



# Process mining machine recoveries to reduce downtime

Freerk Jilderda

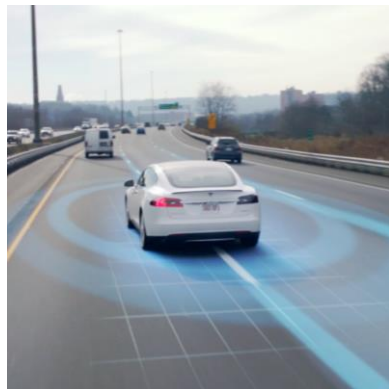
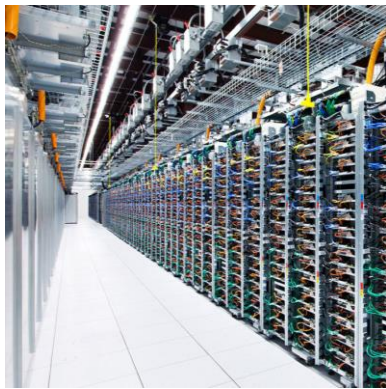
Project Manager - Development & Engineering - Cross Sector Structural Improvements

June 20, 2019 Eindhoven, Netherlands

# Agenda

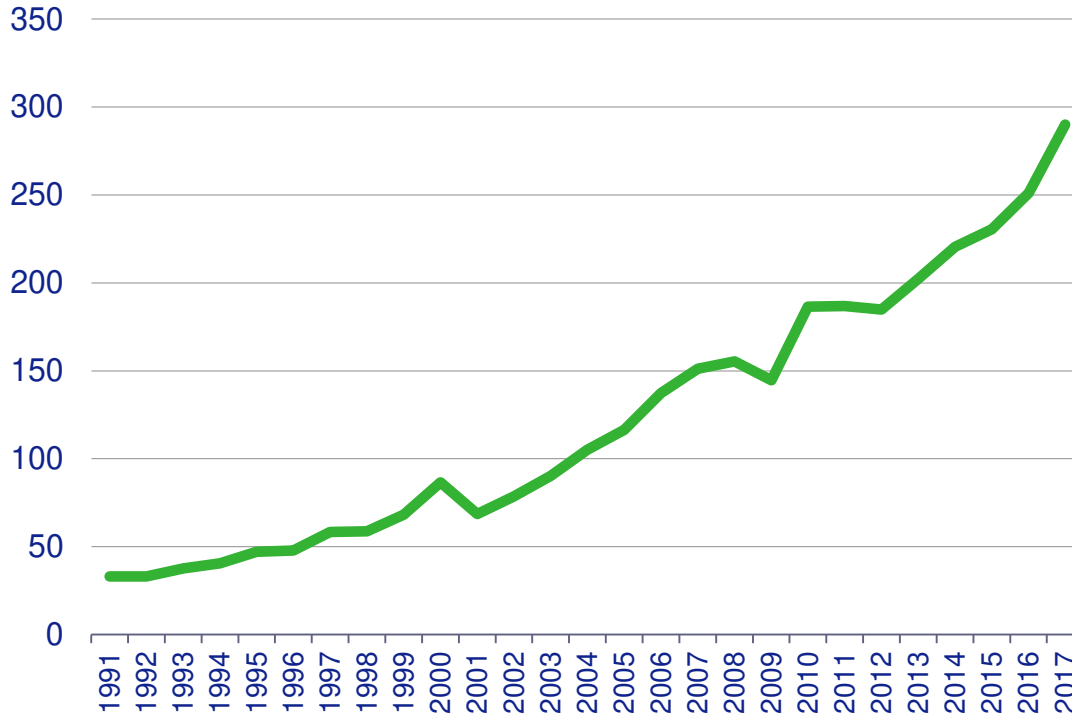
- Introduction to ASML
- Outline of the project
- Examples of findings
- Learnings and way forward

# It's hard to imagine a world without chips



# Nearly 300 billion ICs are made every year

## IC units, in billions



In 2017, 290 billion ICs were produced — nearly 40 for every man, woman and child on the planet.

Global semiconductor industry sales were \$369 billion.

# ASML makes the machines for making those chips




- Lithography is the critical tool for producing chips
- All of the world's top chip makers are our customers
- 2018 sales: €10.9 billion
- More than 23,000 employees (FTE) worldwide

# Founded in 1984 as a spin-off from Philips



# CSI Department

The improvement engine of Design & Engineering

- CSI: Cross sector Structural Improvements ← The CSI logo graphic features the letters 'CSI' in a bold, white, outlined font against a dark green background with a grid pattern and glowing light effects. A blue arrow points from the right side of the logo towards the first bullet point.
- CSI enables a self learning organization by realizing structural improvements with cross sectoral impact based on facts to maximize customer satisfaction
- Skillset:
  - Project management
  - Change management
  - Lean/six sigma
  - Big data analytics
  - Data analytics & visualization

# The project: Recovery Time reduction

Goal: improve system availability for production

**Recovery:** a set of tests and calibrations to get the machine running

**Typical approach so far:** compare best recovery with worst recovery

**New approach in this project:** Analyze machine logs of all machines



# Challenges

- Low number of comparable recovery instances
- Recoveries typically also contain ad-hoc customer specifics
- Identifying recoveries: when did specific recoveries actually happen?



# ABC recovery: potential instances

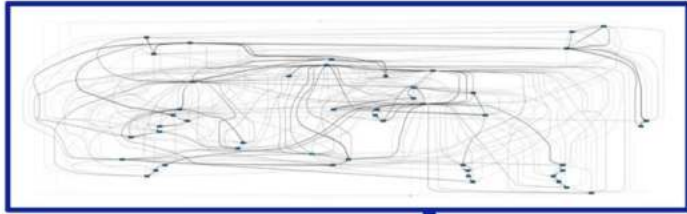
## Scan for concentration of expected tests in event log

COMMERCIAL_TYPE	SW_R_ELEA...	EQUIP_MENT...	2017												2018			
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr			
NXT:1980I	X	1	0.04	0.04	0.24	0.36	0.10	0.06	0.08	0.16	0.80	-	-	-	-			
		2	0.04	0.04	0.06	0.96	0.14	0.18	0.86	0.04	0.14	0.02	0.10	-	-			
		3	0.02	0.02	-	0.02	-	0.10	-	-	-	-	-	0.94	-			
		0.04	0.06	0.96	0.96	0.48	0.06	0.04	0.04	0.18	0.14	0.14	0.66	-				
		0.66	0.94	0.52	0.16	0.18	0.14	0.20	0.24	0.28	0.14	0.18	0.04	0.02				
		0.42	0.66	0.16	-	-	0.42	0.04	0.14	0.26	0.92	0.22	0.04	-				
		-	-	-	-	-	-	-	-	-	0.96	0.24	0.04	0.04	0.02			
		-	-	-	-	-	-	-	-	-	-	-	0.96	0.04	0.04			
		-	-	-	-	-	-	-	-	-	-	-	-	0.96	0.04			
		-	-	-	-	-	-	-	-	-	-	-	-	-	0.96			
NXT:1980I	y	0.08	0.02	0.92	0.08	0.14	0.04	0.02	0.04	0.12	0.14	-	-	-				
		0.02	0.14	0.22	0.06	0.22	0.50	0.10	0.28	0.96	0.30	0.28	0.46	0.02				
		0.22	0.16	0.08	0.02	0.02	0.22	0.12	0.14	0.02	-	0.14	0.02	-				
		0.02	0.04	0.22	0.10	0.22	0.22	0.18	0.08	0.90	0.78	0.20	0.14	0.02				
		-	-	0.16	0.22	0.28	0.10	0.16	0.26	0.06	0.50	0.04	0.74	0.48				
		-	-	-	-	-	-	-	-	-	-	-	-	-	-			

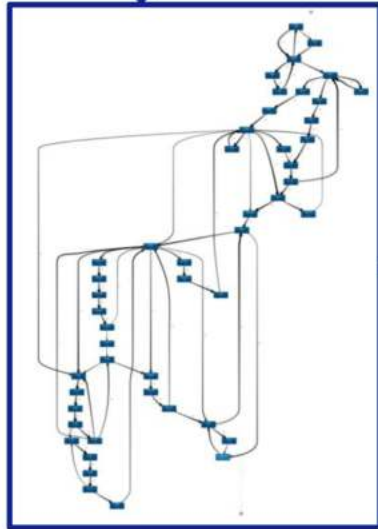
- 14 potential recovery moments detected
- 3x no matching hardware Material Notification but after manual check, recovery was included in analysis

# Total view ABC recovery

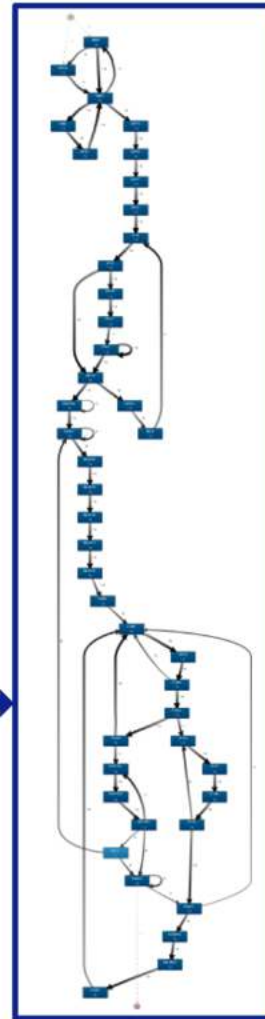
How to simplify the process picture



Total process



Structural process

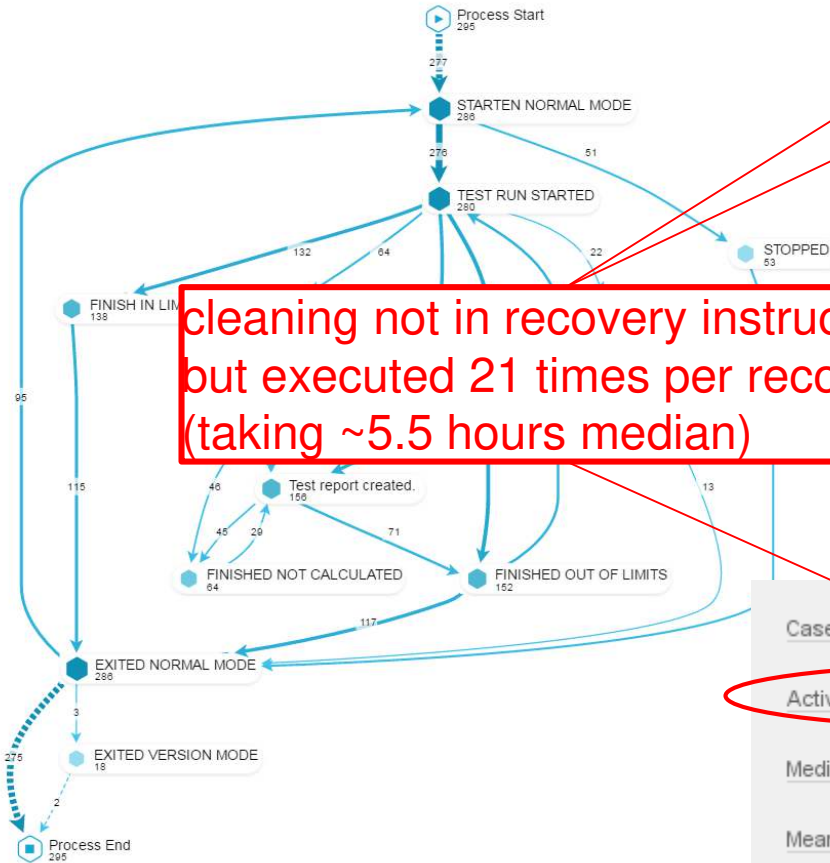


Structural process  
without spider activities

Spider activities can be  
found as idle time

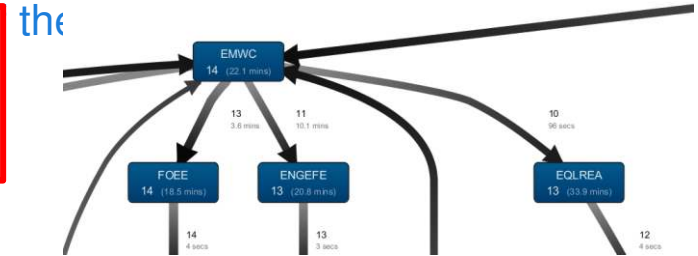
# Example: Analysis of 14 ABC recoveries

## Example of finding 1

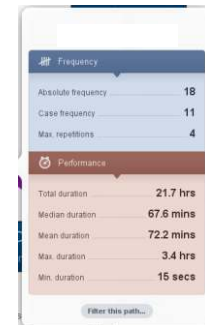


cleaning not in recovery instruction, but executed 21 times per recovery (taking ~5.5 hours median)

- 67/295 need a cleaning action is needed!
- Cleaning is not in guideline/instruction sequence
- Cleaning is used structurally on 4 positions



Cases	295
Activities	21
Median case duration	16.3 mins
Mean case duration	32.3 mins

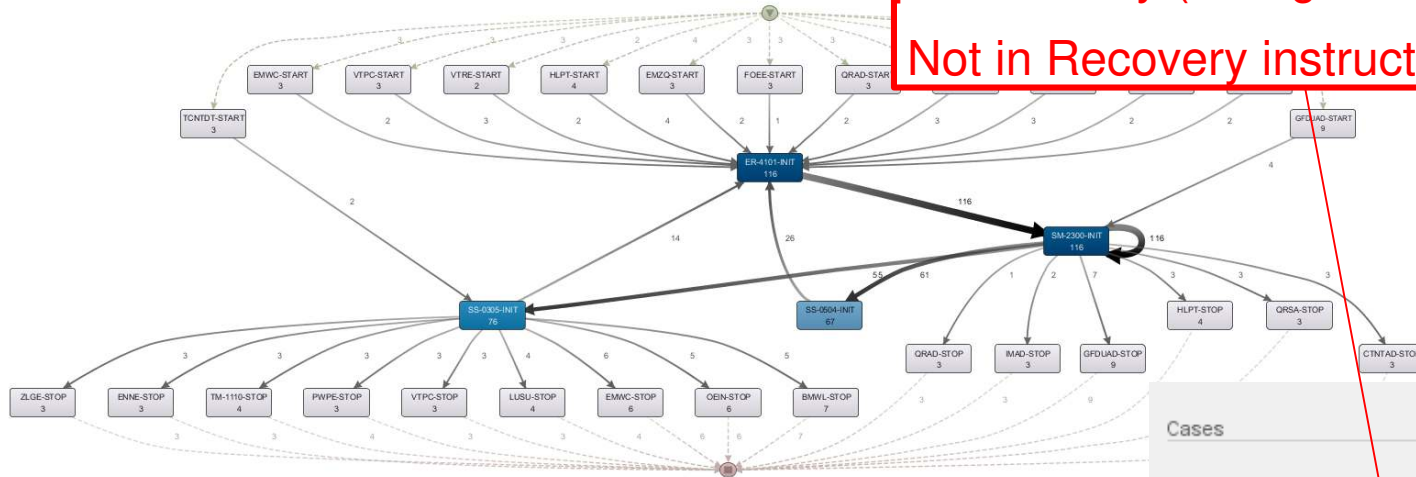


# ABC recovery – frequency of initialization type x

Example of finding 2

116 cases in 14 recoveries

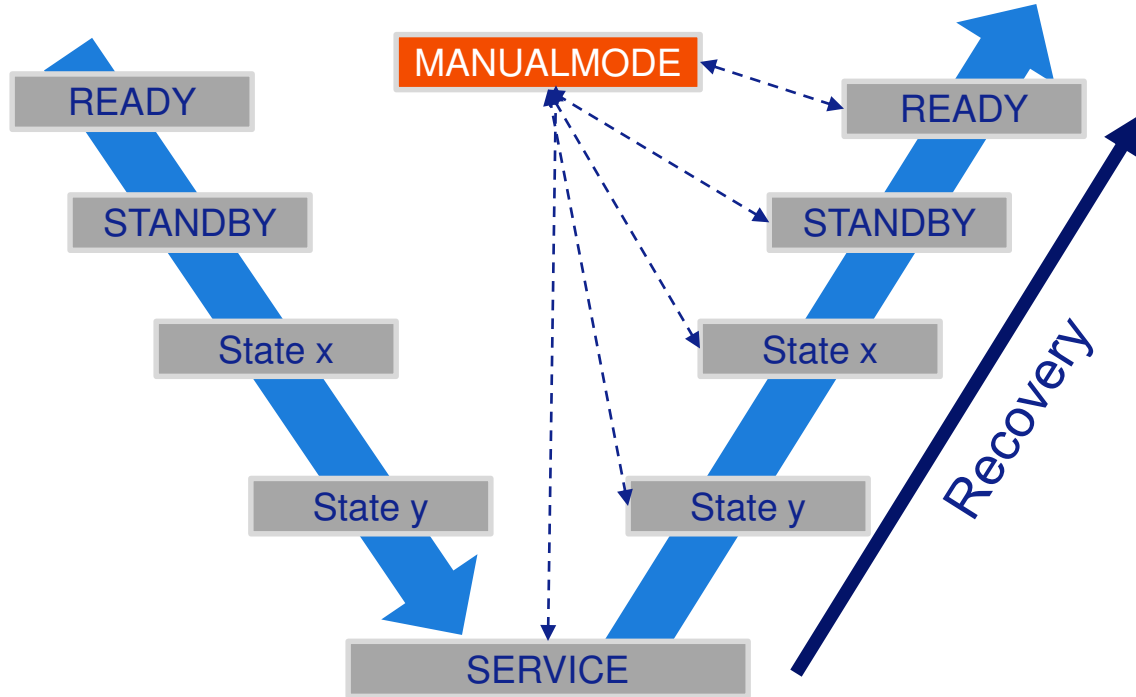
Initialization type x executed 8 times per recovery (taking ~8 hours median)  
Not in Recovery instruction



Cases	116
Activities	130
Median case duration	68.9 mins
Mean case duration	2.8 hrs
Start	02.05.2017 10:55:00
End	31.03.2018 07:31:20

# Example 2: EUV Source State

Desired behavior: prevent usage of manual mode

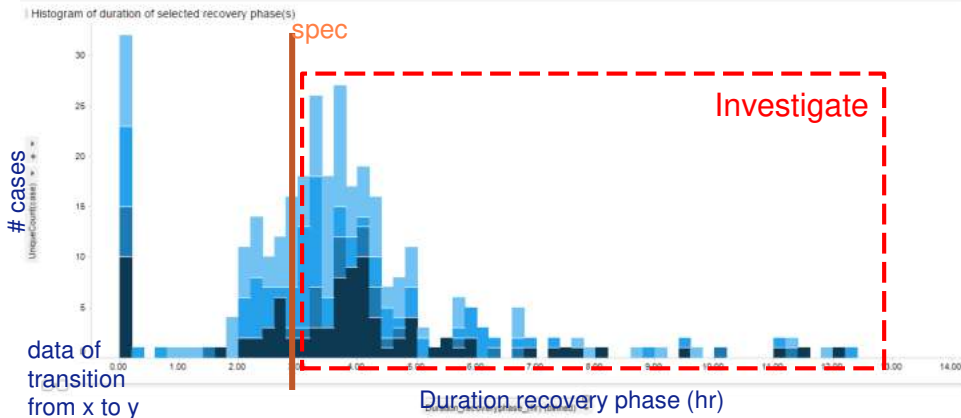


- State transitions should be automatic
- Duration should be within time budget

# Example 2: EUV source recoveries

Frequent use of manual mode and state transitions longer than budgeted

1. Quantify actual use of manual mode + where in recovery flow
  - a. Manual mode occurs from every state, in  $x\%$  of all cases, and  $y$  times on average
2. Recovery state transitions within budget?
  - a. Quantify time actuals for state transitions
  - b. Identify mismatch and which projects need to investigate





# Learnings

- Process mining helps to visualize and quantify assumptions
- Combining domain expertise and process mining/data preparation expertise is essential for good results
- High variation in processes makes recoveries hard to compare
- Data preparation took a lot of time and effort

# How does it continue

- Findings translated into design improvements
- Customer support department trained to use process mining
- Process mining added to CSI toolbox
- Promote further use of process mining in ASML

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 decorative elements: a large, semi-transparent blue arc in the upper left; a series of thin, white, wavy lines that originate from the right side of the ASML text and extend across the lower half of the image; and a solid blue gradient in the upper right.

**ASML**

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