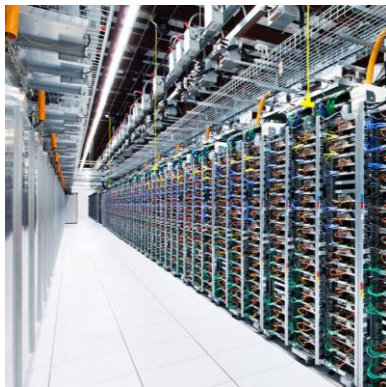
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# It's hard to imagine a world without chips



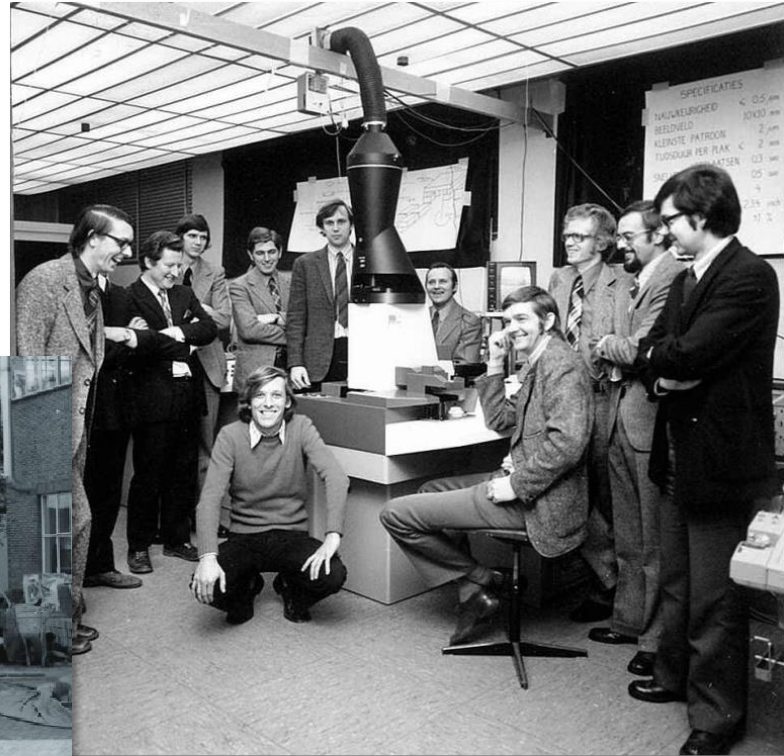
# Example: Self-driving truck (expected between next year and 2025)



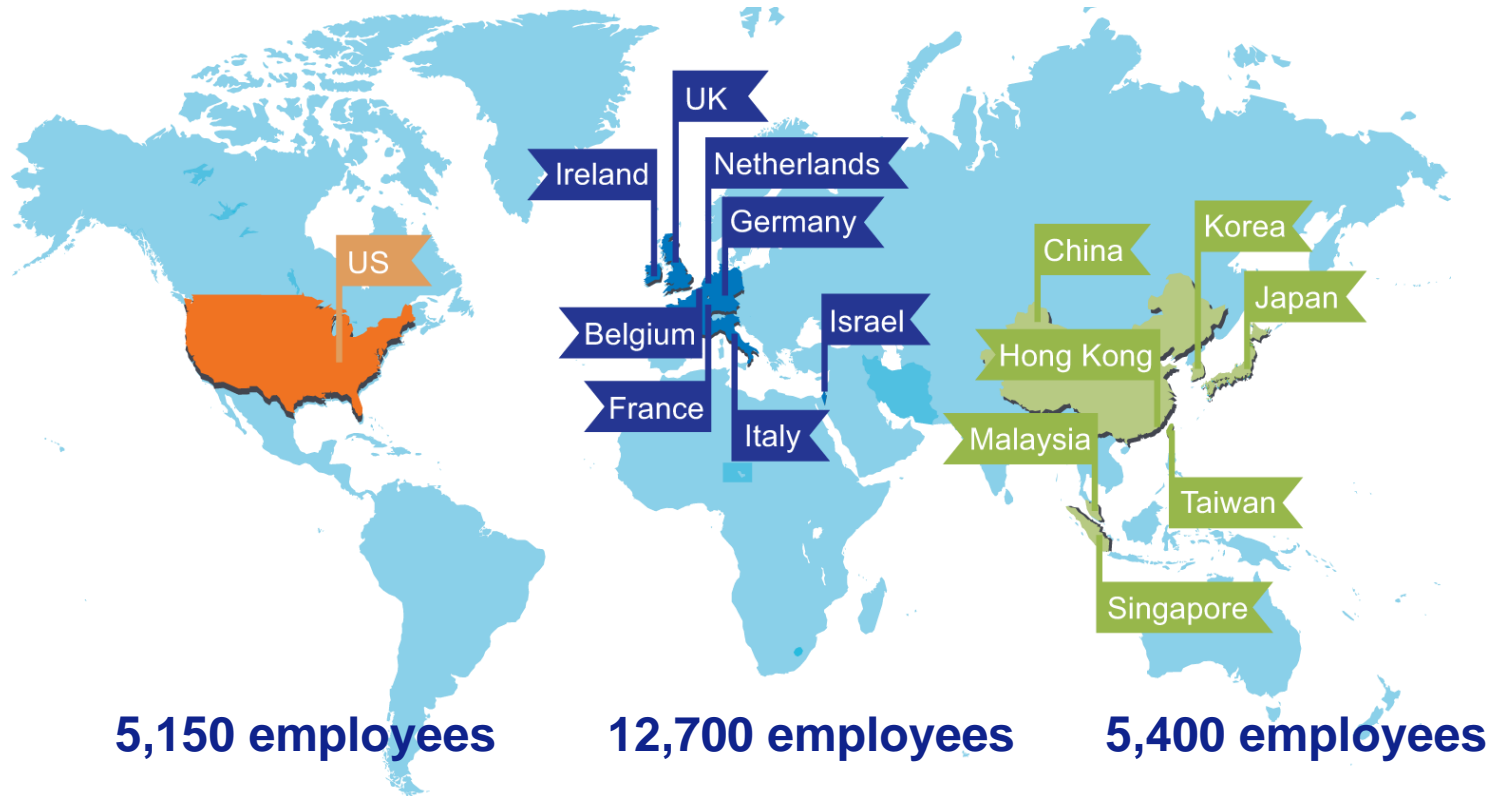
# Founded in 1984 as a spin-off from Philips

**ASML**

Public  
Slide 6  
Q4 2018



# A global presence with >23,000 employees



Offices in over 60 cities in 16 countries worldwide

# Our key locations



Wilton (CT)



San Diego(CA)



Korea



Veldhoven














Chandler (AZ)



Taiwan



# All major chipmakers are our customers

Company	Segment	2018 capex (est., \$B)
	Foundry + Memory	24.0
	Integrated Devices	14.0
	Foundry	11.0
	Memory	11.0
	Memory	8.5
 	Memory	7.3
	Foundry	4.5
	Foundry	1.9
	Foundry	1.1
	Others	1.0
Others		30.7
<b>Total</b>		<b>115.0</b>

# Driving the semiconductor industry: Moore's Law

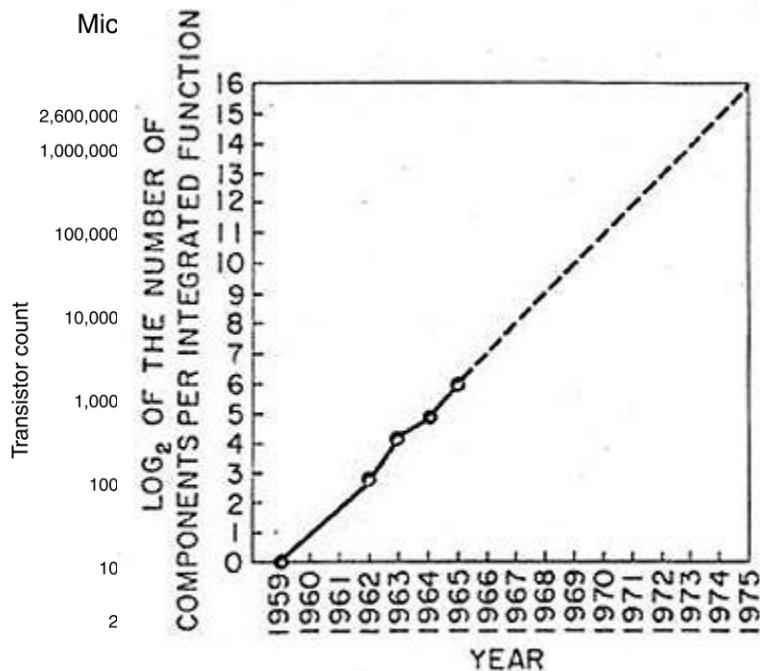
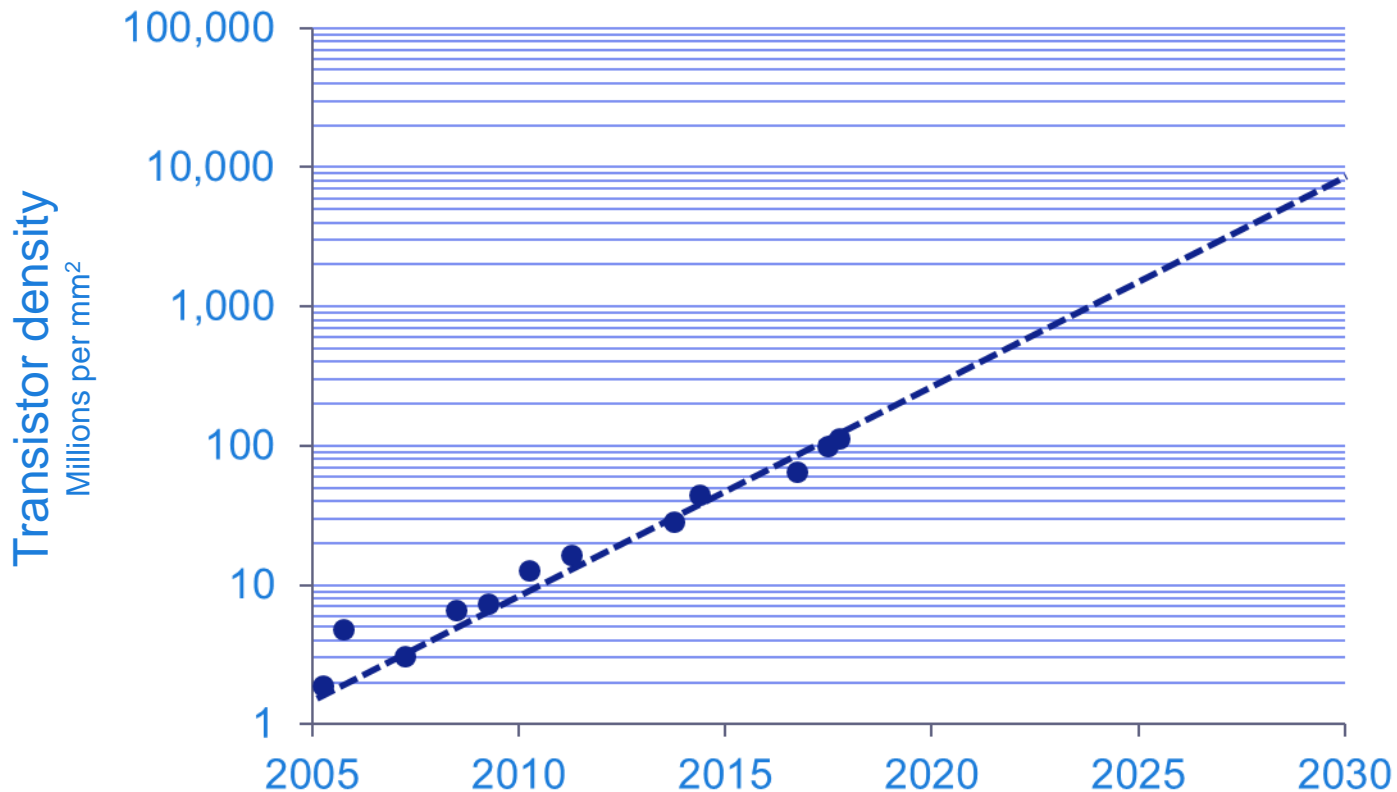


Fig. 2 Number of components per Integrated function for minimum cost per component extrapolated vs time.

Gordon Moore (1965):  
Number of transistors per  
chip doubles every year.

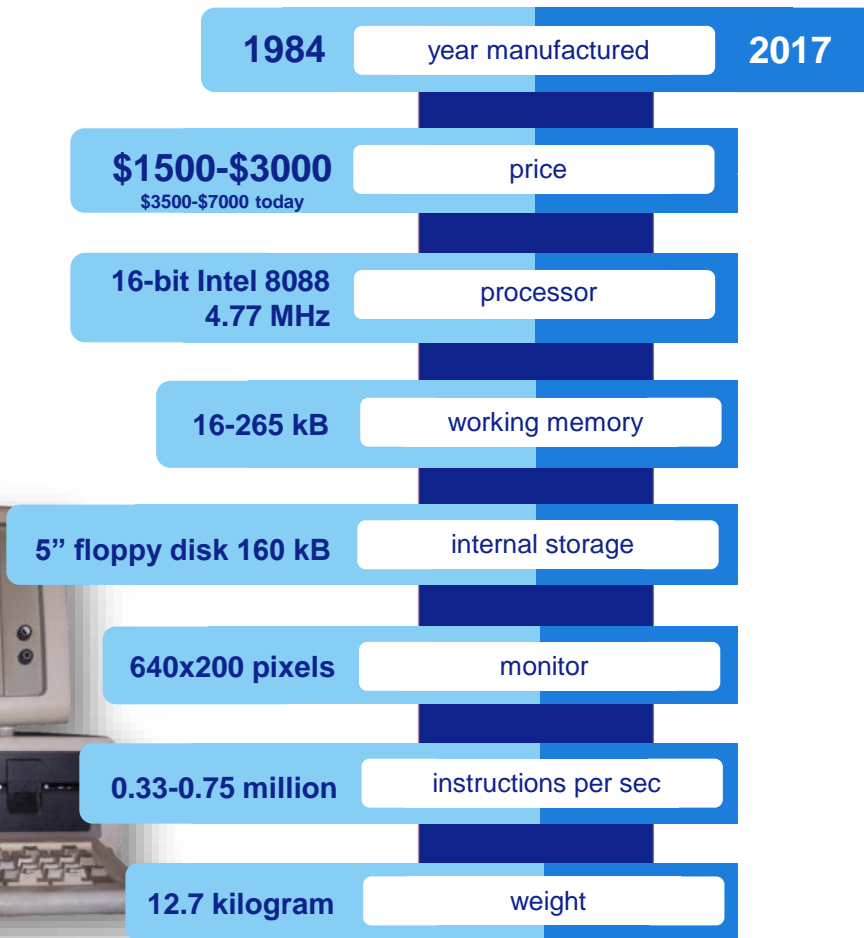
Later adjusted to two years,  
the trend has held for more  
than four decades.

We see this trend continuing beyond the next decade  
Our industry is moving towards 1 billion transistors per mm<sup>2</sup>



# Moore's Law powers innovation and lowers cost

## IBM 5150

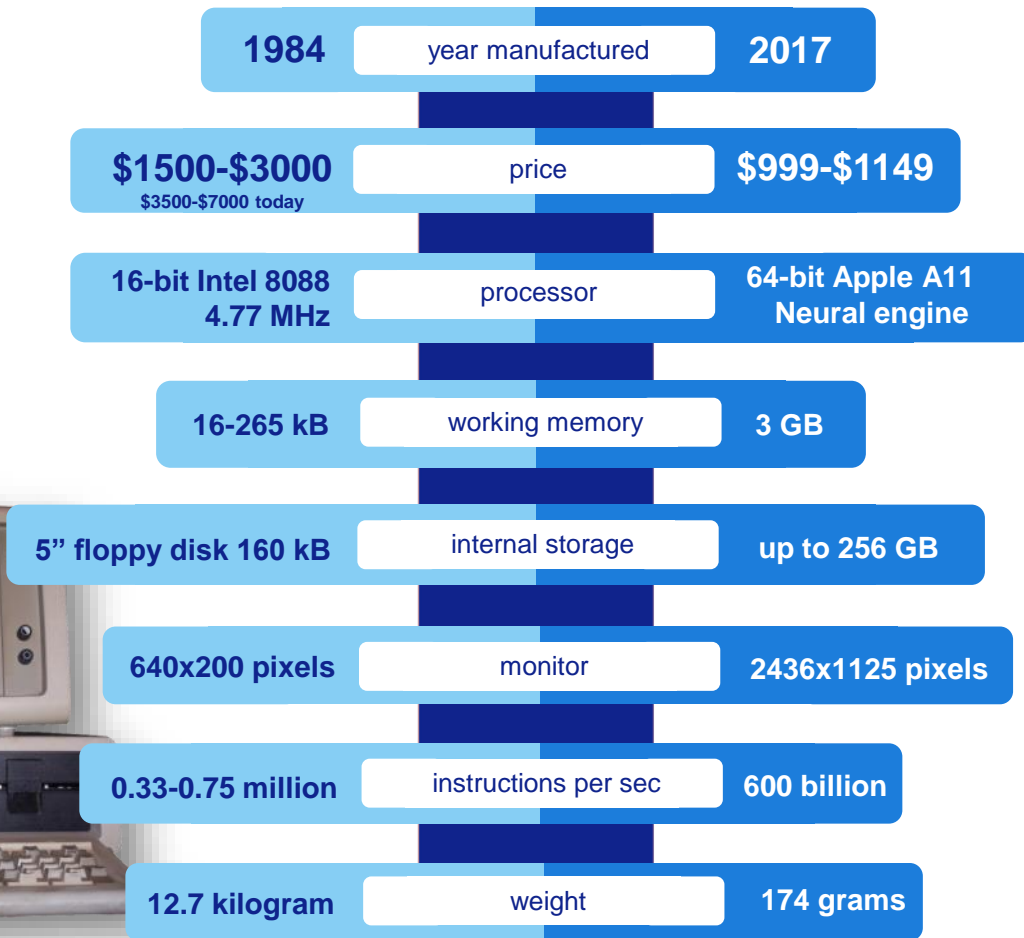


## Apple iPhone X



# Moore's Law powers innovation and lowers cost

**IBM  
5150**



**Apple  
iPhone X**



# Keeping up with Moore's Law



**1984**

**PAS 2000**

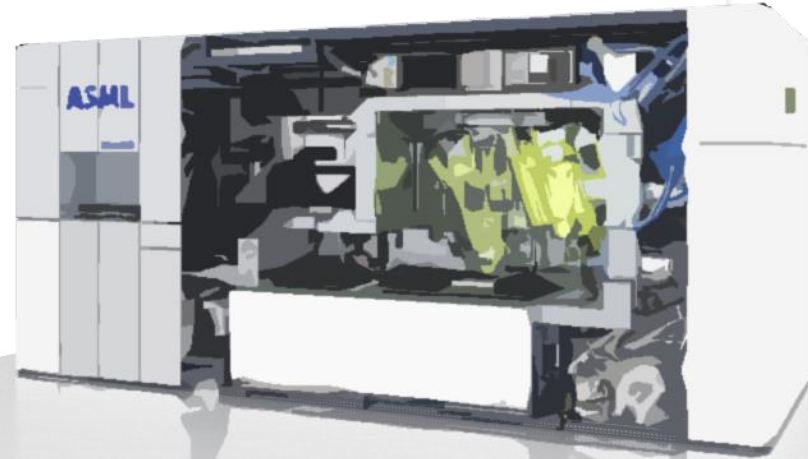
ASML's first stepper



**2015**

**TWINSKAN NXT:1980Di**

Our most advanced  
immersion system



**2018**

**TWINSKAN NXE:3400B**

High volume  
EUV system

## Summary

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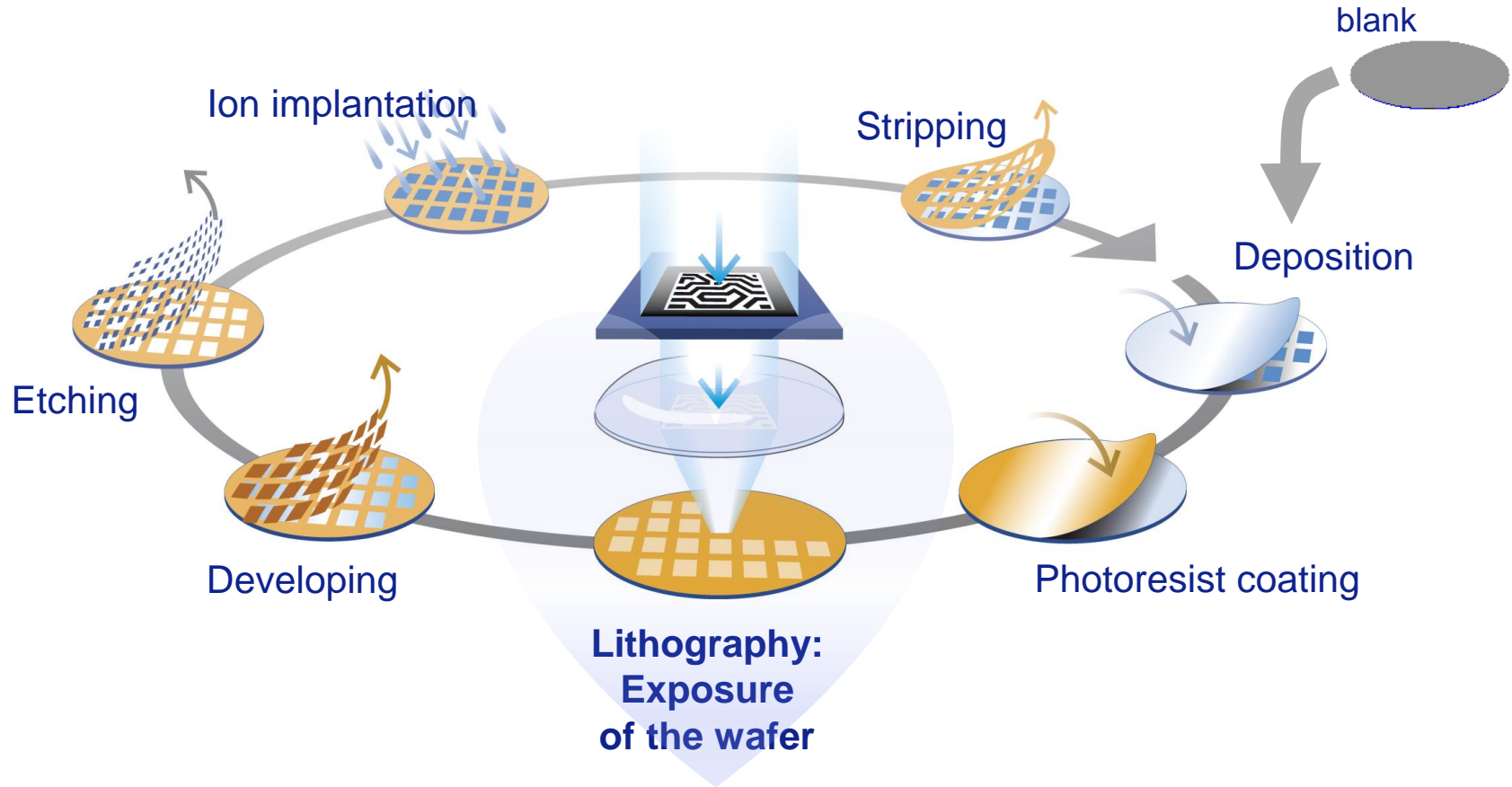


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and vertically integrated

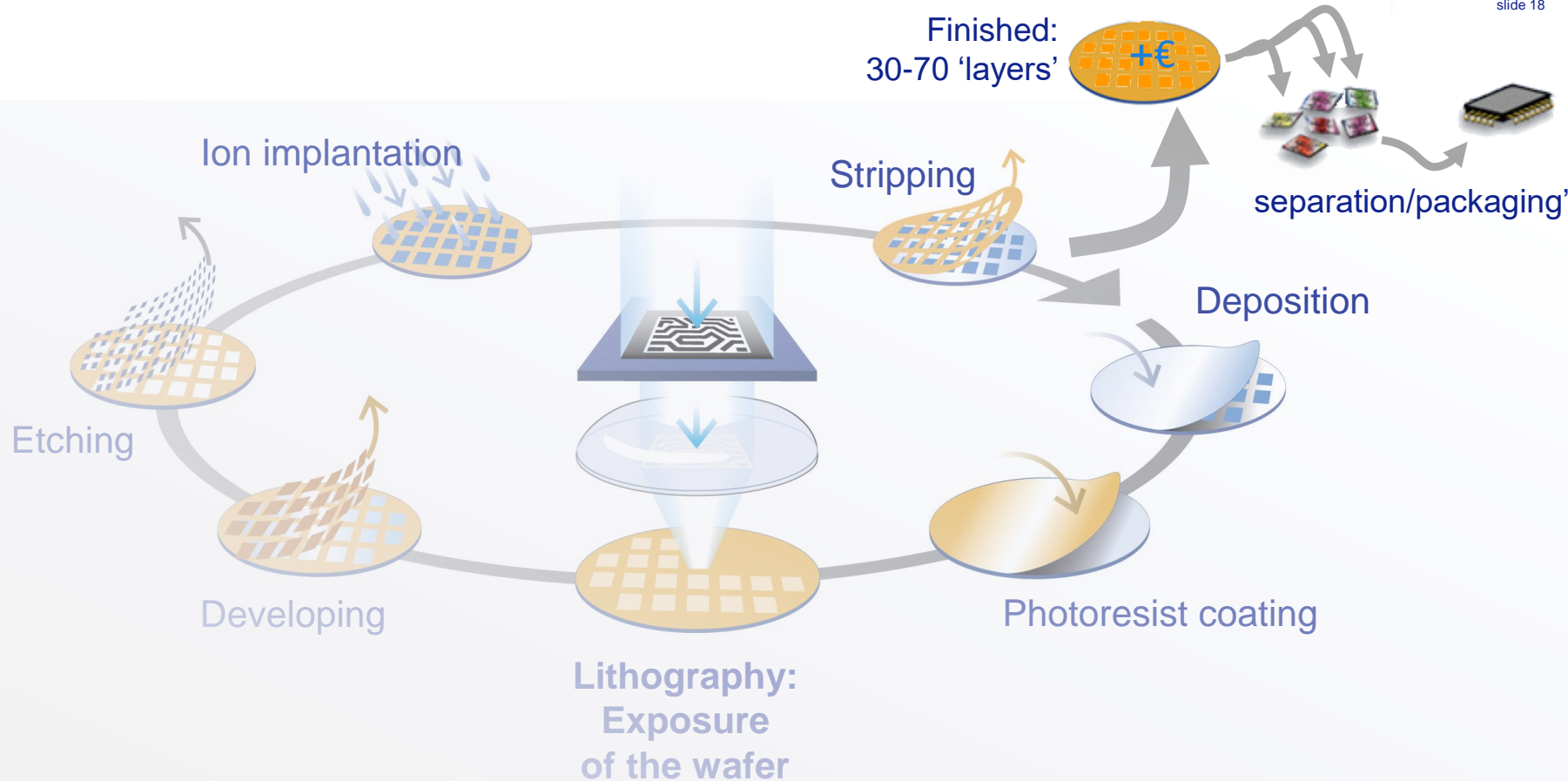
Horizontal integration is the most challenging

# Lithography is at the heart of chip manufacturing



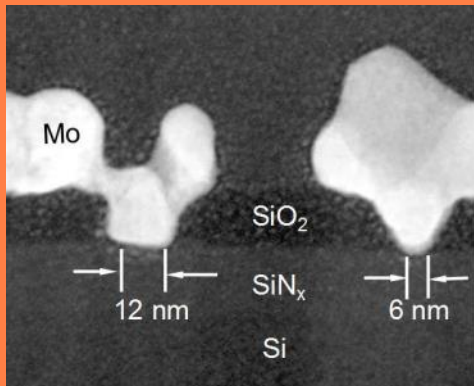


# Lithography is at the heart of chip manufacturing



# Keeping up with Moore's Law

Structure in a chip:  
6 nanometer detail



1984

PAS 2000

ASML's first stepper

2015

TWINSKAN NXT:1980Di

Our most advanced  
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2018

TWINSKAN NXE:3400B

High volume  
EUV system

# Keeping up with Moore's Law

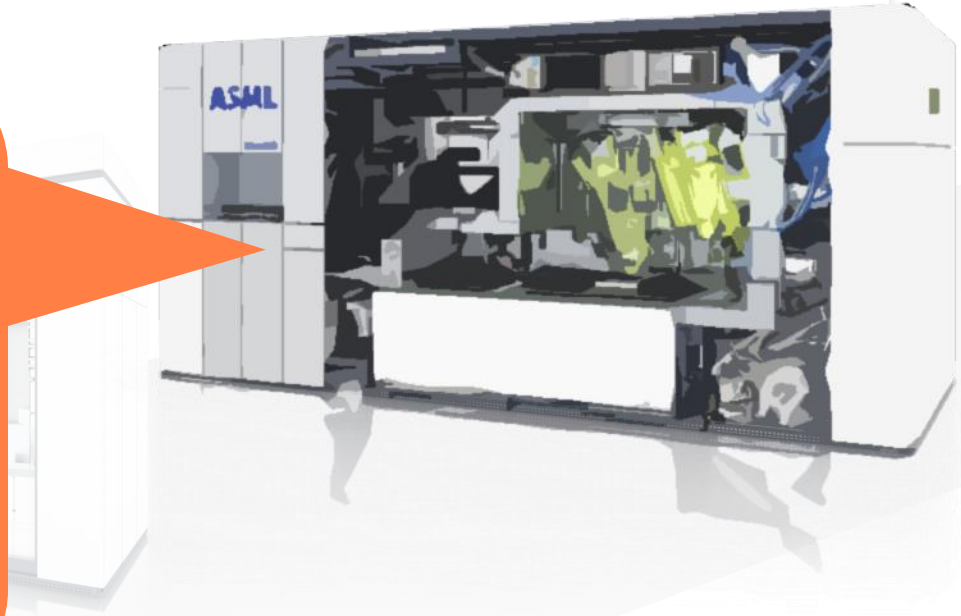
Wavelength:  
13.5 nanometers

Resolution:  
≤ 22 nanometers

**Overlay:  
1.0 nanometers**

Wafer size:  
300 mm

Productivity:  
125 wafers per hour



1984

PAS 2000

ASML's first stepper

2015

TWINSCAN NXT:1980Di

Our most advanced  
immersion system

2018

TWINSCAN NXE:3400B

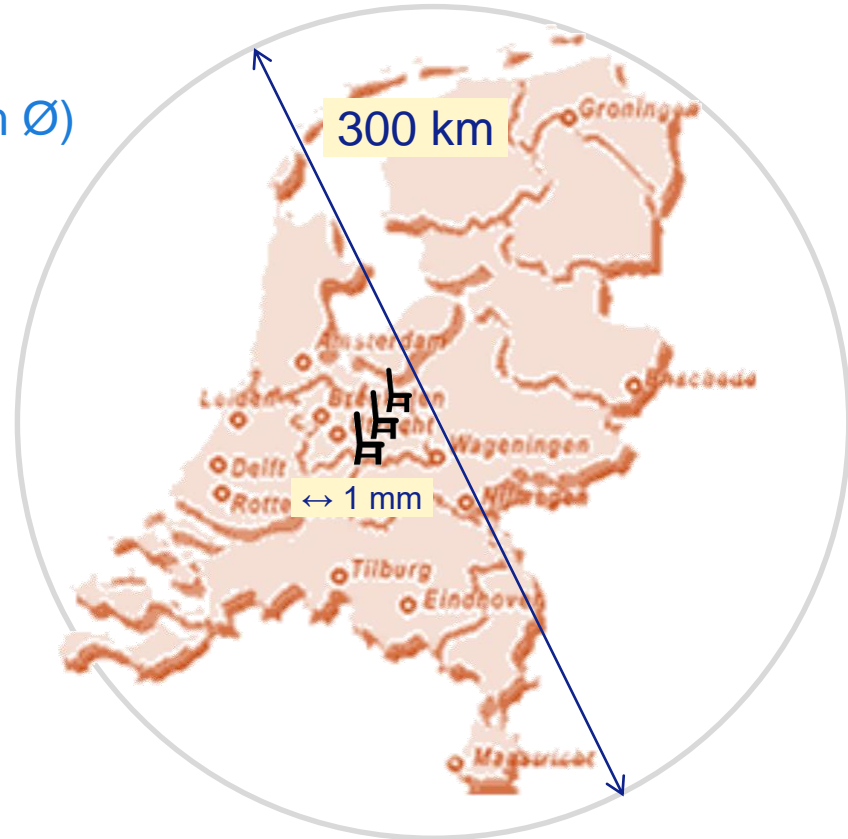
High volume  
EUV system

# Control at nm level is really fine-grained

1 mm motion

on scale of The Netherlands (300 km Ø)

1:300,000,000



# Control at nm level is really fine-grained

1 mm motion

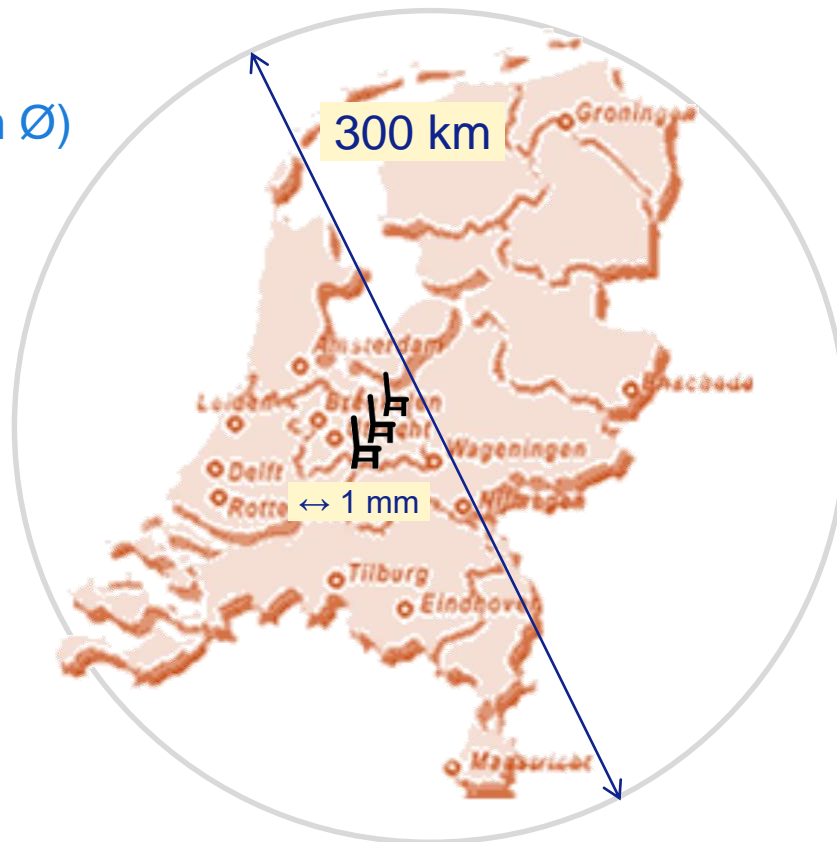
on scale of The Netherlands (300 km Ø)

1:300,000,000

1 nm motion

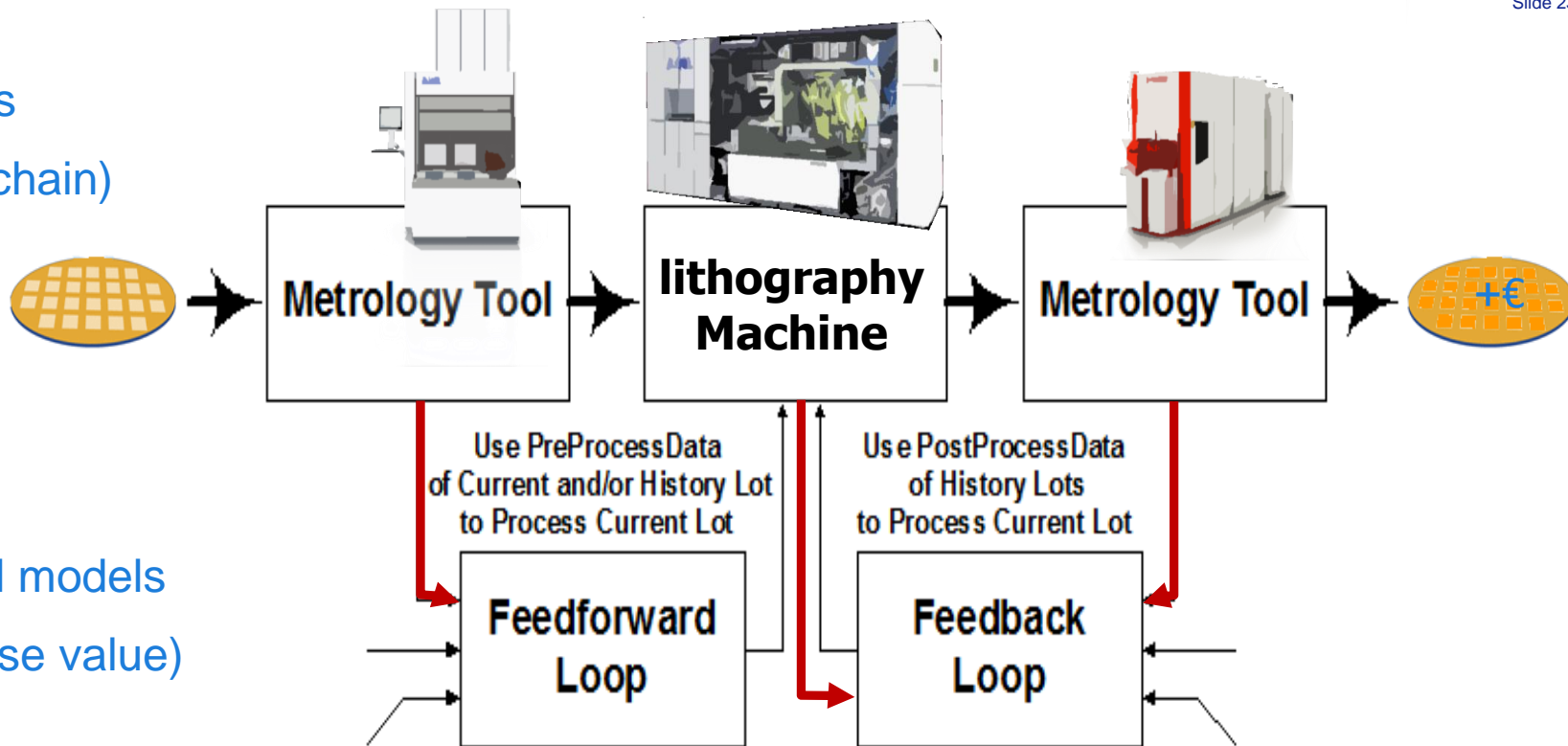
on scale of wafer (300 mm Ø)

1:300,000,000



# nm control is about integration of metrology (measuring)

Process  
(value chain)



Control models  
(increase value)

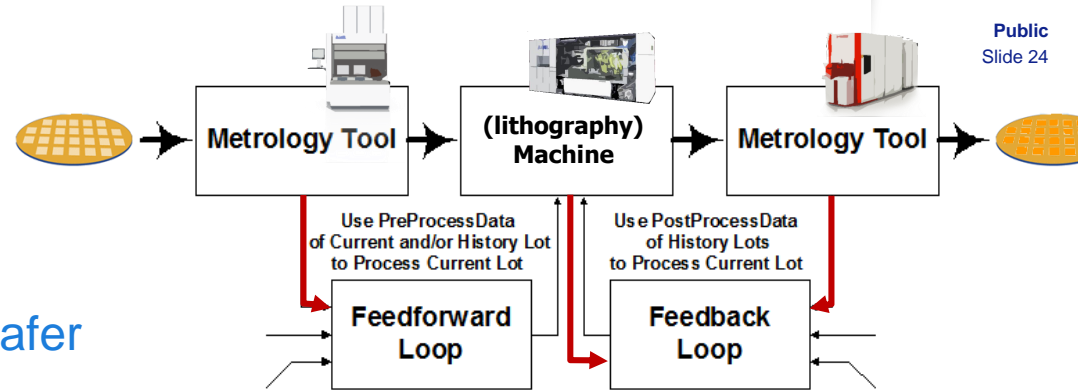
# nm control is based on lots and lots of data

Output: >200 wafers per hour,  
> million per machine per year

Lithography: 10,000 samples per wafer  
→ TeraBytes of data per year

Metrology tool: 100-10,000 samples per wafer  
→ TeraBytes of data per year

Fabs use this to control every square mm<sup>2</sup> of every wafer:  
Input per wafer: 100,000 x 6 axis = 600,000 inputs/wfr



# A tightly integrated set of solutions for scaling and yield



**Image**

Make the image printable and optimize for yield

Keep production stable

**Holistic lithography keeps scaling affordable**

**Model**

**Measure**

Ensure measurement captures a maximum of relevant information



Product reticles




Product wafers



## Summary

ASML is a patterning/lithography company

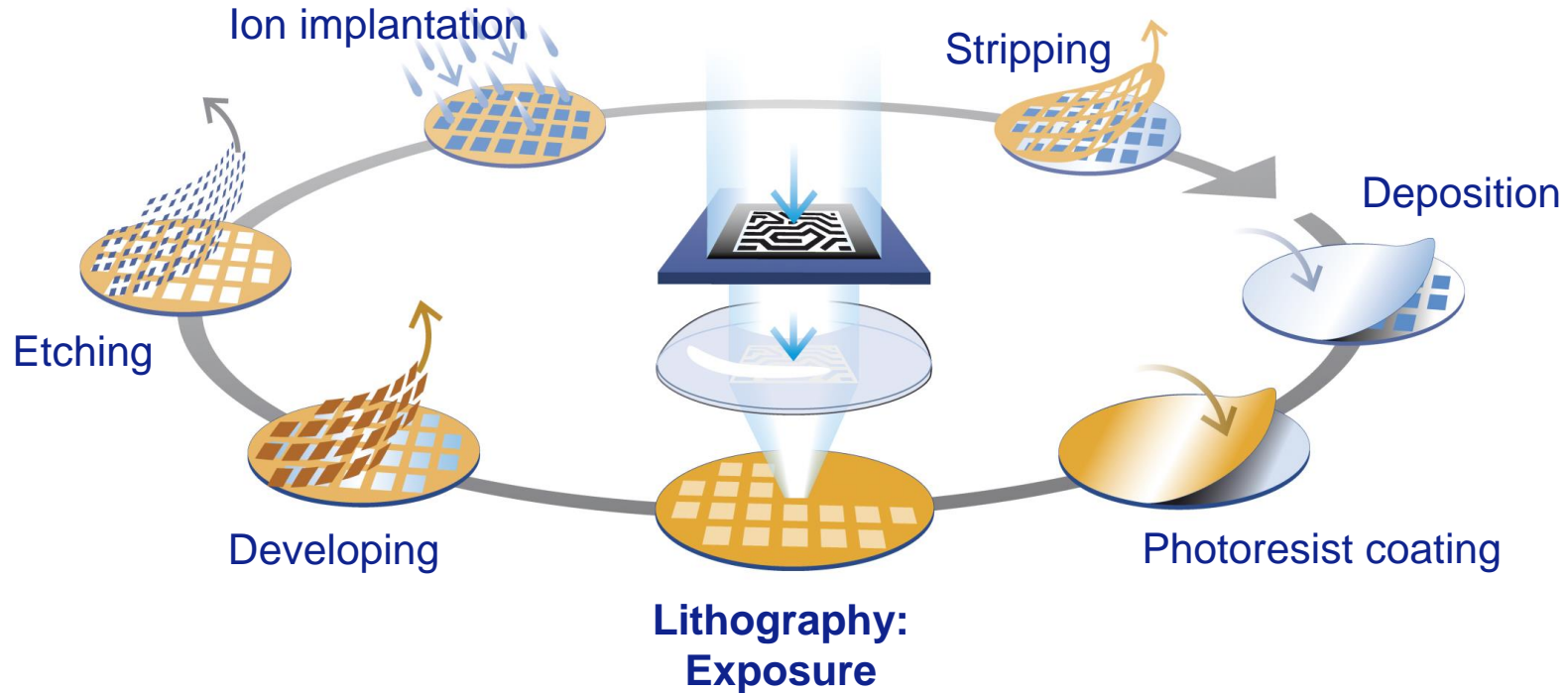
Chips are made with data



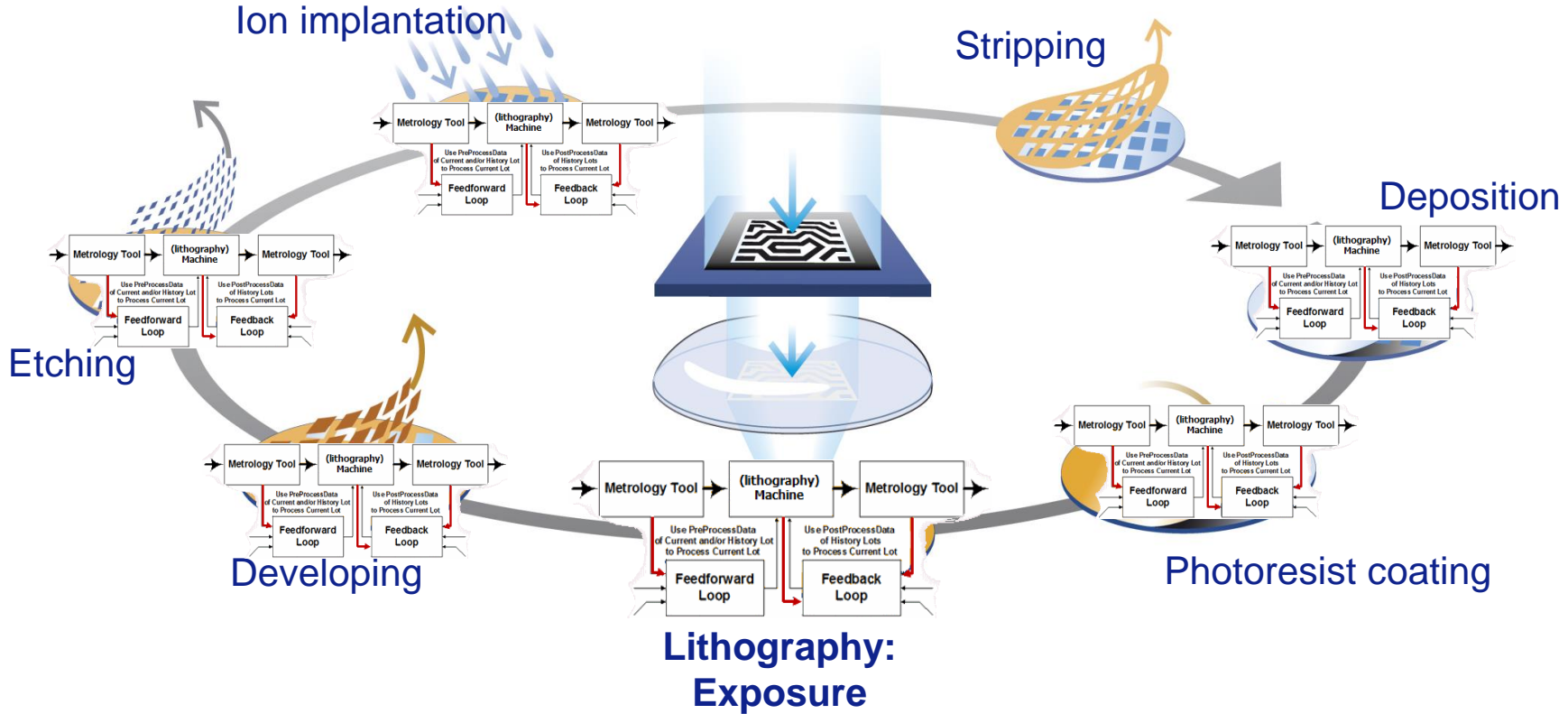
Two digital twins are horizontally  
and vertically integrated

Horizontal integration is the most challenging

# Lithography value chain: 700+ steps

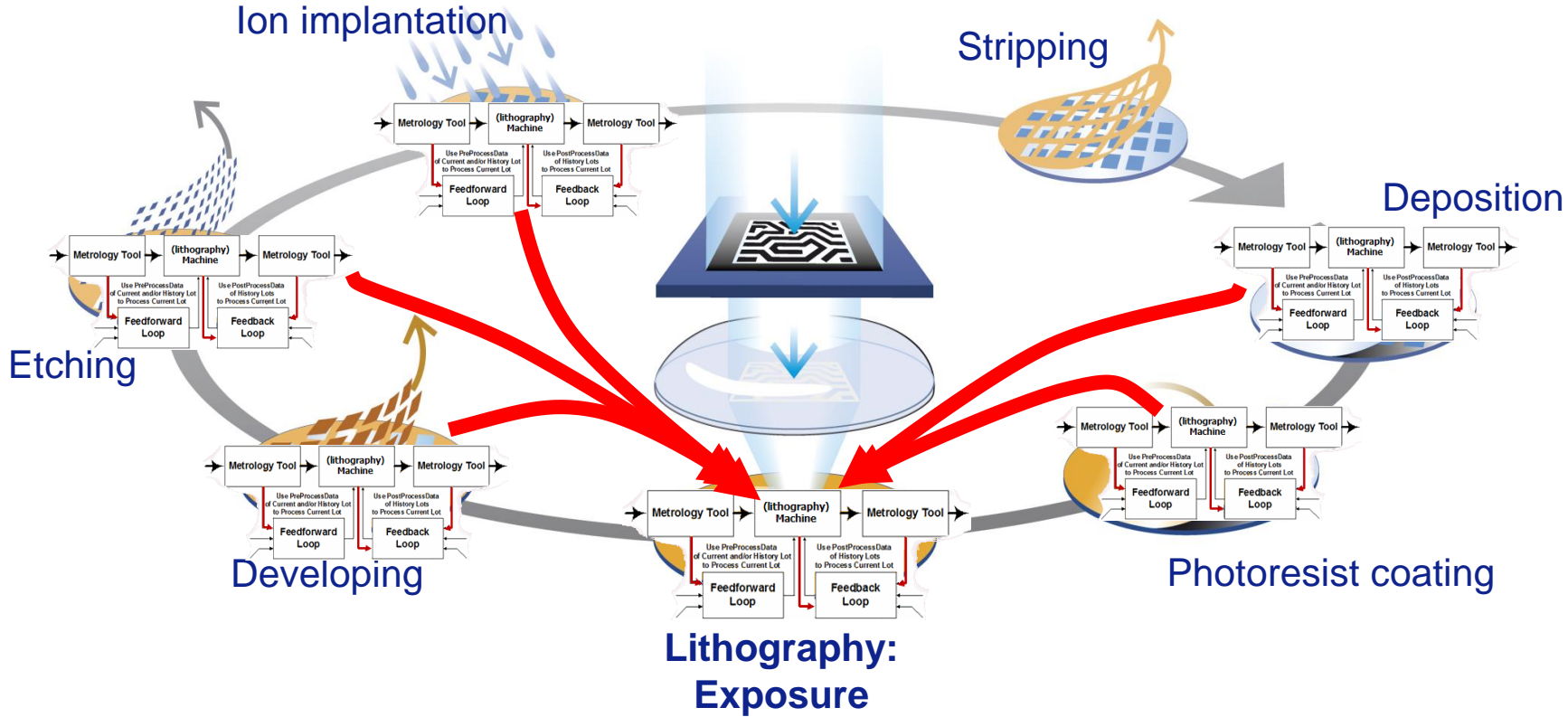


# Lithography is horizontally integrated in 700+ steps

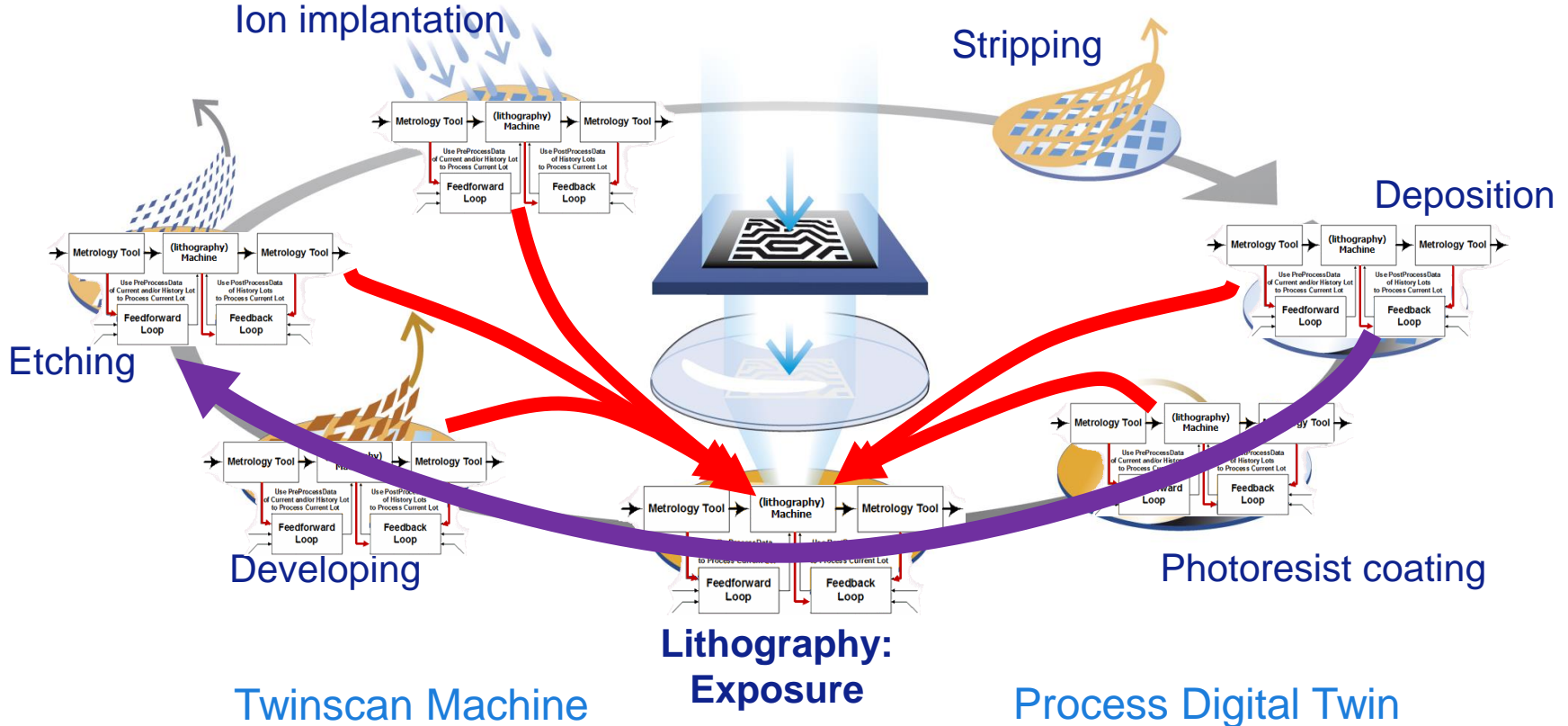


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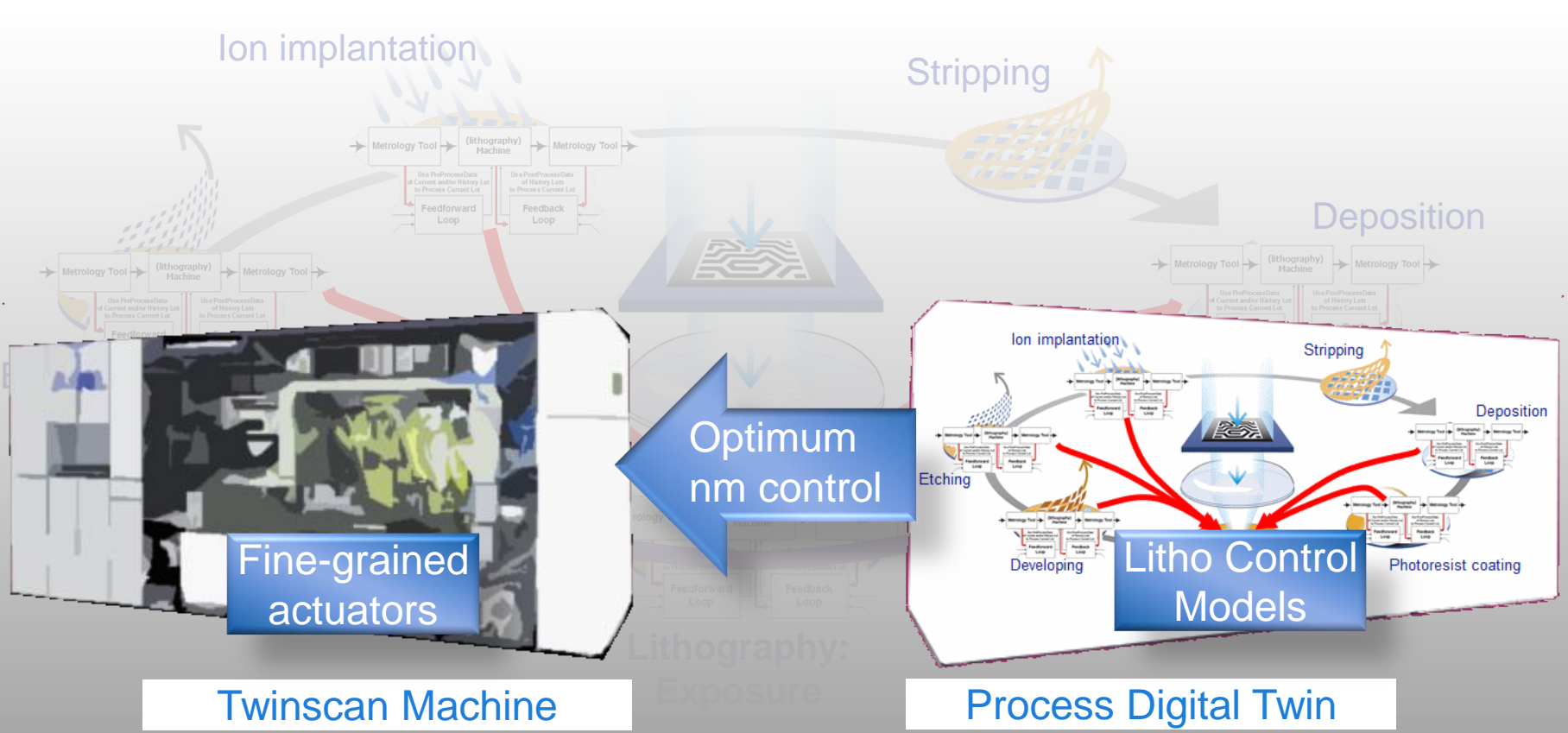
Upstream and down stream steps feed data into our litho models



Lithography is horizontally integrated in 700+ steps  
Upstream and down stream steps feed data into our litho models  
so the patterns 'after etch' come out almost nm-perfect.



# Litho Control Models are a 'digital twin' of the complete litho process using 'all' process data



Twinscan Machine

Process Digital Twin

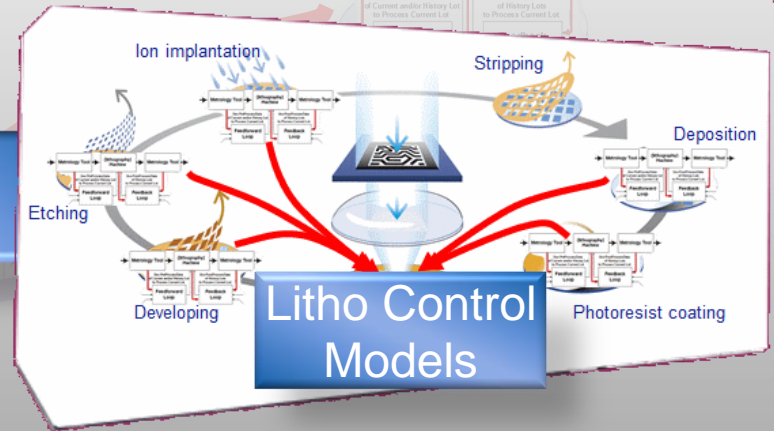
# Litho Control Models are a 'digital twin' of the complete litho process using 'all' process data

Cyber Physical System:  
optimum nm control



Twinscan Machine

Optimum  
nm control



Process Digital Twin

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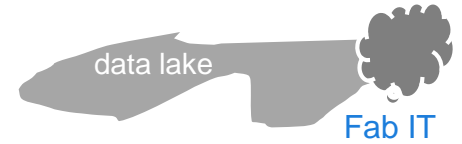
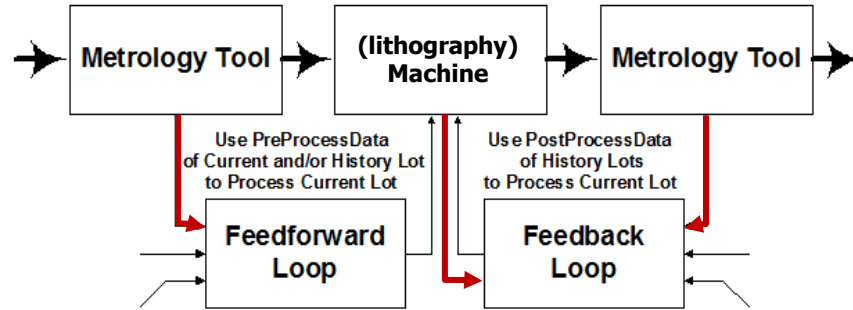
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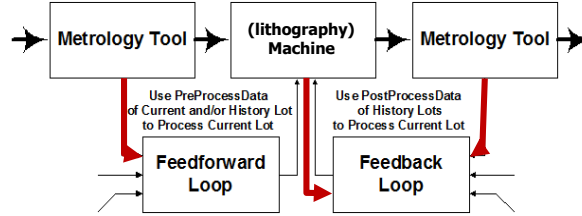
# Vertical 'integration': separate data lakes fab/ASML

Fab Customer  
nm control

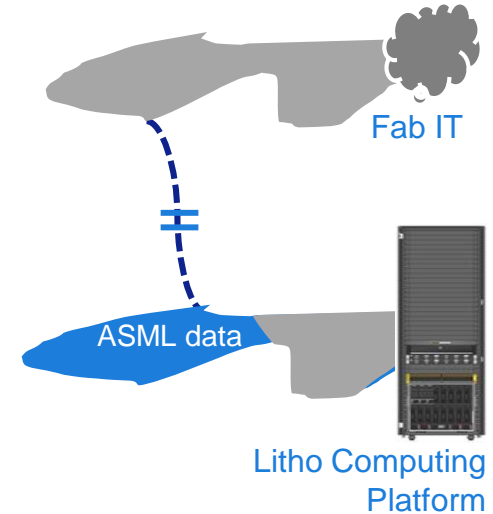
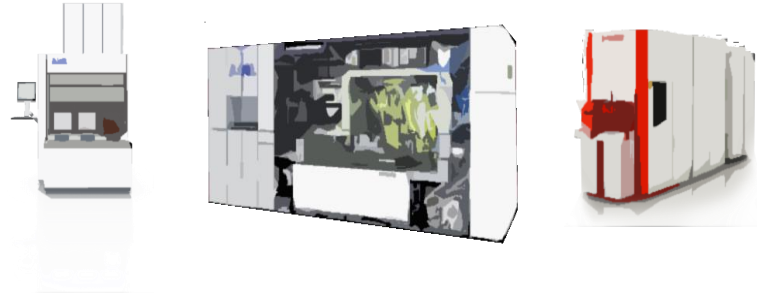


# Vertical 'integration': separate data lakes fab/ASML

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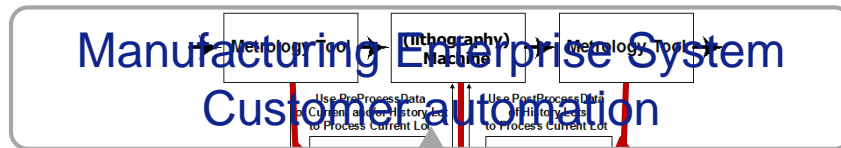


ASML  
machines  
in fab

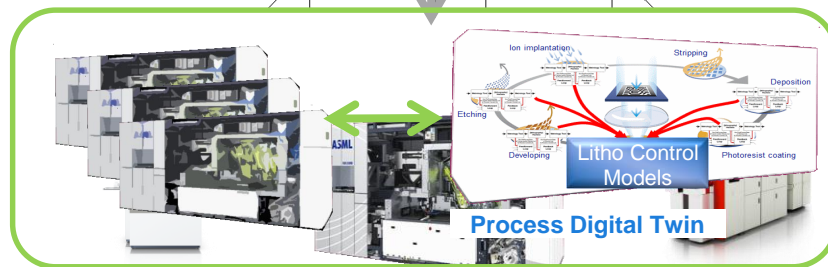


# Vertical 'integration': separate data lakes fab/ASML

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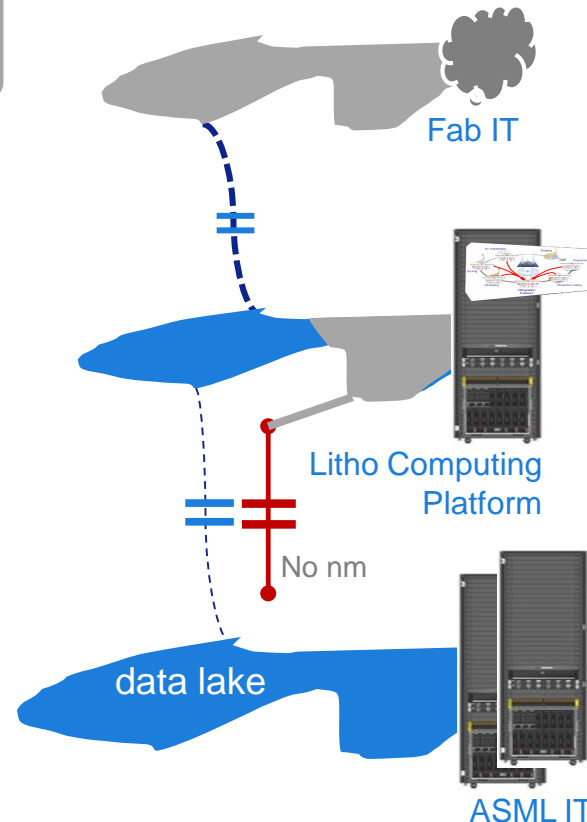
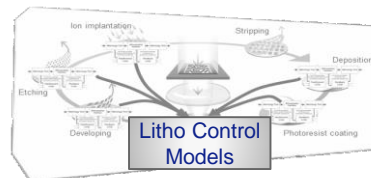


ASML  
machines  
in fab



ASML HQ

Equipment Twin

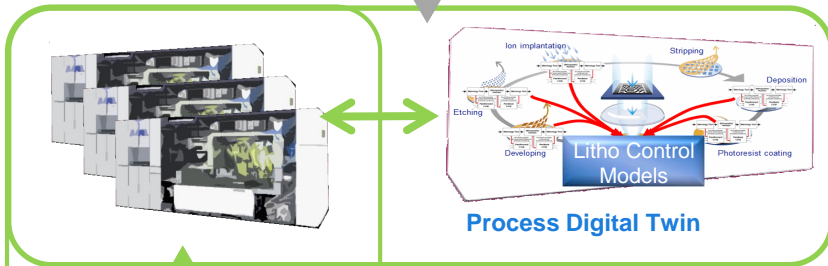


# Two digital twins, not yet happily married

Fab Customer  
nm control

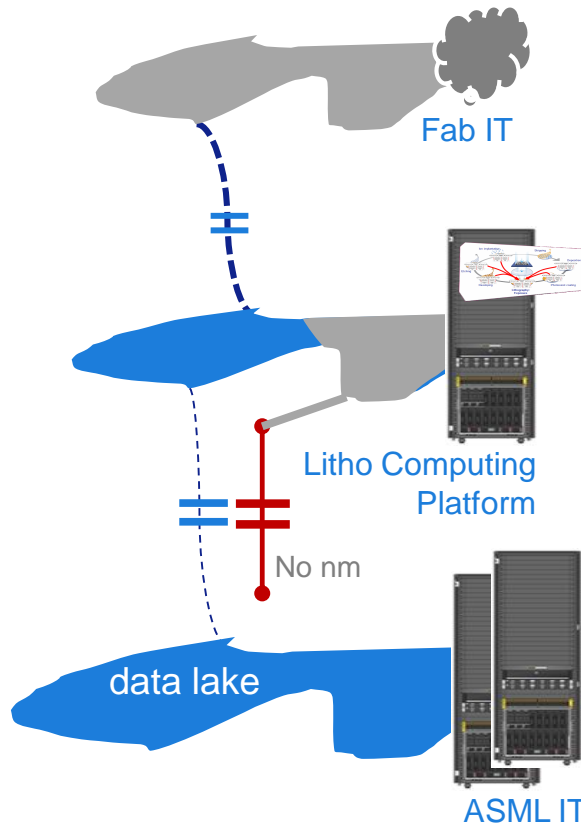


ASML  
machines  
in fab



ASML HQ

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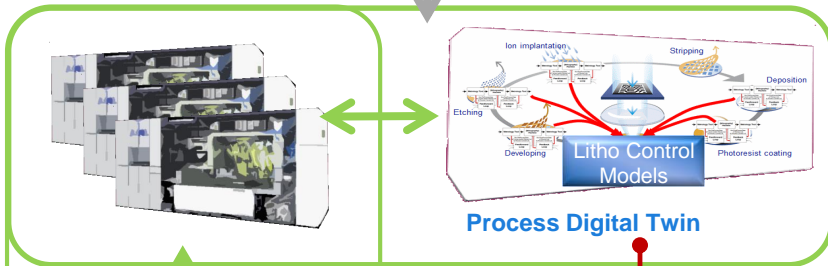


# Two digital twins, happily married

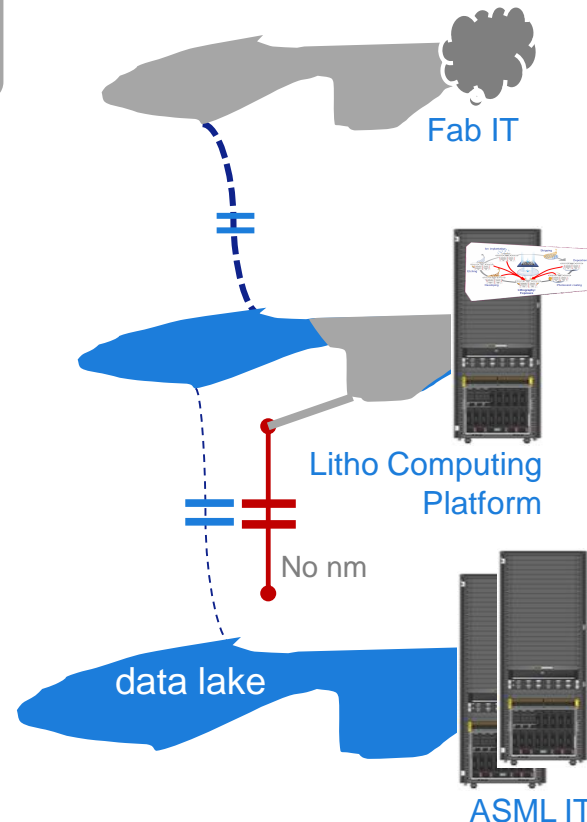
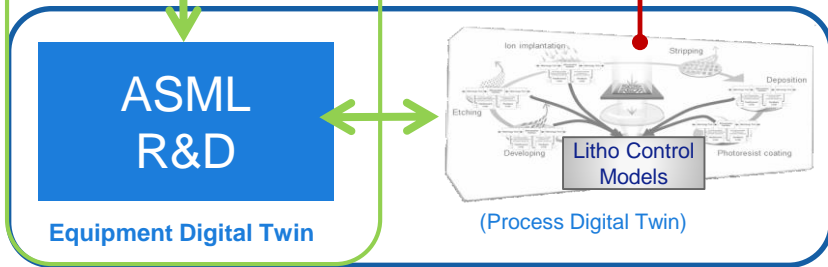
Fab Customer  
nm control



ASML  
machines  
in fab



ASML HQ  
Equipment Twin



## Summary

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Chips are made with data

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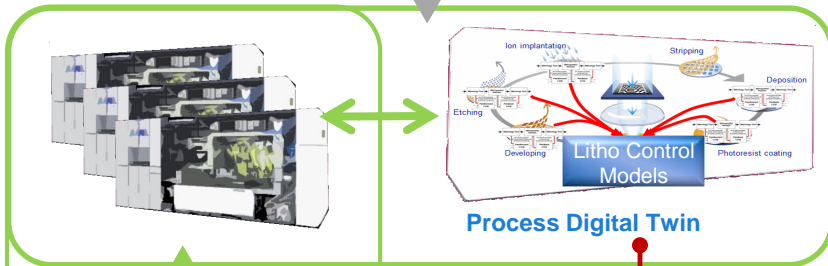
Horizontal integration is the most challenging

# Vertical integration is challenging but doable

Fab Customer  
nm control

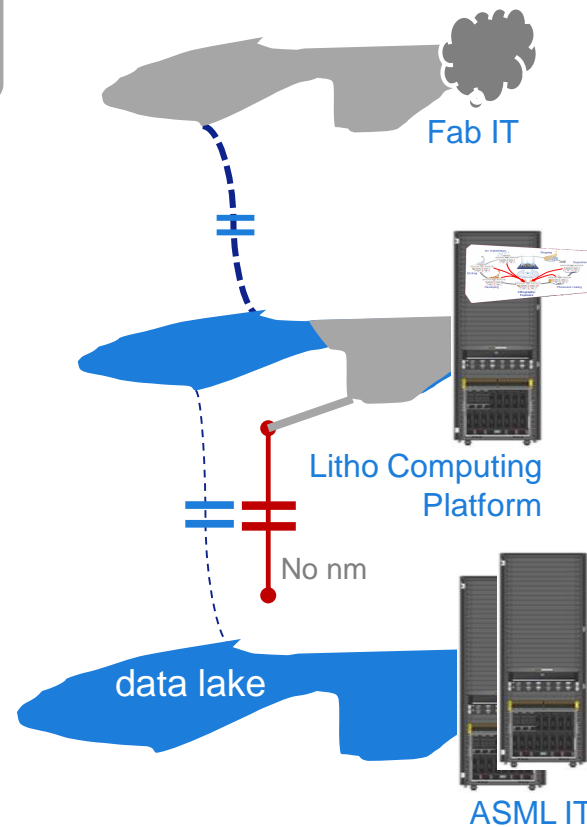
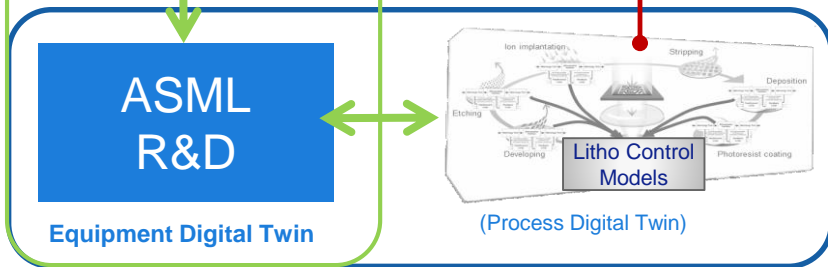


ASML  
machines  
in fab



ASML HQ

Equipment Twin



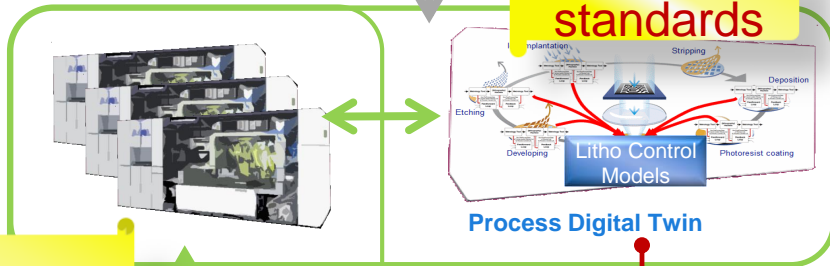
# Vertical integration is challenging but doable

Fab Customer  
nm control



Few standards

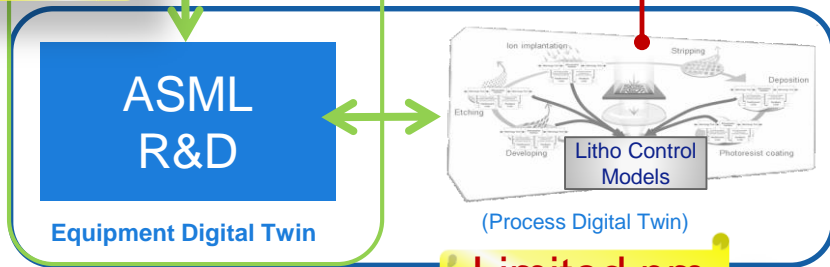
ASML machines in fab



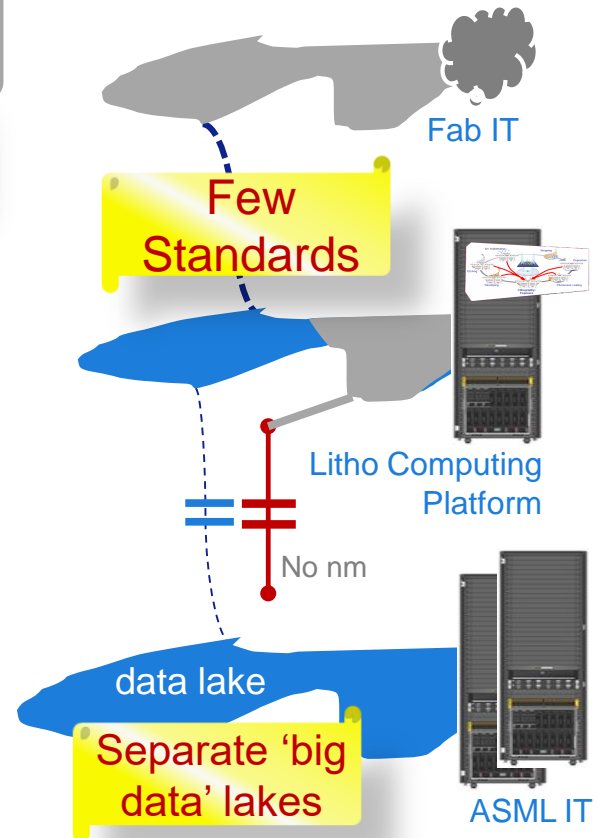
Firewalls

ASML HQ

Equipment Twin



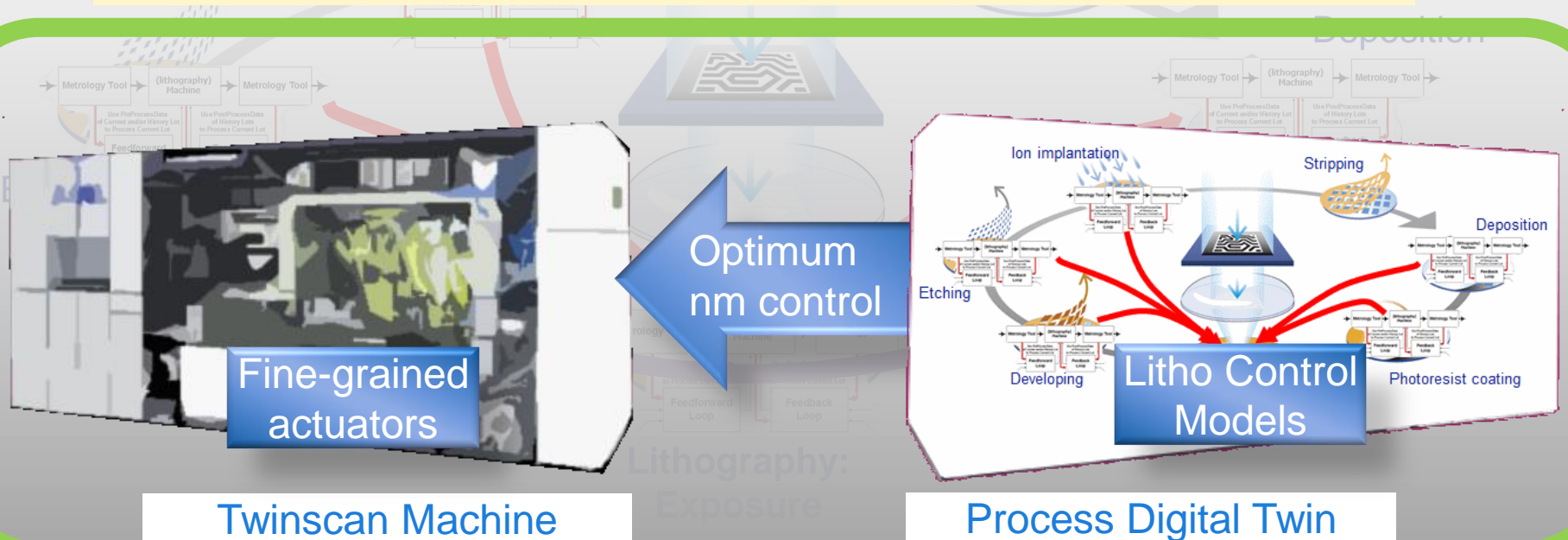
Limited nm data





# Horizontal integration is the most challenging

- This is our customers' expertise and value chain → team up
- ASML does not (can not) get all nm data → link data lakes
- nm control implies ppb (part per billion) accuracy levels: subtle trends, 1:1,000,000 incidents → access to 'all' data needed



# Conclusions

Horizontal and vertical integration happens, driven by economics (i.e. nm gain)

Standards for vertical integration are essential to allow cross-enterprise cooperation to work

Horizontal integration – via teams – requires a way to have interoperable CPS'es and Data Lakes

Recap

ASML is a patterning/lithography company

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Horizontal integration is the most challenging

The image features the ASML logo in a bold, dark blue font on the left side. The background is a light blue gradient with several large, overlapping, curved shapes that create a sense of motion and depth. On the right side, there are numerous thin, white, wavy lines that flow from the center towards the right edge, adding a dynamic and futuristic feel to the overall design.

**ASML**