

## A Model Predictive Control Approach for Managing Semiconductor Manufacturing Supply Chains under Uncertainty

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## Outline

- A process-oriented viewpoint to supply chain management in semiconductor manufacturing
- Model Predictive Control as a tactical decision policy
- Case studies:
  - ✓ Basic problem with backlog
  - ✓ Die-packaging problem (in presentation record)
  - ✓ Assembly/Test2 stochastic split problem
- Conclusions and future research



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## Supply Chain Management in Semiconductor Manufacturing

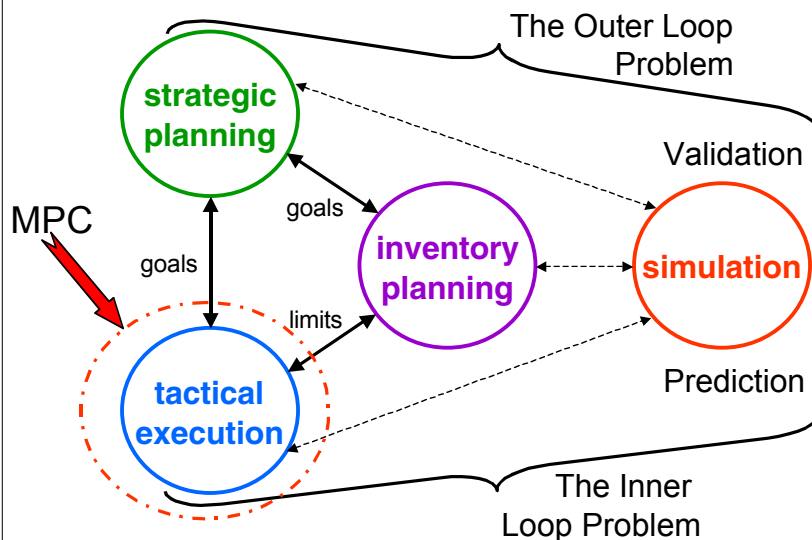
- Strategic and inventory planning steps using optimization are already part of operational practice in semiconductor mfg.
  - Usually deterministic (linear or dynamic programming)
  - Long time horizons (weekly, monthly)
- The need exists for an integrated tactical execution layer
  - Addresses system nonlinearity and stochasticity
  - Involves daily decision-making



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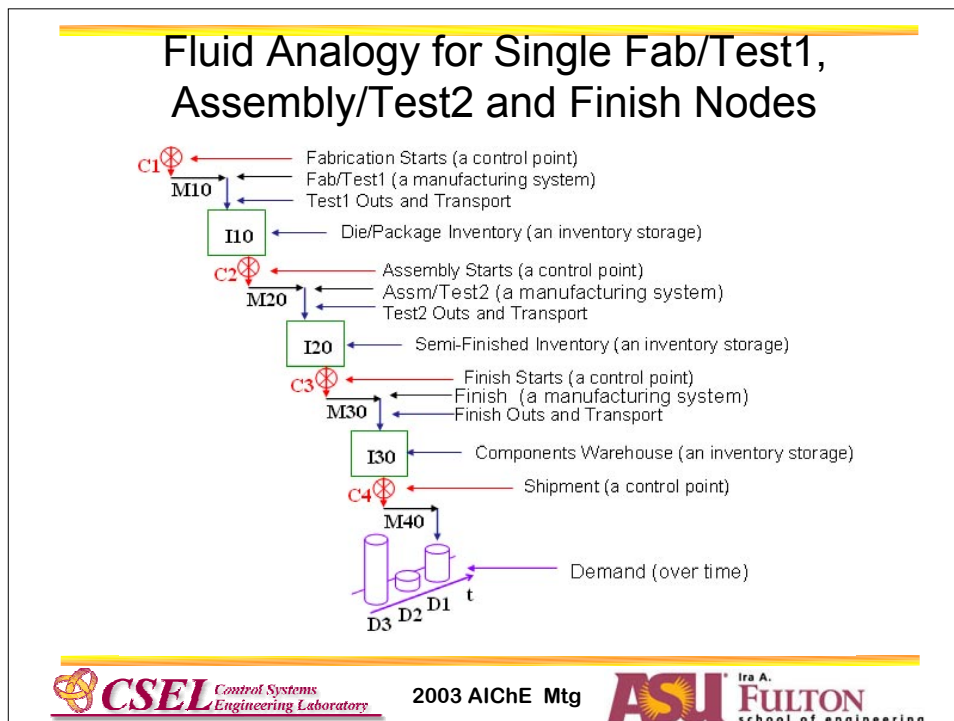
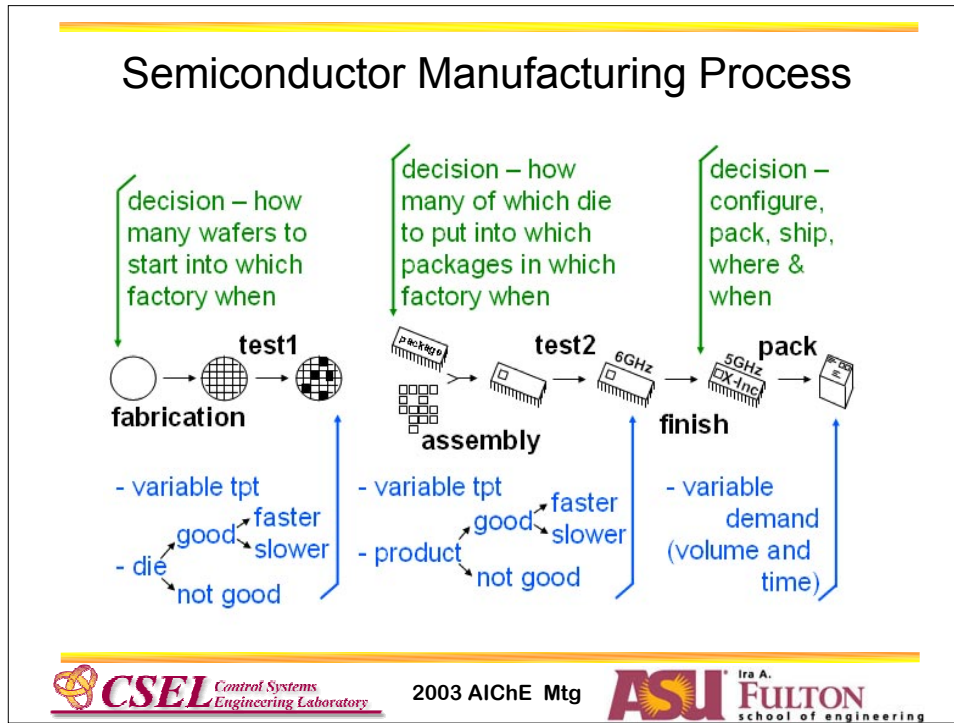


## Proposed Architecture



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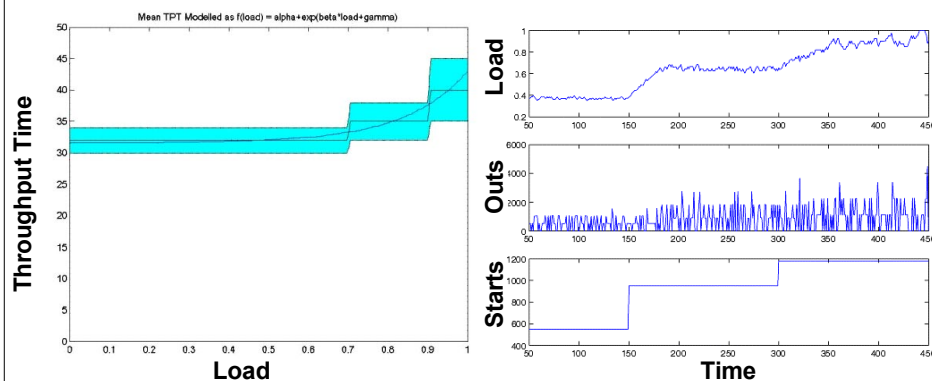




## Modeling Issues and Challenges

- The manufacturing process displays long throughput times (TPT) which are stochastic and nonlinearly dependent on load
- Yields are also stochastic
- There is an error between the forecasted and actual demand, which is also stochastic
- Additional problem features include package dynamics, stochastic splits in die properties, and multi-factory issues involving cross-shipments, shared capacity, and correlated demands.

## Fab/Test1 manufacturing node properties

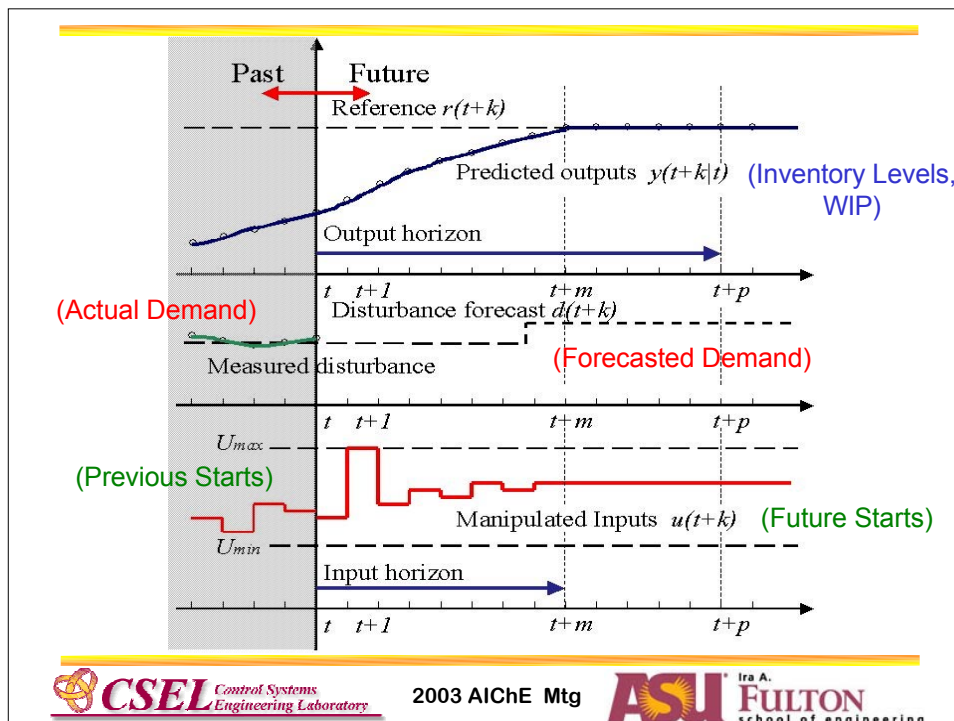


## Model Predictive Control Appeal for Dynamic Inventory Management in Supply Chains

- As an *optimizer*, an MPC-based algorithm can minimize or maximize an objective function that represents a suitable measure for supply chain performance.
- As a *controller*, an MPC algorithm can be tuned to achieve stability, robustness, and performance in the presence of plant/model mismatch, failures and disturbances which affect the system.



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### MPC Objective Function

Keep Inventories at Inventory Planning Setpoints

$$J = \sum_{l=1}^p Q_e(l) (\hat{y}(k+l|k) - r(k+l))^2$$

Penalize Changes in Starts

$$+ \sum_{l=1}^m Q_{\Delta u}(l) (\Delta u(k+l-1|k))^2$$

Maintain Starts at Strategic Planning Targets

$$+ \sum_{l=1}^m Q_u(l) (u(k+l-1|k) - u_{target}(k+l-1|k))^2$$

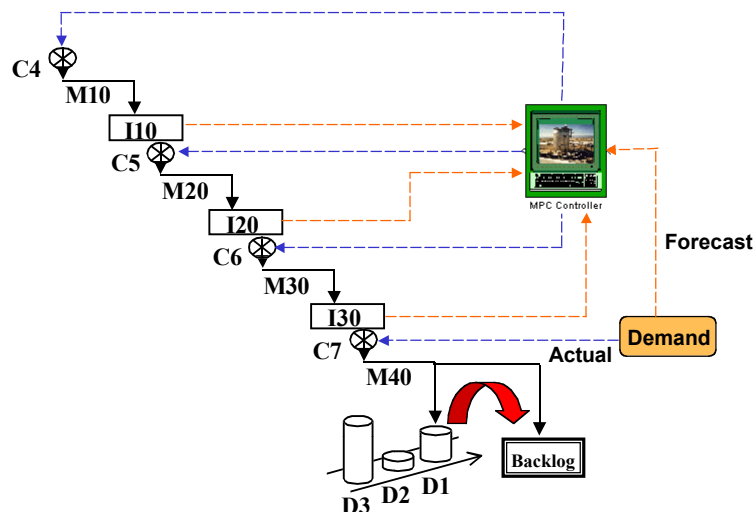
s.t. constraints on starts, inventories and Work In Progress (WIP)



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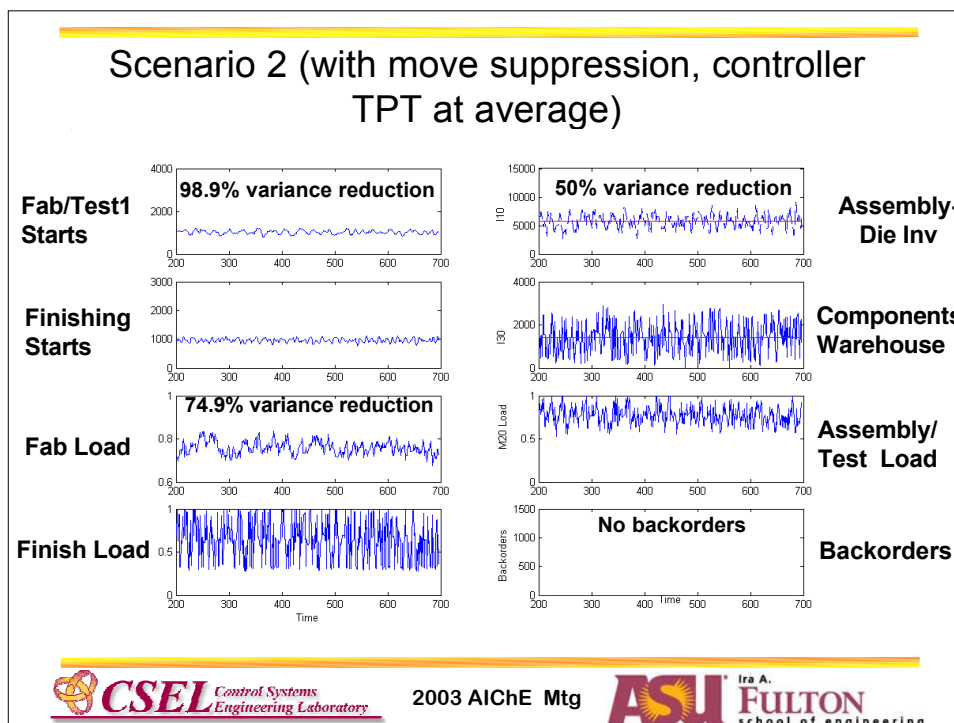
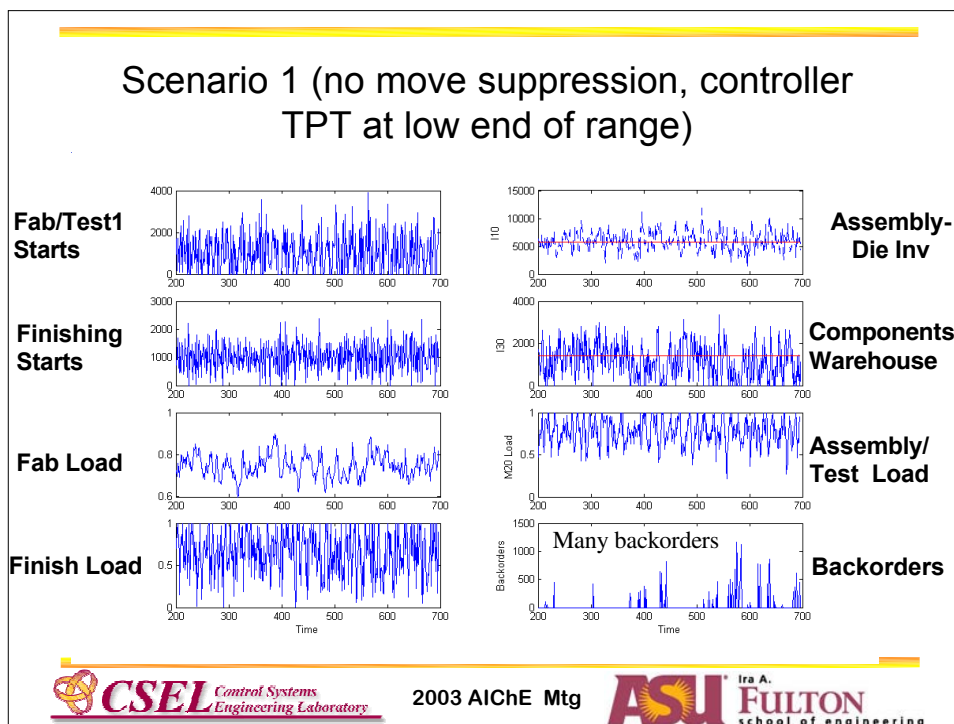


### Case Study: Basic problem with backlog



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### Case Study: Assembly/Test2 Stochastic Split Problem

The outcome of the Assembly/Test2 process is stochastic in terms of the number of fast and slow devices that result.

Fast devices can be used to make high speed products (C37). Slow devices can be used to make low speed products (C39).

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### Stochastic Split Modeling

$$I_{20}(k + 1) = I_{20}(k) + \alpha \cdot Y_2 C_{36}(k - \theta_2) - C_{37}(k) - C_{38}(k)$$

$$I_{21}(k + 1) = I_{21}(k) + (1 - \alpha) \cdot Y_2 C_{36}(k - \theta_2) - C_{39}(k)$$

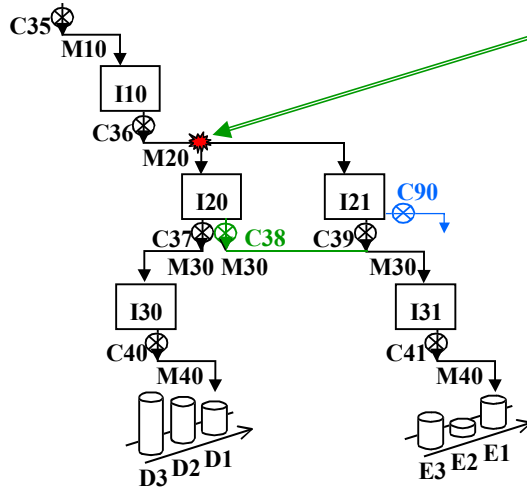
$\alpha$ : Split Factor;  
 $\theta_*$ : Throughput Time;  
 $I_*(k)$ : Inventory Levels;  
 $C_*(k)$ : Starts of Manufacturing Nodes

BIN SPLITS	I20	hi	spd		I21	lo	spd	
case 1	max	ave	min		max	ave	min	
balanced	0.49	0.39	0.29	unif	0.71	0.61	0.51	unif
case 2								
downbin hi	0.59	0.49	0.39	unif	0.61	0.51	0.41	unif
case 3								
discard lo	0.39	0.29	0.19	unif	0.81	0.71	0.61	unif

**Average demand for fast devices: 351 units/day (39%)**  
  
**Average demand for slow devices: 551 units/day (61%)**

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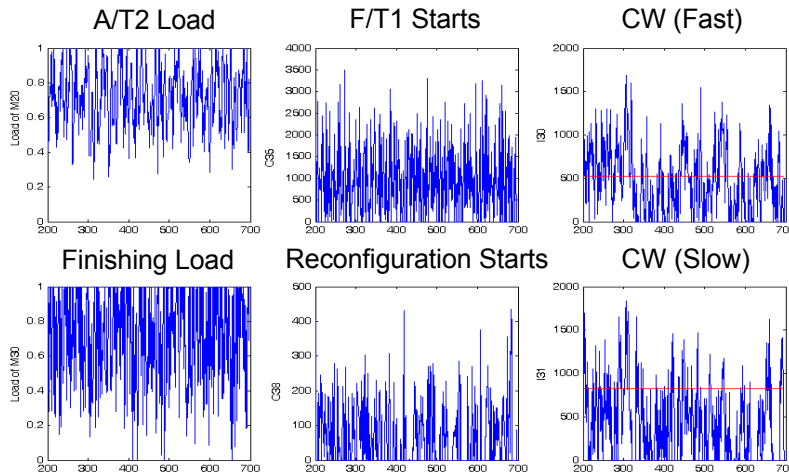
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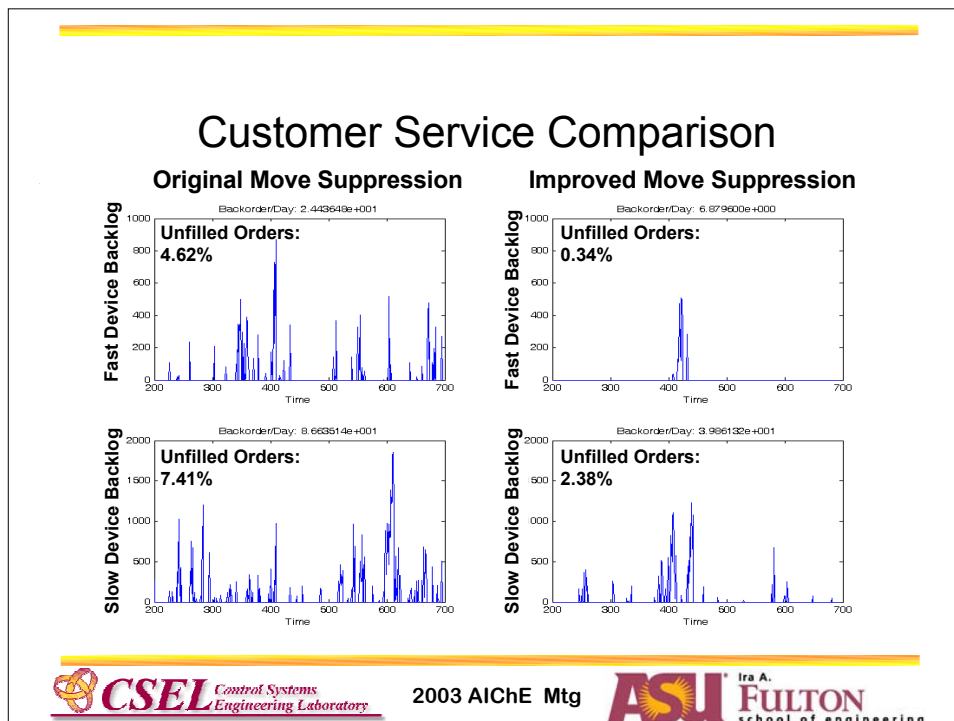
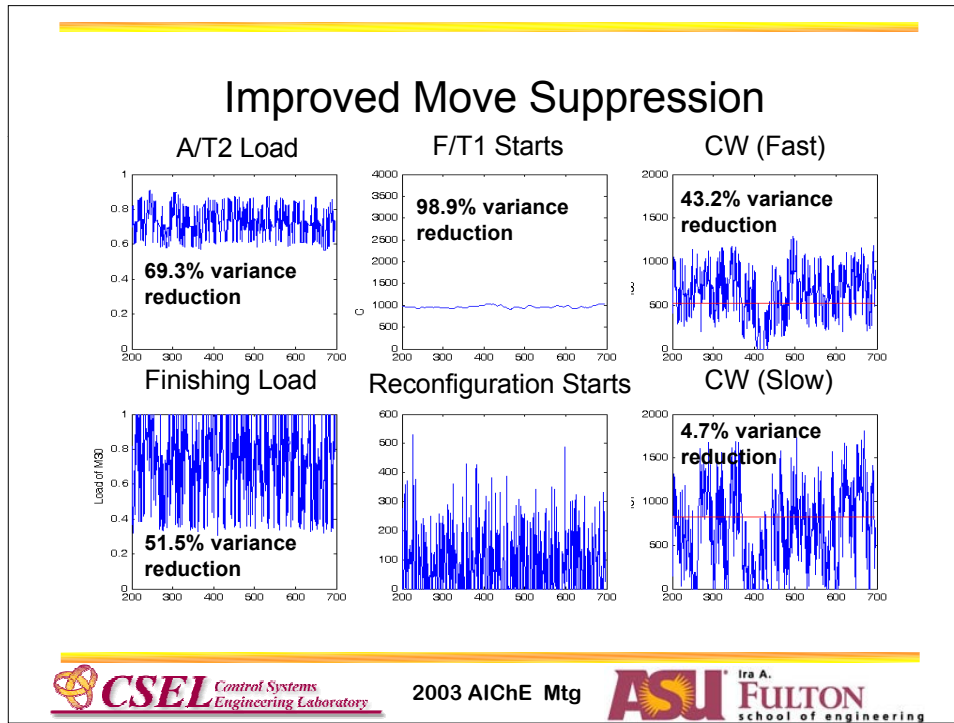


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## Original Move Suppression





## Conclusions and Future Research

- MPC is a useful tool for tactical decision-making in semiconductor manufacturing supply chain management. It can handle stochastic and nonlinear manufacturing process using linear model with fixed parameters
- Judiciously picking tuning and model parameters can help to achieve performance robustness and improve customer service
- Good inventory targets from the outer loop will help reduce backorders and costs
- Future research will examine combination problems involving configuring, packaging, sharing capacity, etc



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