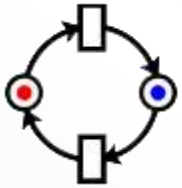

System Architectures Laboratory

Cluster Tool Simulation:

Implant Source Life and Recipe Scheduling

Cluster Tool Simulation Group (CTSG)
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Agenda

- Sponsor
- Background
- Problem Statement
- Scope & Objectives
- Approach
- Sample Analysis
- Results
- Recommendations
- Summary
- Possible Future Work

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Sponsor

System Architectures Laboratory (SAL)

- Conducts research in the modeling of system architectures
- Currently working on issues in semiconductor manufacturing with Micron Technology (our previous sponsor and a current stakeholder)
- Interested in the analysis of cluster tools to improve process performance

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Background

Semiconductor processing in Virginia:

- **One of the largest exports in state of VA***
- **Exceeds tobacco revenue and coal production**

VA is home to a number of semiconductor manufacturing companies:

- **Micron Technology**
- **White Oak Semiconductors**
- **Free-scale Semiconductors (formerly Motorola)**

Source: Northern Virginia Technology Council (NVTC)

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Cluster Tools

Cluster tools

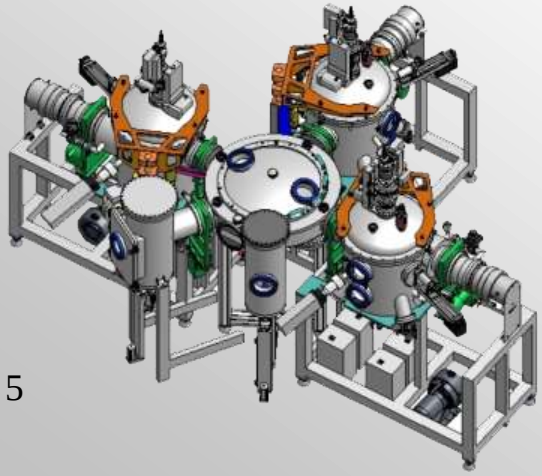
- **Semiconductor processing systems**
- **Used in microelectronics manufacturing**

Composition

- **Robots, elevators, various chambers, etc.**

Tool of interest

- **Implant tool**
- **Creates layers of specific elements through implantation**



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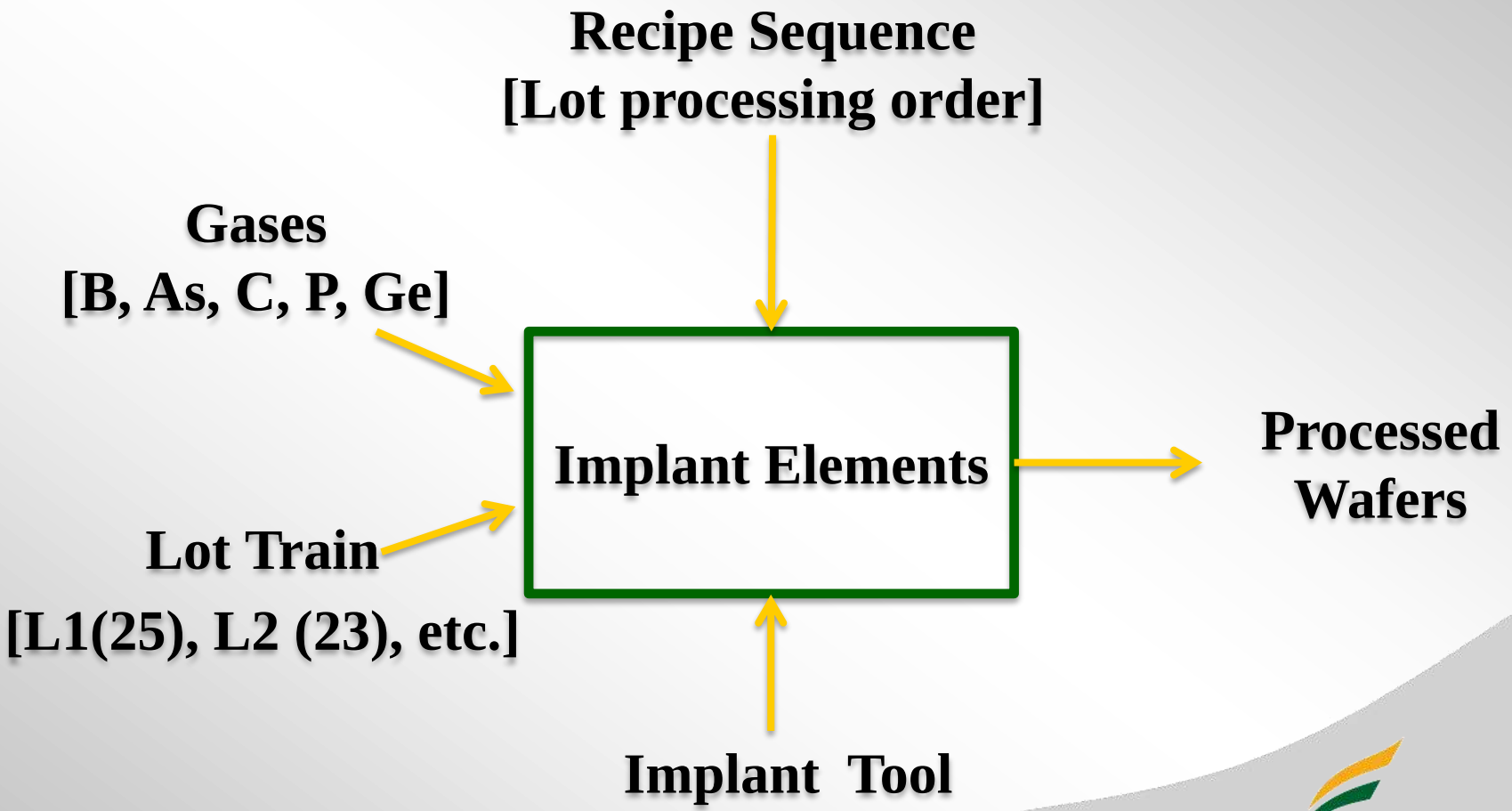
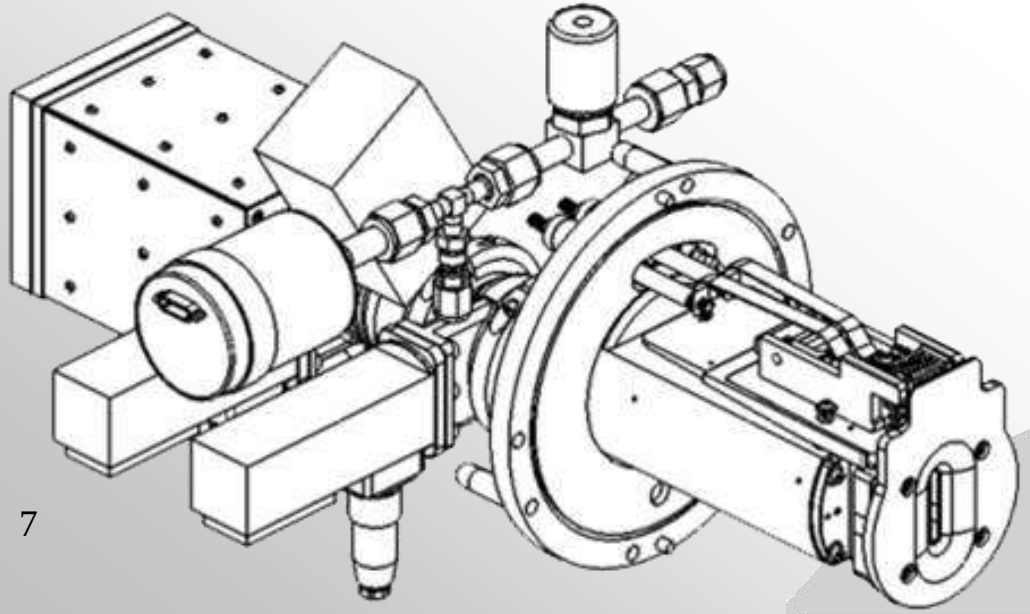
Implant Process



Ion Source

The Implant tool utilizes an ion source to generate plasma for implantation

The ion source has a limited lifetime, which is affected by the recipes used during implantation.



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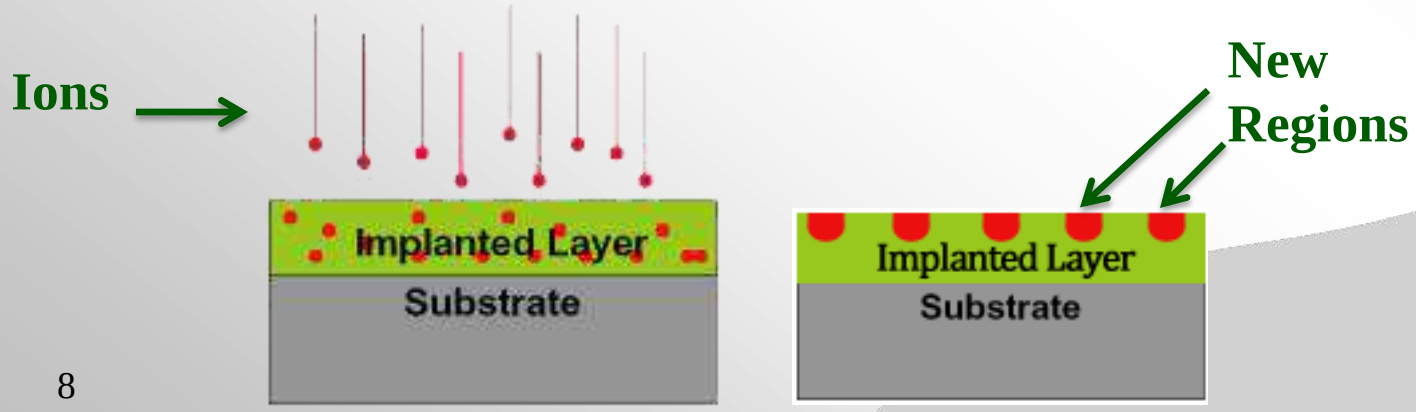
Implant Process

Shower wafers' surface with an ion beam to create layers of positively/negatively charged elements

The layers can be made of Boron (B), Arsenic (As), Carbon (C), Phosphorous (P), and Germanium (Ge)



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Recipe Sequencing

Used to improve the throughput of implant tools

Organizes recipes to minimize processing time

Set-up times between recipes affect the processing time of the lot train.

Ex 1:

lot train=[L1,L2,L3,L4], recipe sequence=[B,B,C,As]

processing time = 2 hours

Ex 2:

lot train=[L1,L3,L2,L4], recipe sequence=[B,C,B,As]

processing time = 3 hours

Problem Statement

Current recipe sequencing doesn't take source deterioration into account, resulting in:

- **Short and unpredictable source life**
- **Frequent and costly source changes**
- **Extended set-up times from instability**
- **Potentially less than optimal throughput**
- **Lost productivity due to reduced tool availability**

There's a need for a tool to aid in the scheduling of lots to:

- **Extend implant tool availability**
- **Increase tool throughput**

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Scope & Objectives

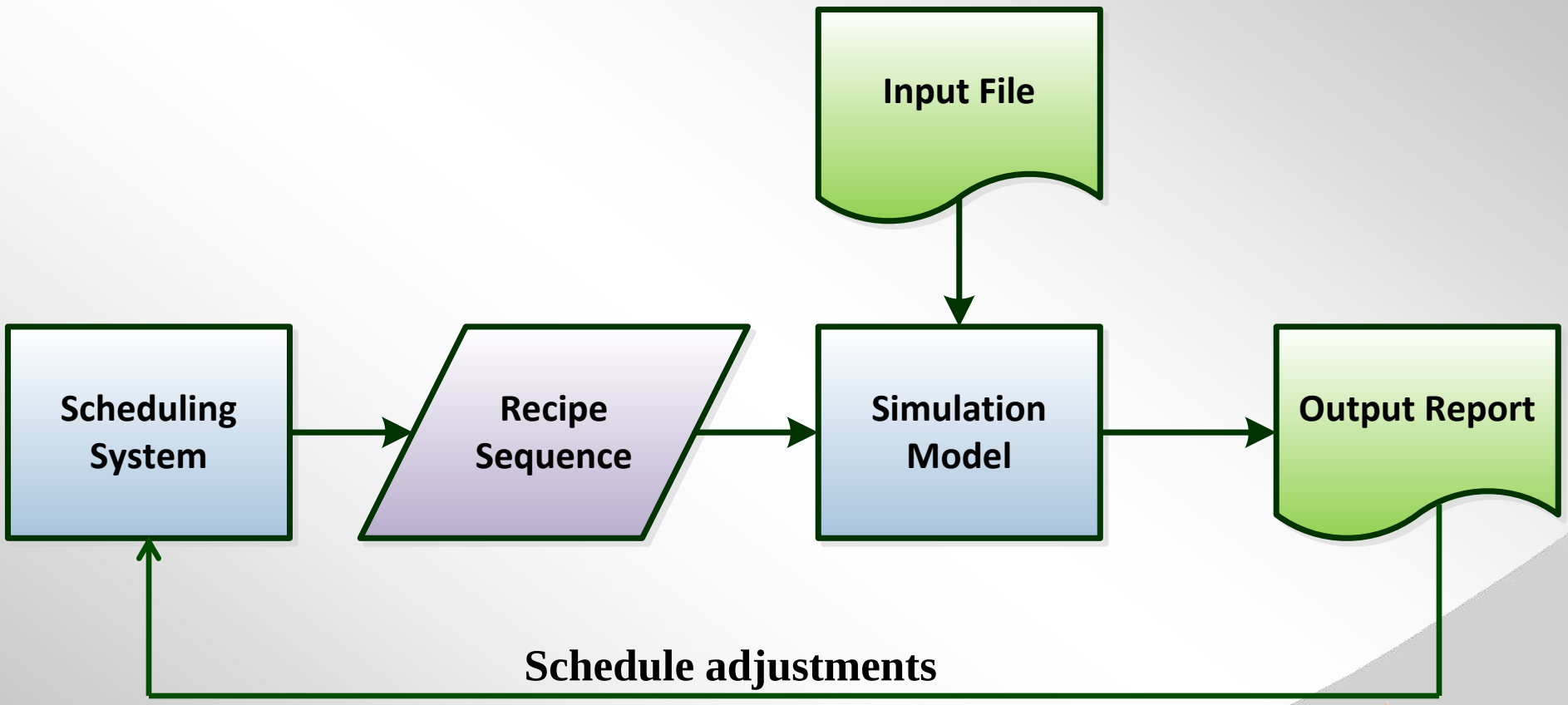
Scope:

- **Model the behavior of 1 implant tool with ion source deterioration.**

Objectives:

- **Application of a systems engineering approach to cluster tool modeling**
- **Development of an executable model that can simulate an implant tool with ion source deterioration**

Approach Flow



Previous Sponsor

Had to provide

- **Ion source deterioration information**
- **Scheduling algorithms to run on the simulation model**

Unfortunately this was proprietary information

We developed mechanisms to test the simulation model

- **Simple schedules through algorithms**
- **User defined ion source deterioration due to recipes**

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Modeling Assumptions

- All lots are available at time zero
- The only delays between lot processing are the recipe set-up times
- Assumed random distributions to illustrate deterioration for demonstration purposes

Simulation Model

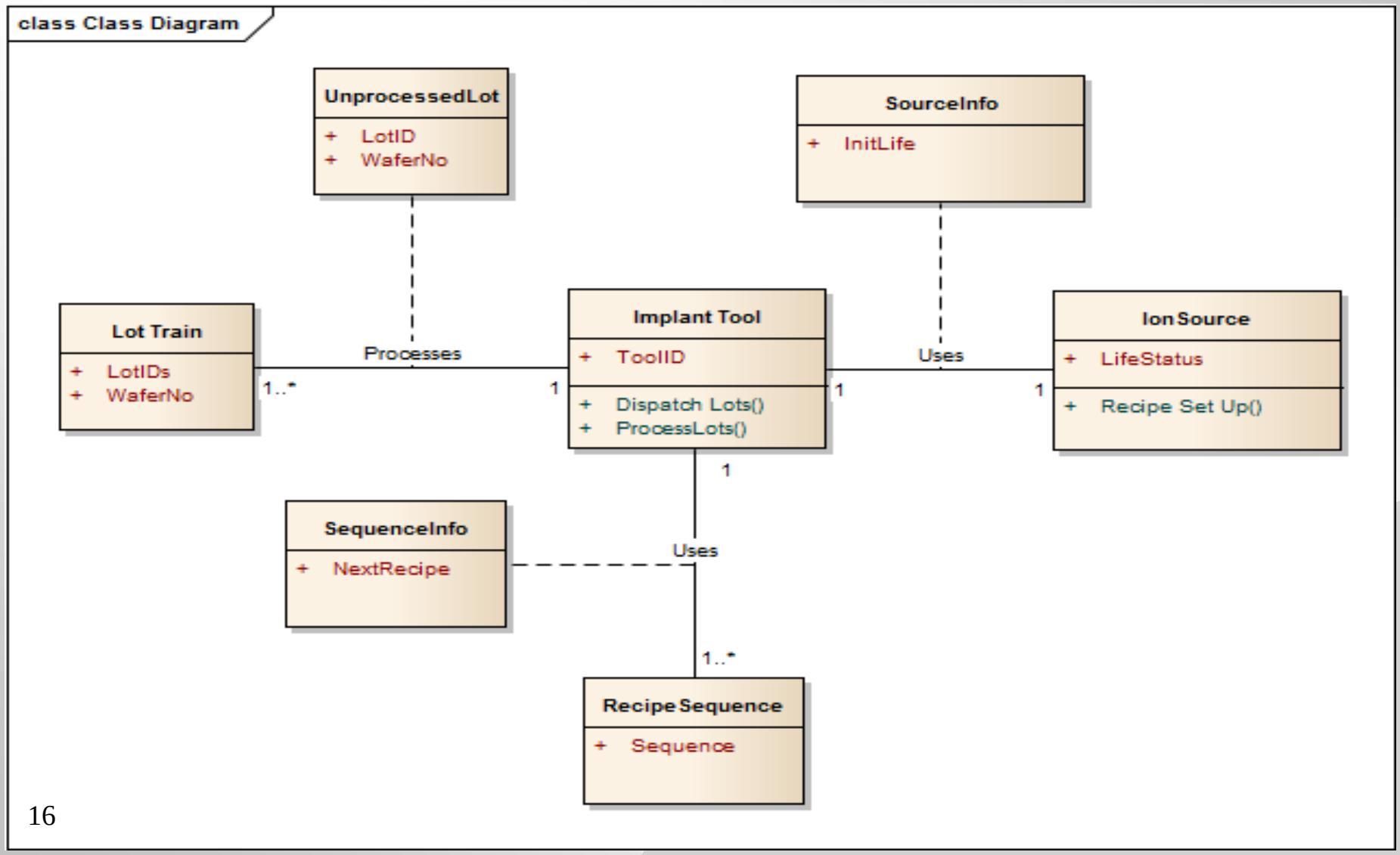
Unified Modeling Language (UML)

- **Used to develop object oriented diagrams for implant tool description**

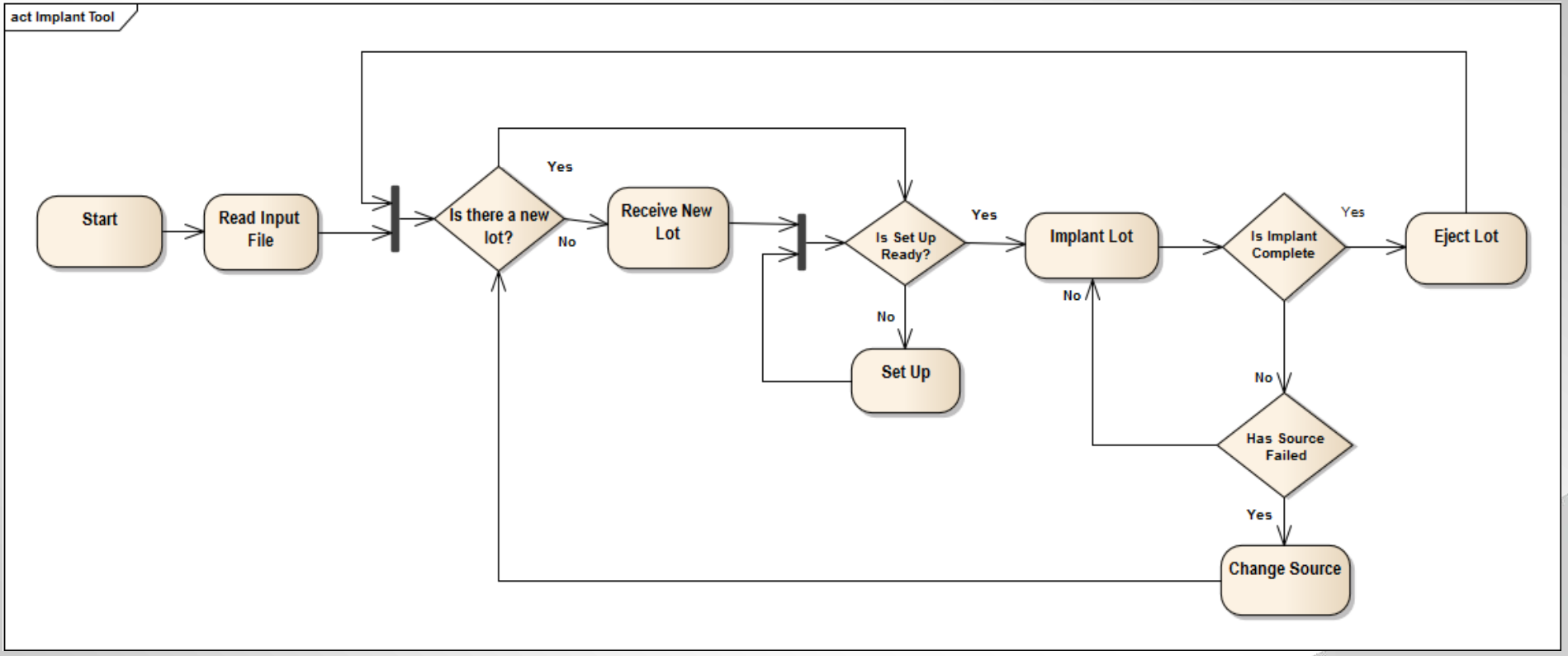
Colored Petri Nets (CPN)

- **Used to develop the implant tool simulation executable model**

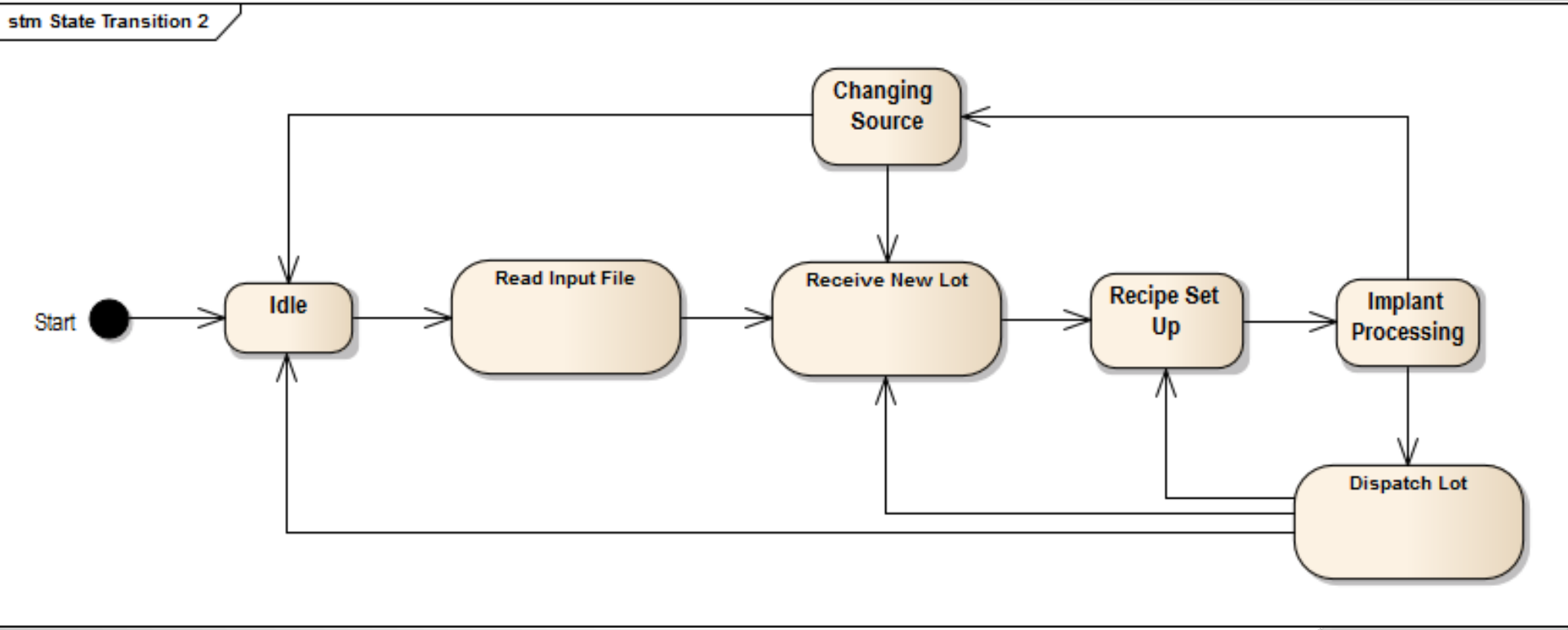
Class Diagram



Activity Diagram



State Transition Diagram



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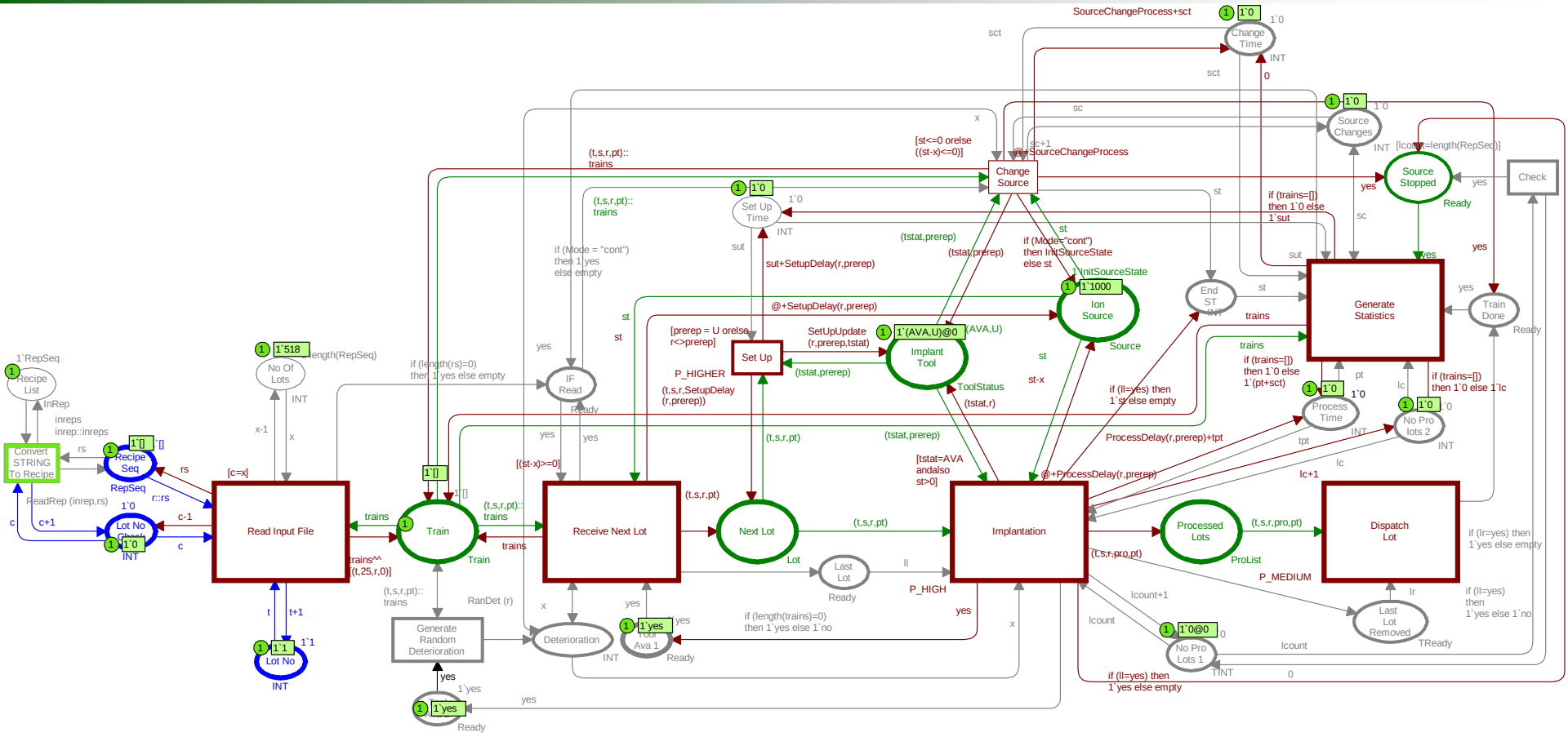
CPN Model



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CPN Model (Cont.)

Has two modes of operation

- Continuous
  - Processes all lots making the necessary source changes
- Failure
  - Only processes as many lots as one source permits

Takes information about

- Recipe processing times
- Set-up times
- Recipe source deterioration
  - Deterministic or random

CPN Model (Cont.)

Provides information about:

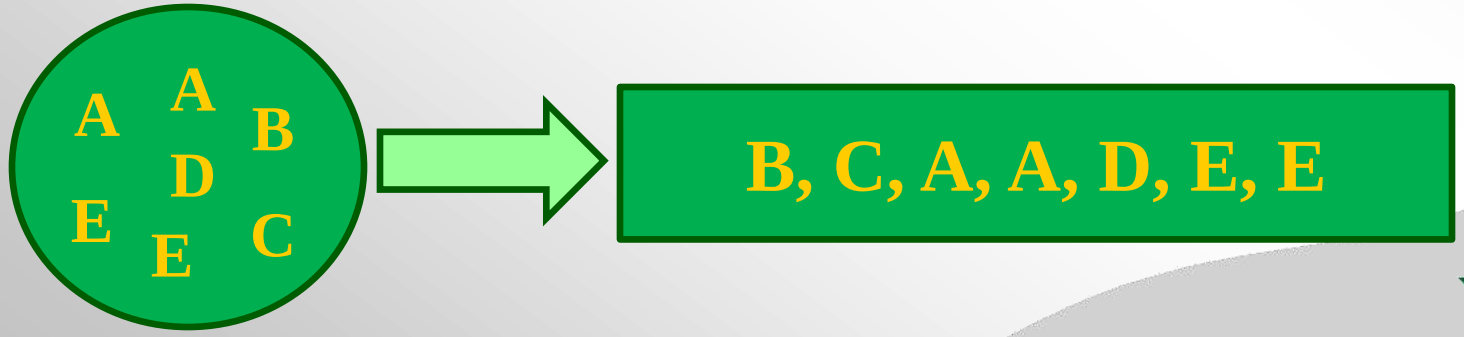
- **Lots**
  - **Start and end times**
  - **Number of processed and unprocessed lots**
- **Processing times**
  - **Total implantation time**
  - **Total set-up time**
- **Ion source**
  - **Deterioration**
  - **Number of changes**

Scheduling System

Developed to organize lots for demonstration of the use of the simulation tool

Scheduling algorithms:

- **Shortest job greedy**
- **Longest job greedy**
- **Permutation algorithm**



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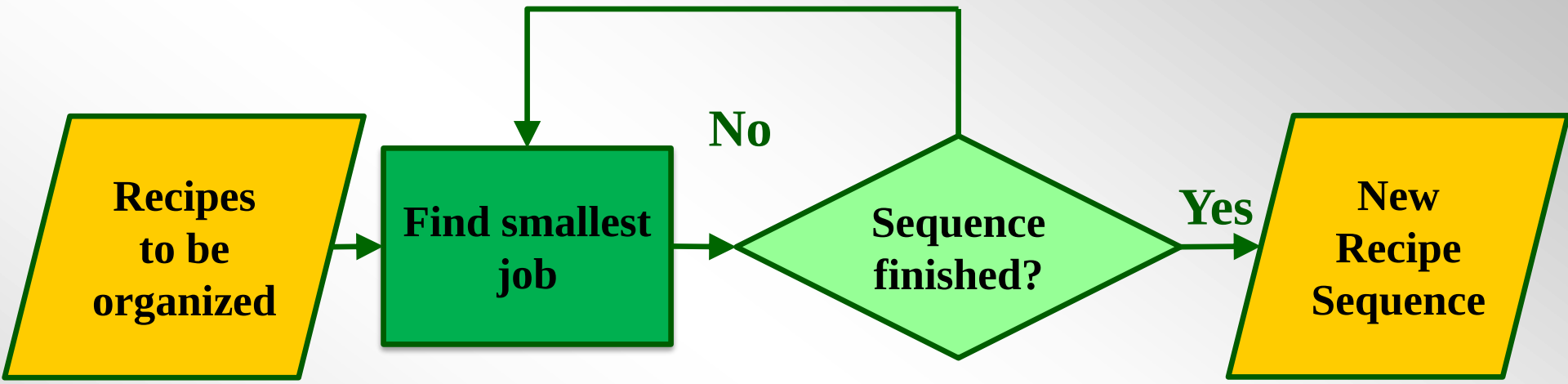
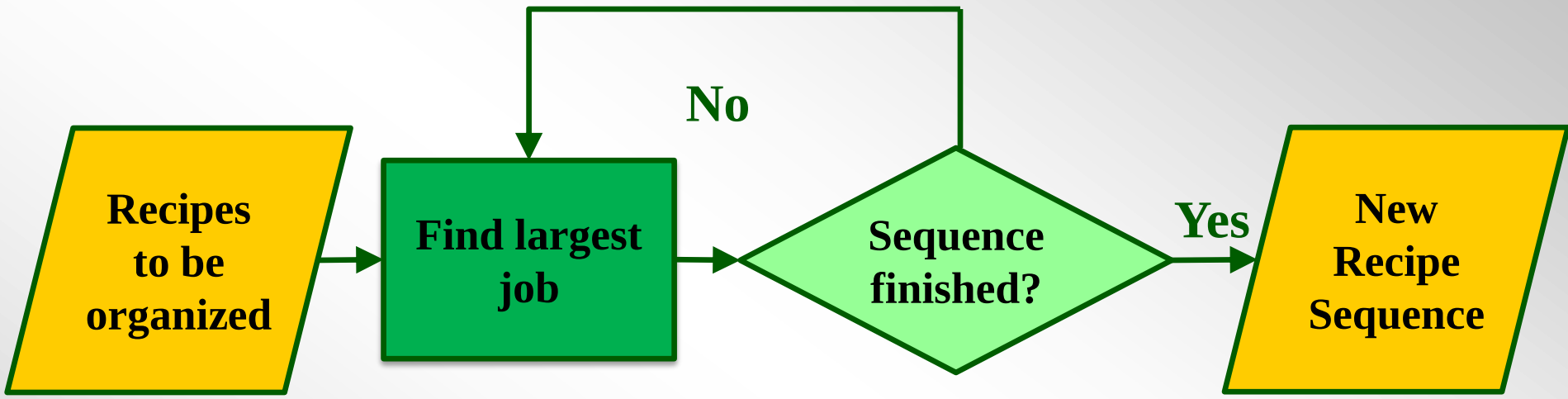
Shortest job-Greedy



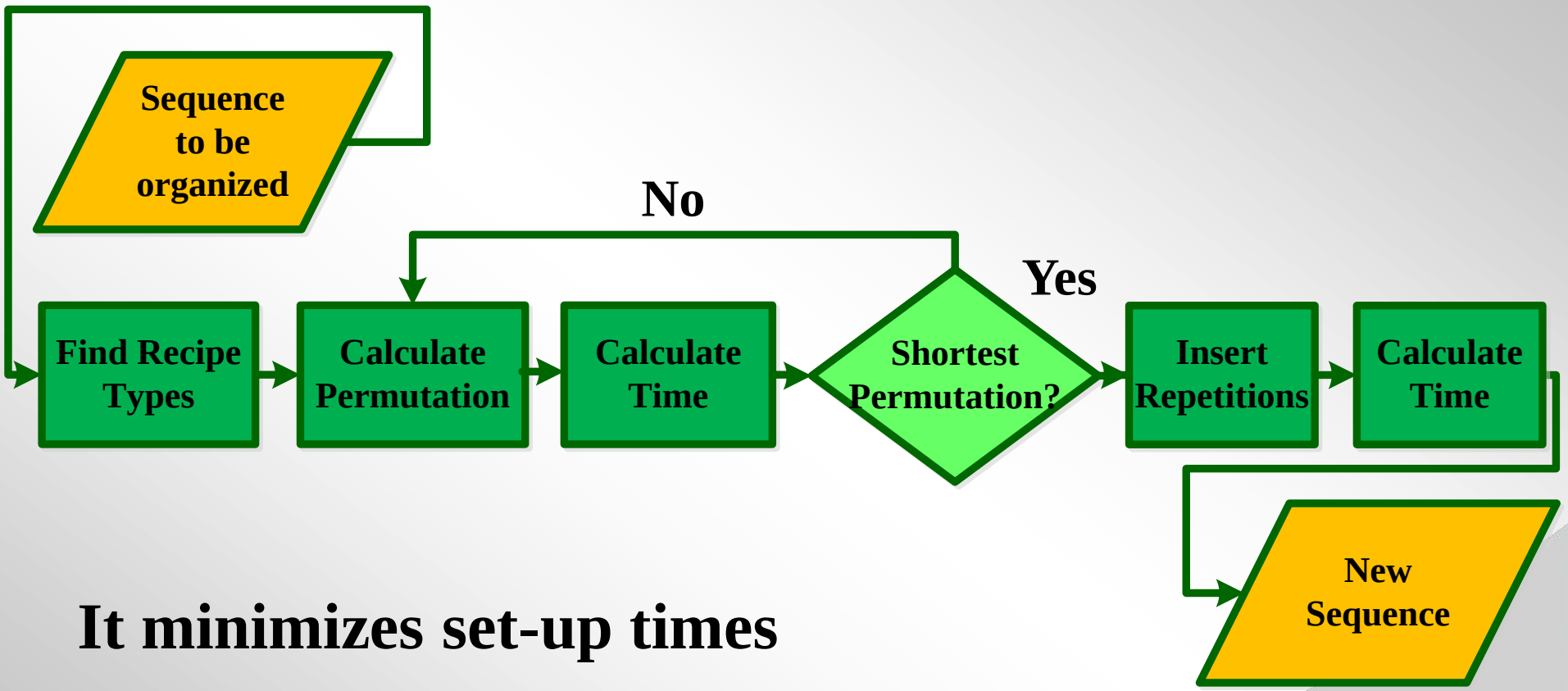
It tries to minimize set-up times

Longest job - Greedy



It tries to maximize set-up times

Shortest Permutation Algorithm



It minimizes set-up times

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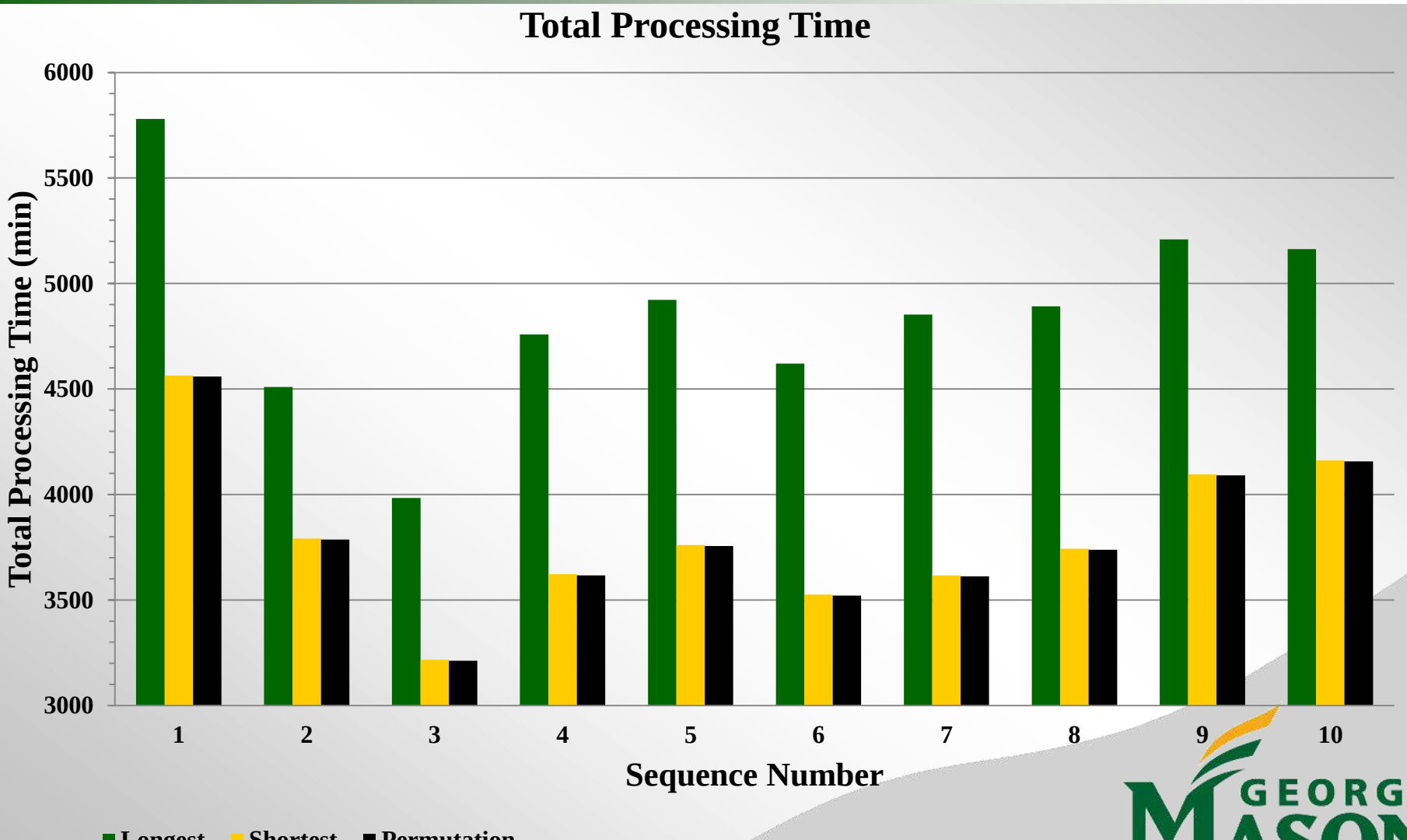
Sample Scheduling Analysis

- Proof-of-concept analysis
- Objective: to demonstrate the benefits of using our simulation model
- Used a random generator to create lot sequences
- Organized lots using our scheduling algorithms
- Studied the trade-off between process time and ion source deterioration

Scheduling Analysis Results



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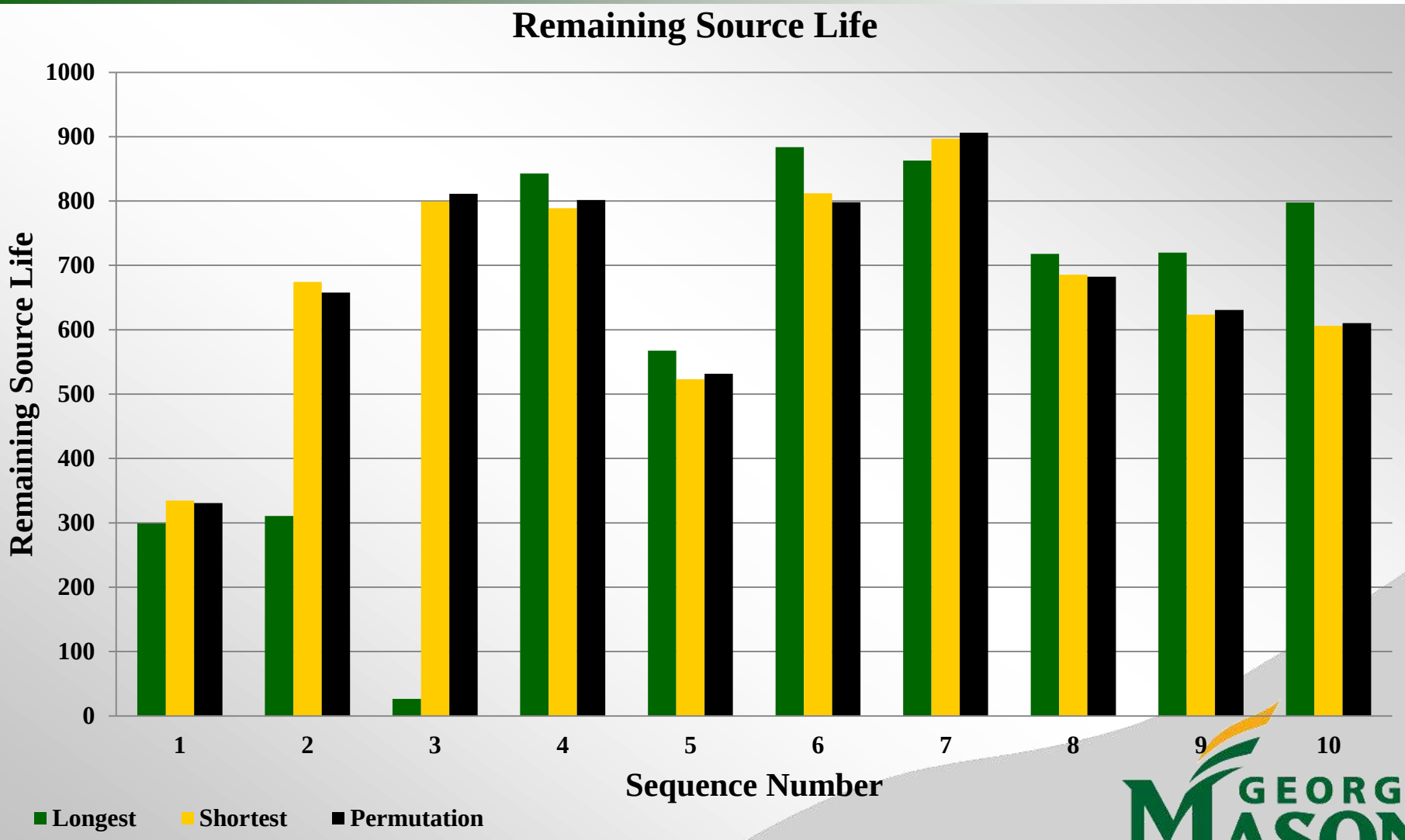
Scheduling Analysis Results (Cont.)



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Scheduling Analysis Results (Cont.)

Algorithm	Average Processing Time (min)	Average Remaining Source Life	Average Source Changes
Longest	4869.1	602.92	2.83
Shortest	3809.9	674.45	2
Permutation	3804.9	676.08	2

Scheduling Analysis Results (Cont.)

- Longest greedy algorithm does not take source deterioration into account
- The two fastest scheduling algorithms reduced source deterioration by reducing the set-up times

Summary

Our tool can be used to:

- **Study the benefits of different scheduling techniques**
- **Test schedules before implementation**
- **Identify if the current schedule needs adjustments to minimize source changes**
- **Adjust schedules based on results of simulation**
- **Increase tool availability**
- **Meet manufacturing demand**
- **Save money**

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Possible Future Work

- Study the failure or deterioration of other semiconductor processes (e.g. process chambers)
- Expand simulation tool to study a group of (5 or 6) implantation tools
- Develop a scheduling algorithm that organizes lots based on ion source deterioration and test it with our tool

Questions?

Thanks To:

Dr. Zaidi, Dr. Hoffman, Dr. Huang, and our classmates for their helpful comments and advice and everyone else for their attention

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