Efficient & Comprehensive FMECAs: Harnessing the Power of MBSE Models in Capella

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Systems Engineering, Applied Materials

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make possible

AGENDA

Applied Materials Introduction

Development of Electrostatic chucks using MBSE Methodology

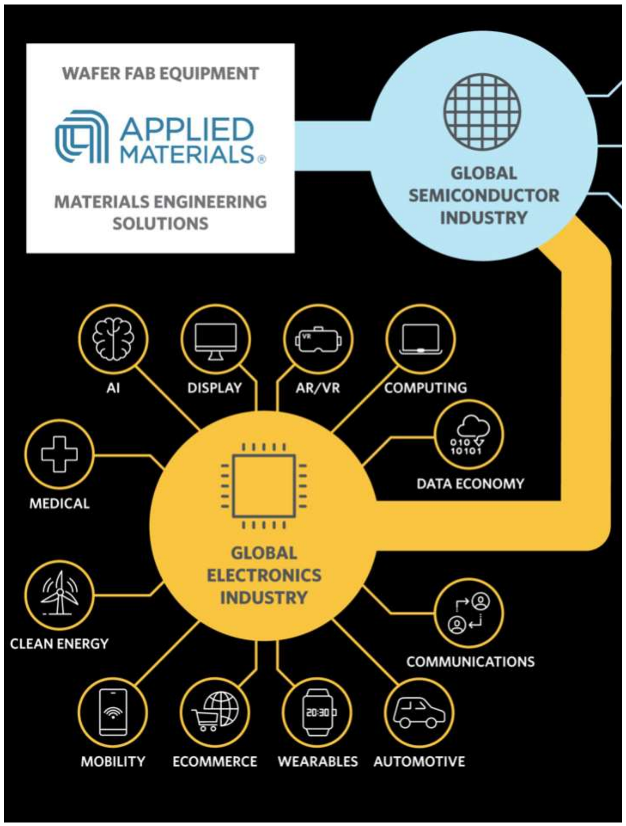
FMECA from MBSE models

Implementation & Advantages

Future work

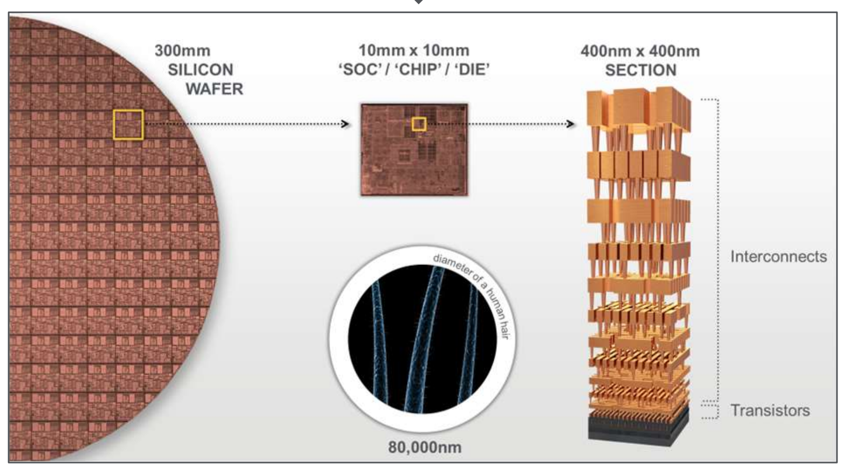
Magic behind chips! | Applied Materials

Applied Materials is the equipment maker for semiconductor and display systems



Anatomy of a Manufacturing Tool

Complex multi-disciplinary systems



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Product development & MBSE

MBSE approach advantages

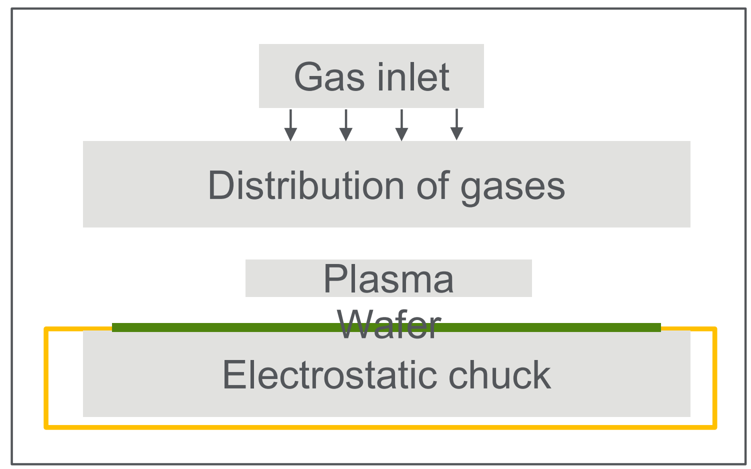
- **Wafer performance** → Precision control on process parameters
- Building system of systems
- Shrink product development cycle
- Market inflections
- Changing customer needs

Gas delivery

Plasma distribution

Heat distribution

↓ Node size / Tolerance



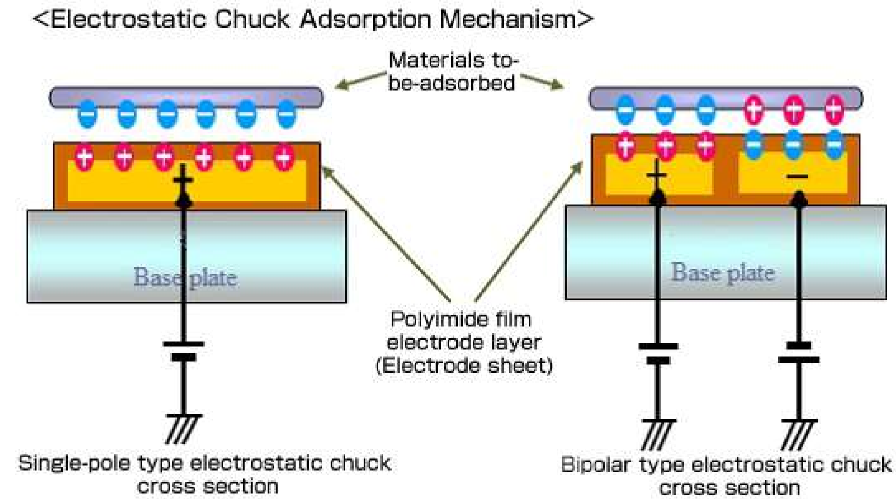
Schematic of wafer supported by electrostatic chuck

Electrostatic chuck

- Hold the wafer during process
- Heat/cool the wafer
- Support plasma process

Process critical

Wafer thickness uniformity and electrical properties



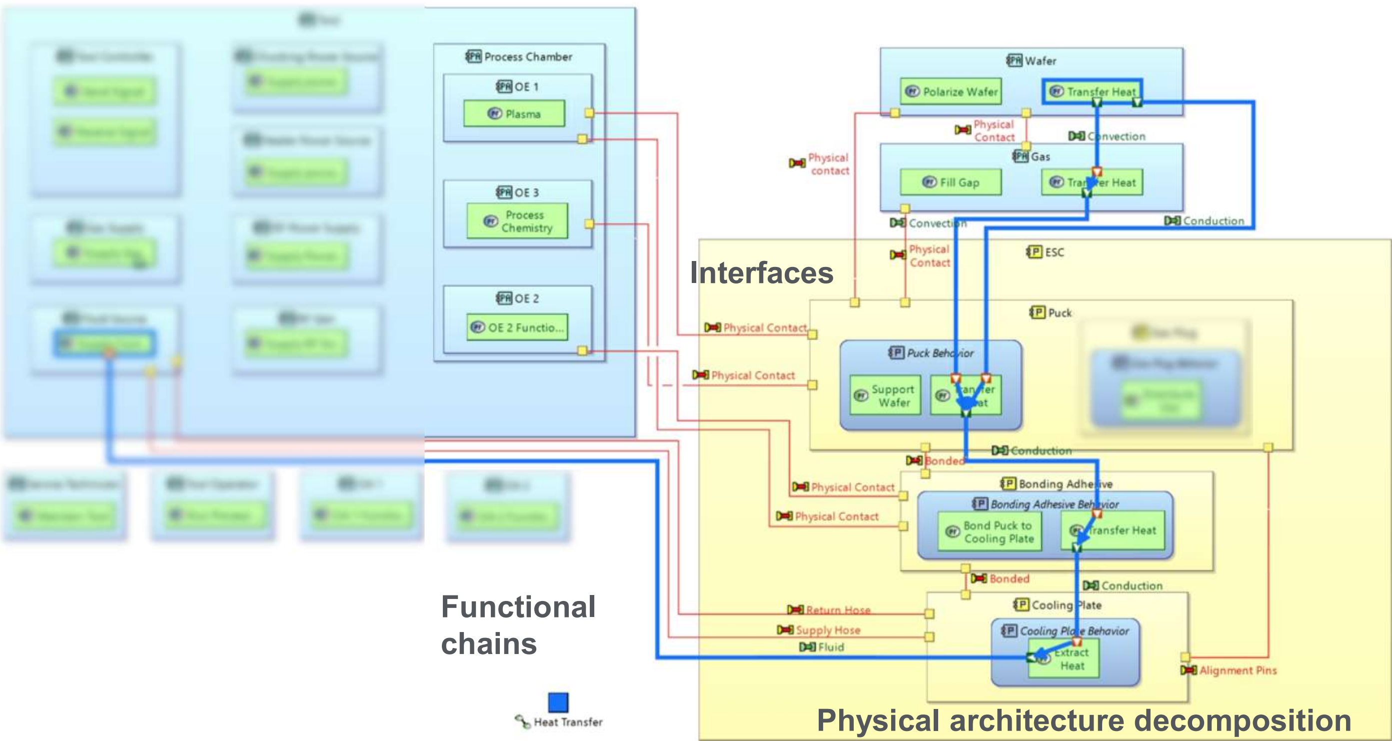
https://www.tomoegawa.co.jp/english/product/electro/seiden_chaku.html

- Multi-physics functionalities
- Different operating mechanisms
- Complex structure

MBSE driven design for E-chuck

MBSE model for E-chucks is built for

- Process requirements traceability
- Library of Standardized of E-chucks
- Knowledge Capture for future iterations



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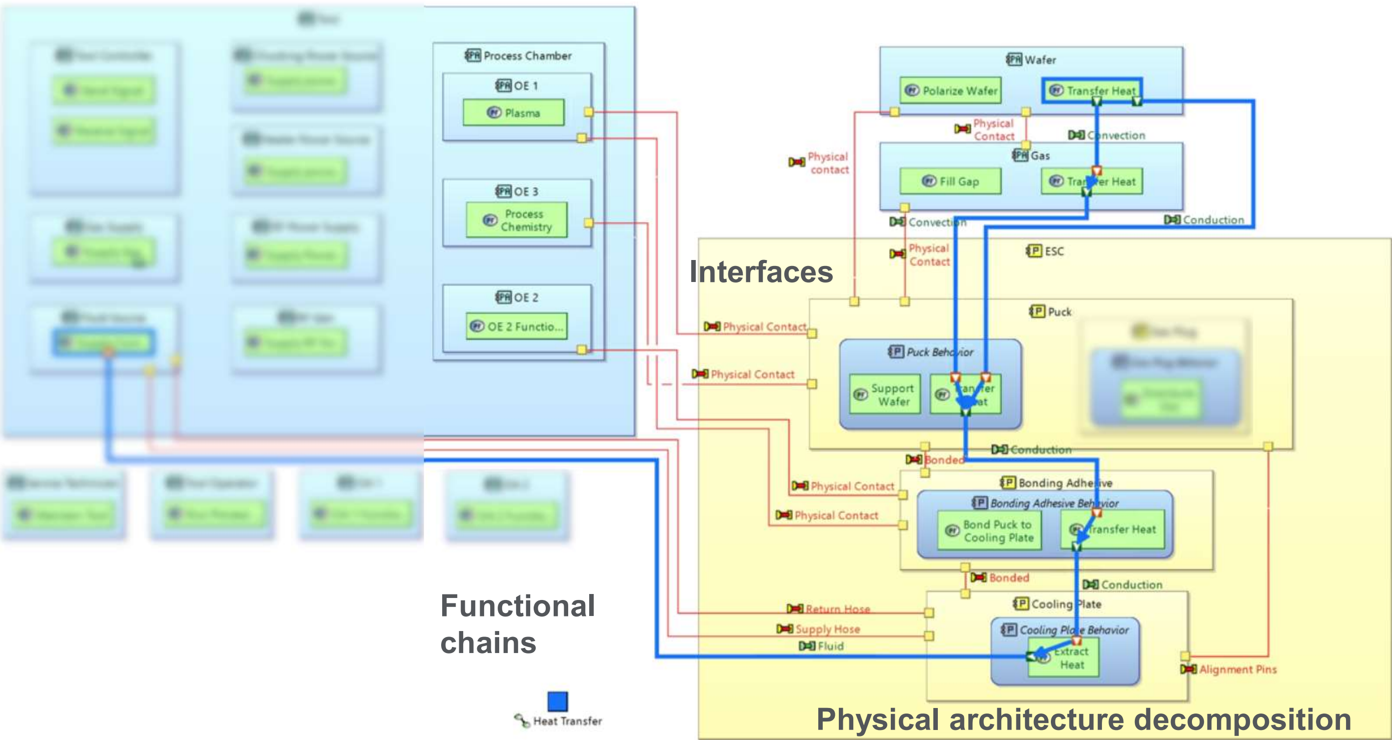


Can the MBSE model derive FMECA matrix?

?

Failure modes

System Interactions

Impact of Failure Modes

Likelihood of Occurrence

FMECA: Failure Modes, Effects, & Criticality Analysis

- What is a FMEA / FMECA ?
  - FMEA / FMECA is a **systematic and structured approach** used to identify and prioritize potential failure modes of a system, process, or product, assess their effects on system performance or safety, and determine their criticality based on severity, occurrence, and detection.

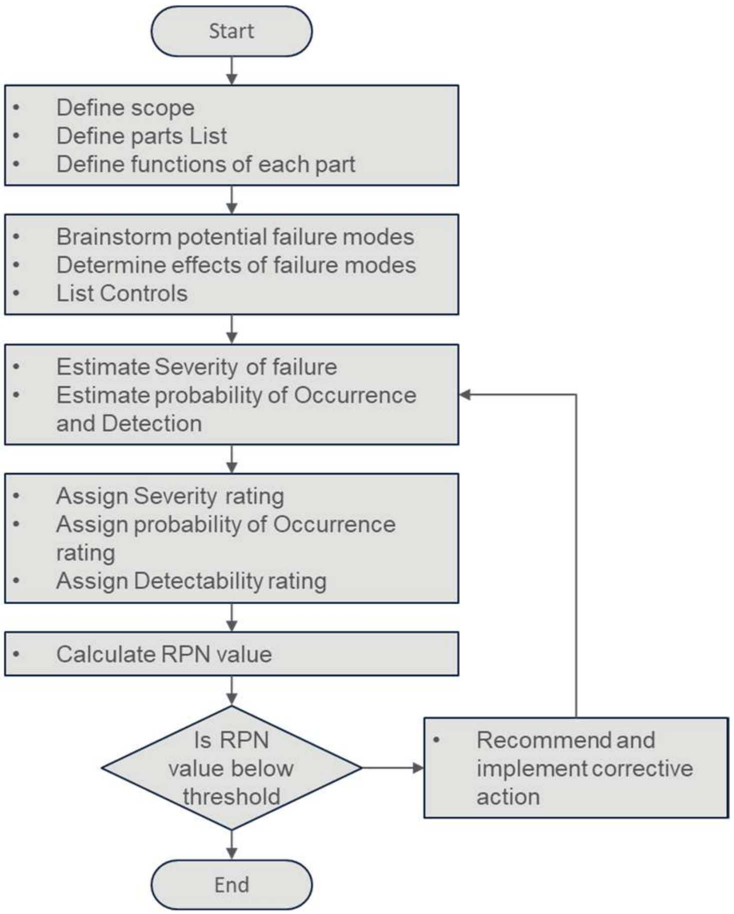
- FMECAs were first used by the US Military in the 1940s and adopted by NASA in the 1960s for the Apollo missions.

- Today, the use of FMECAs has expanded to other industries like Semiconductors, Energy, Aviation, Automotive, Electronics, Railways, Medical Devices, Pharmaceuticals, and even Banking and Financial Services.

- Common types of FMECAs:

Software FMECA	Process FMECA	Functional FMECA	Hardware FMECA	System FMECA	Safety FMECA

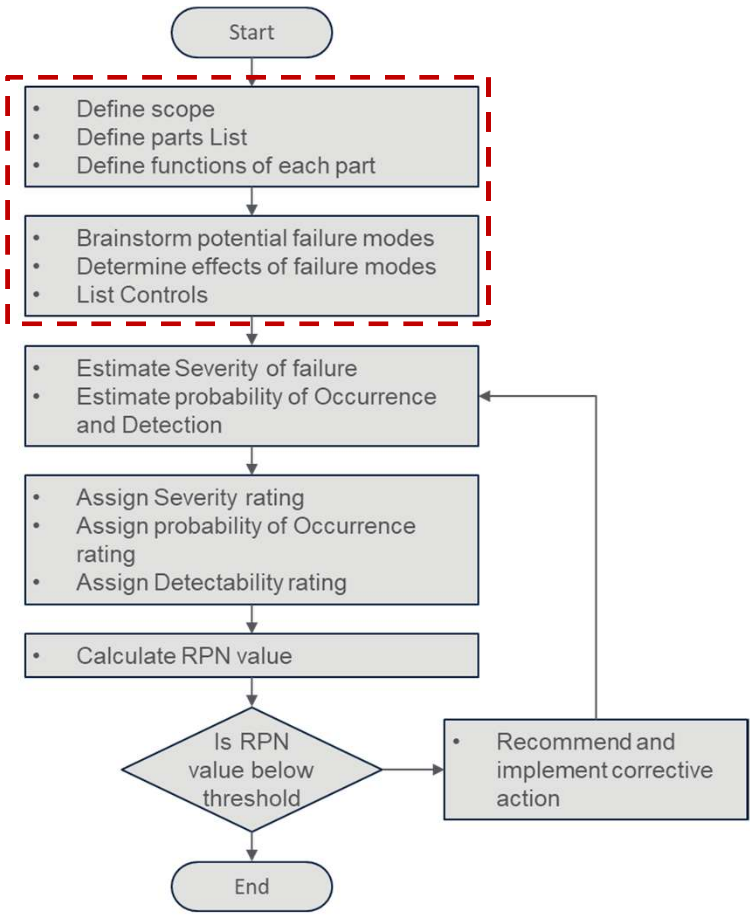
Typical Design FMECA Process



Parts	Functions	Potential Failure Mode	Effects of Failure Mode	Possible Causes of Failure/Defect	Severity (S)	Occurrence (O)	Criticality = (S X O)	Recommended Preventive Actions	Action Owner and Commit Date

Example of a FMECA Template

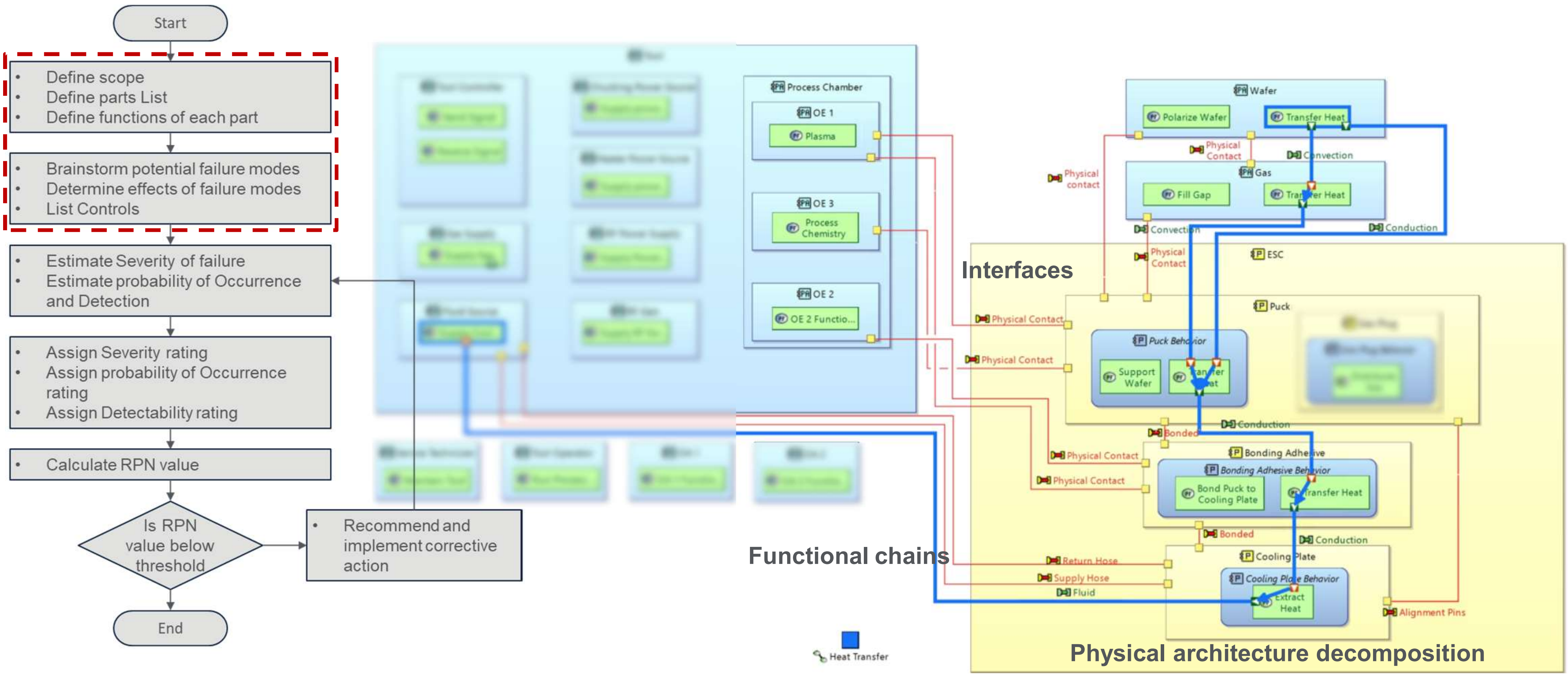
Shortcomings of Current Process



Impact of not identifying all failure modes

- Incomplete risk assessment
- Uncertain mitigation actions
- Increased probability of system failure
- Inadequate & missed opportunities for design improvements
- Cost and time overruns
- Safety and liability risks

Leveraging MBSE Models for FMECAs



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Building FMECA matrix from MBSE model

- Select the applicable diagram to export information from
- Identify the scope of the system
- Identify FMECA template and modify as needed for new information being added to it
- Report out
  - » List of Physical Components
  - » Functions for each physical component
  - » Functional exchanges
  - » Physical Links
- Get feedback from team and edit reported information or template as needed

- Python libraries used:
  - Openpyxl
  - Python4capella libraries

Components	Functions; Functional Exchange; Physical Links	Part 1	Part 2	Potential Failure Mode	Effects of Failure Mode	Possible Causes of Failure/Defect
Puck	Support Wafer					
	Transfer Heat					
	Conduction	Puck	Wafer			
	Convection	Puck	Backside Gas			
	Conduction	Puck	Bonding Adhesive			
	Physical Contact	Puck	Wafer			
	Physical Contact	Puck	Backside Gas			
	Physical Contact	Puck	Plasma			
	Physical Contact	Puck	Process Chemistry			
	Bonded	Puck	Bonding Adhesive			
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Advantages & Next steps

- A comprehensive list of failure modes that includes component-level functions as well as system-level interactions
- Increased efficiency by pre-populating failure modes for the project team to analyze
- Leverages the MBSE benefit of "knowledge capture" and reduces reliance on undocumented expertise
- Ability to customize the export from MBSE model into an existing FMECA template
- Existing Python libraries make the export process more efficient

- Leverage the feature of Functional Chains to auto-populate the *Effects of Failure Mode* column
- Use the *Description* tab for other Capella objects to document Severity ratings
- Expand the use of this methodology to create other types of FMECAs (eg: Safety FMECA)
- Import relevant information from other sources into the FMECA (as part of an org-level Digital Thread) –
  - Failure rates
  - Part Numbers
  - Validation data

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Thank You!

- Thank You for attending!
- Reach out to us for more information!
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