

# Model-Based Decision Making Through Simulation-Optimization Decision-Support Systems (DSS)

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# Outline of Presentation

- ✦ Context – MSU model & application development activities
- ✦ Basic Concepts -- Decision Support Systems (DSS)
- ✦ Examples of Model-based DSS (MB-DSS)

- ✦ Panel Shop

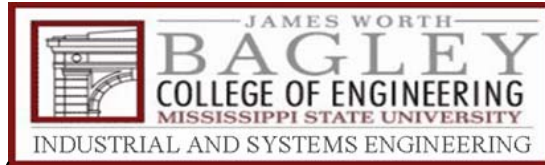
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- ✦ Pipe Shop

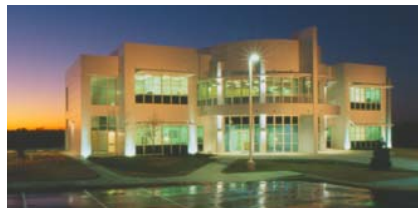
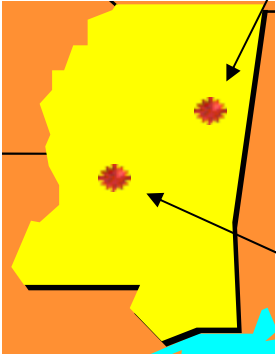
- ✦ Lean Manufacturing Flight Simulator



# Mississippi State University

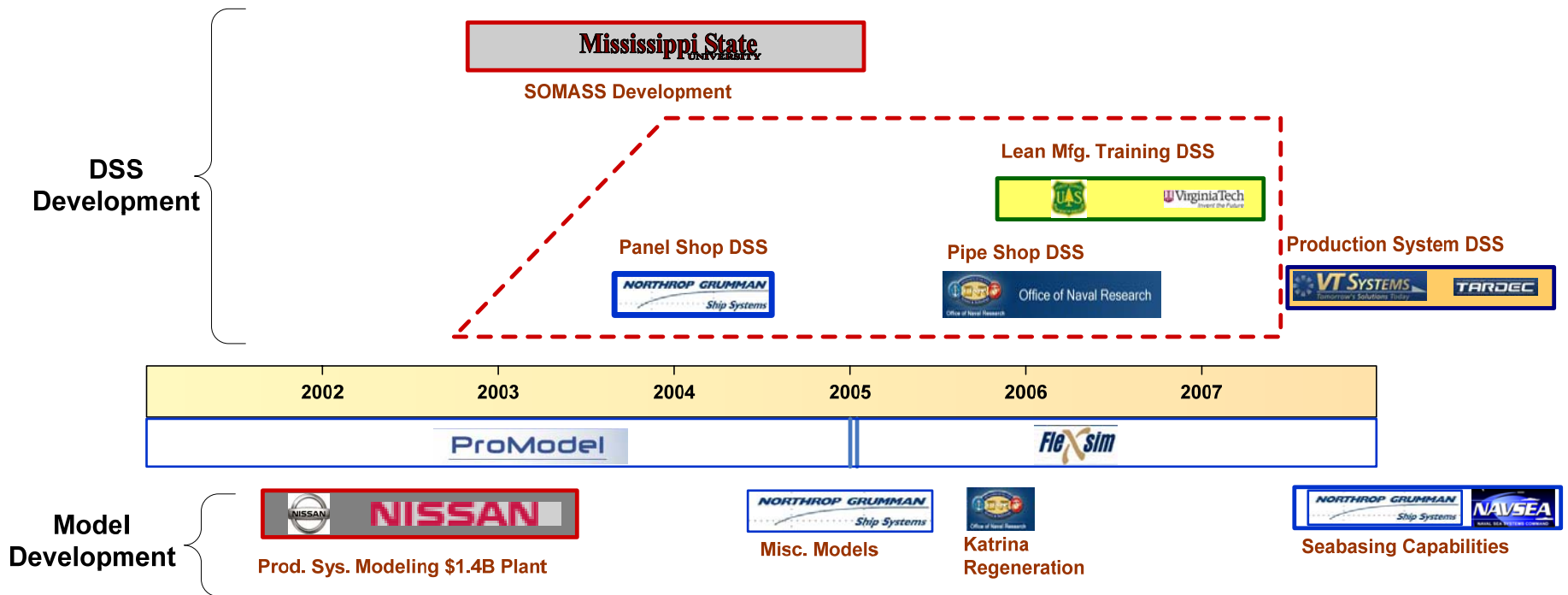


The Department of Industrial and Systems Engineering (ISE) provides education, research, and outreach in order to design, analyze, and manage systems of people, materials, information, equipment, and energy.



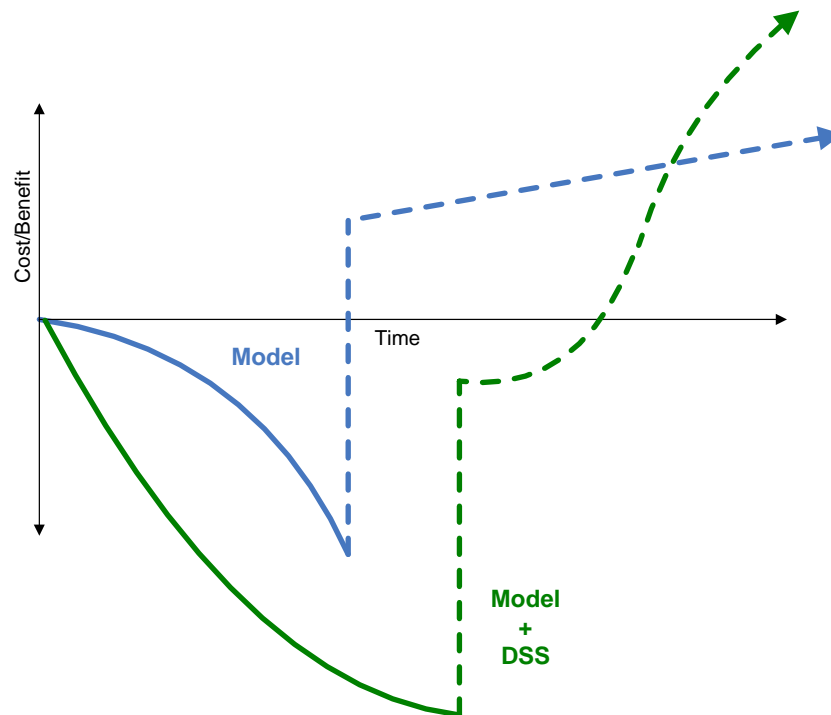
The Center for Advanced Vehicular Systems (CAVS) provides new capabilities for Mississippi industry in order to reduce development and production costs while improving quality.

# Key Projects to Provide Context

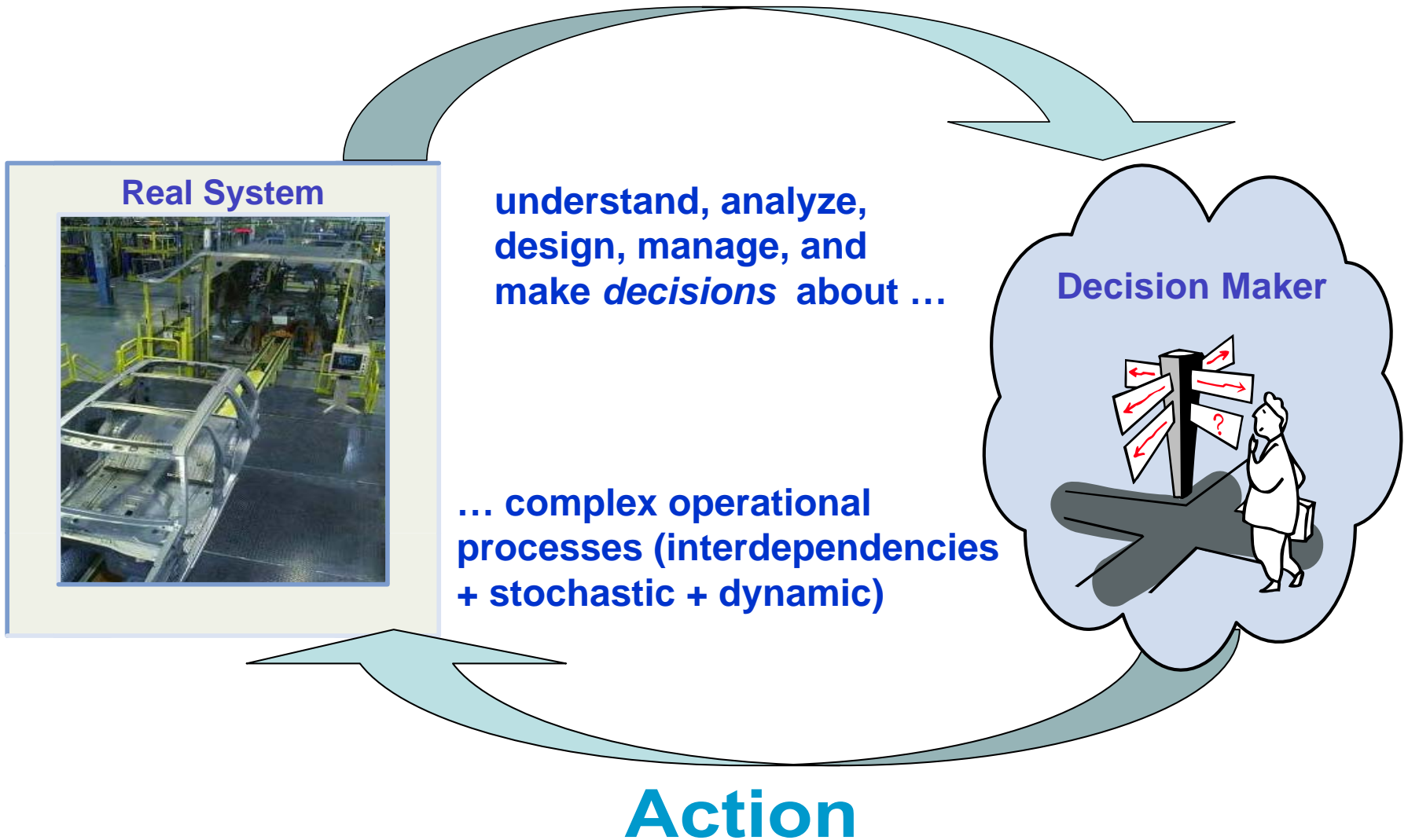


# Why Model-based DSS? Enhance Organizational Performance

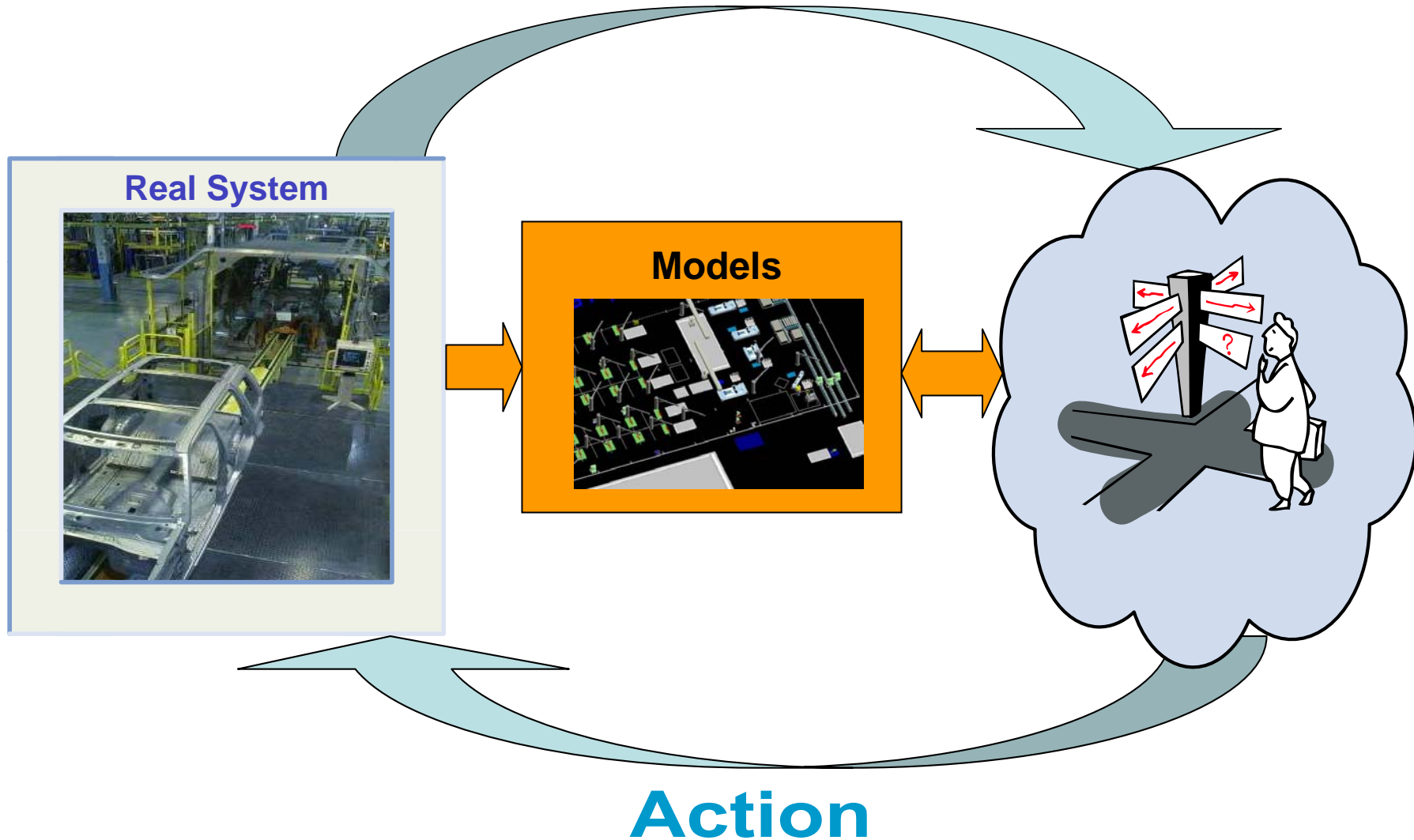
- ✦ put sophisticated engineering tools into the hands of the decision makers to improve decision making
- ✦ increase the useful life of models; get a greater return on model investment



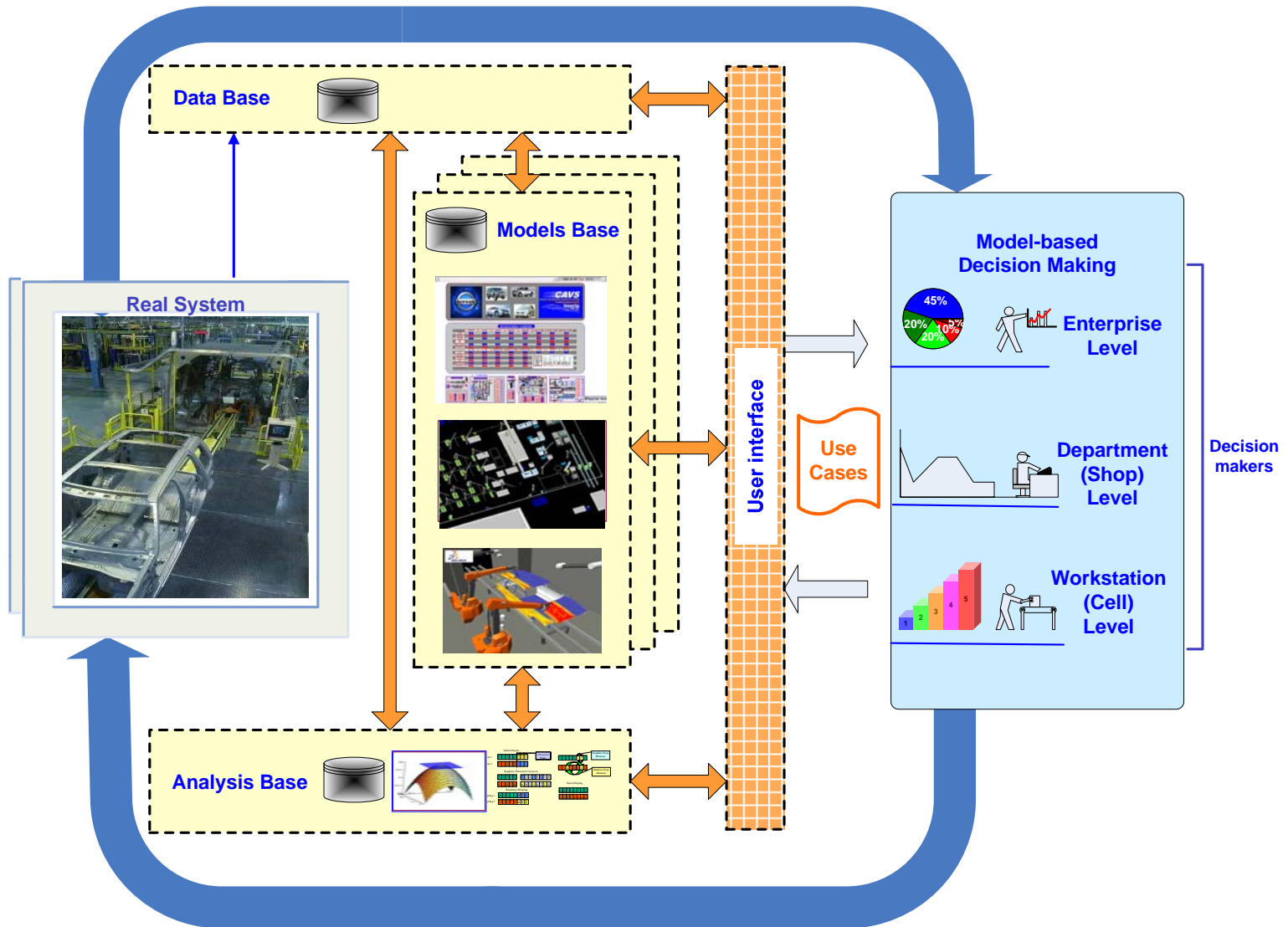
# “Traditional” Decision Making Information



# “Model-based” Decision Making Information

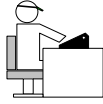


# Model-Based Decision Making

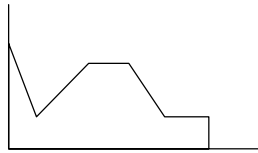




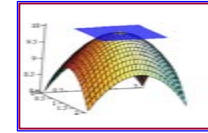
# What changes need to be made?



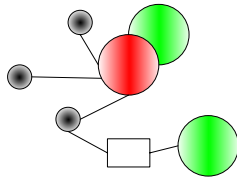
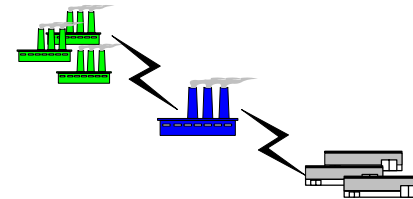
from modeler/analyst centric to  
decision-maker centric



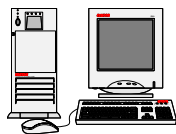
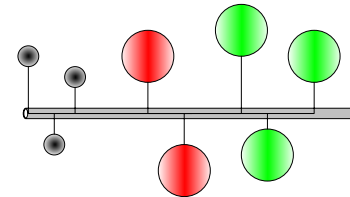
from point solutions to  
optimization



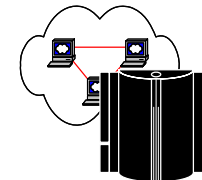
from work-cell → enterprise →  
supply-chain applications



from closed, local analyses to  
open, distributed analyses



from PC/server based to  
web/GRID based



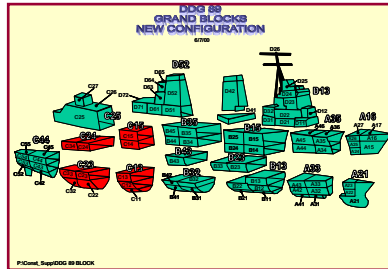
# Applying the MB-DSS Approach at NGSS



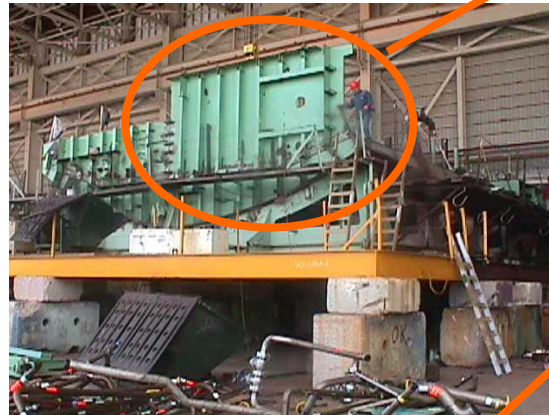
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# Sim-Opt DSSs for NGSS



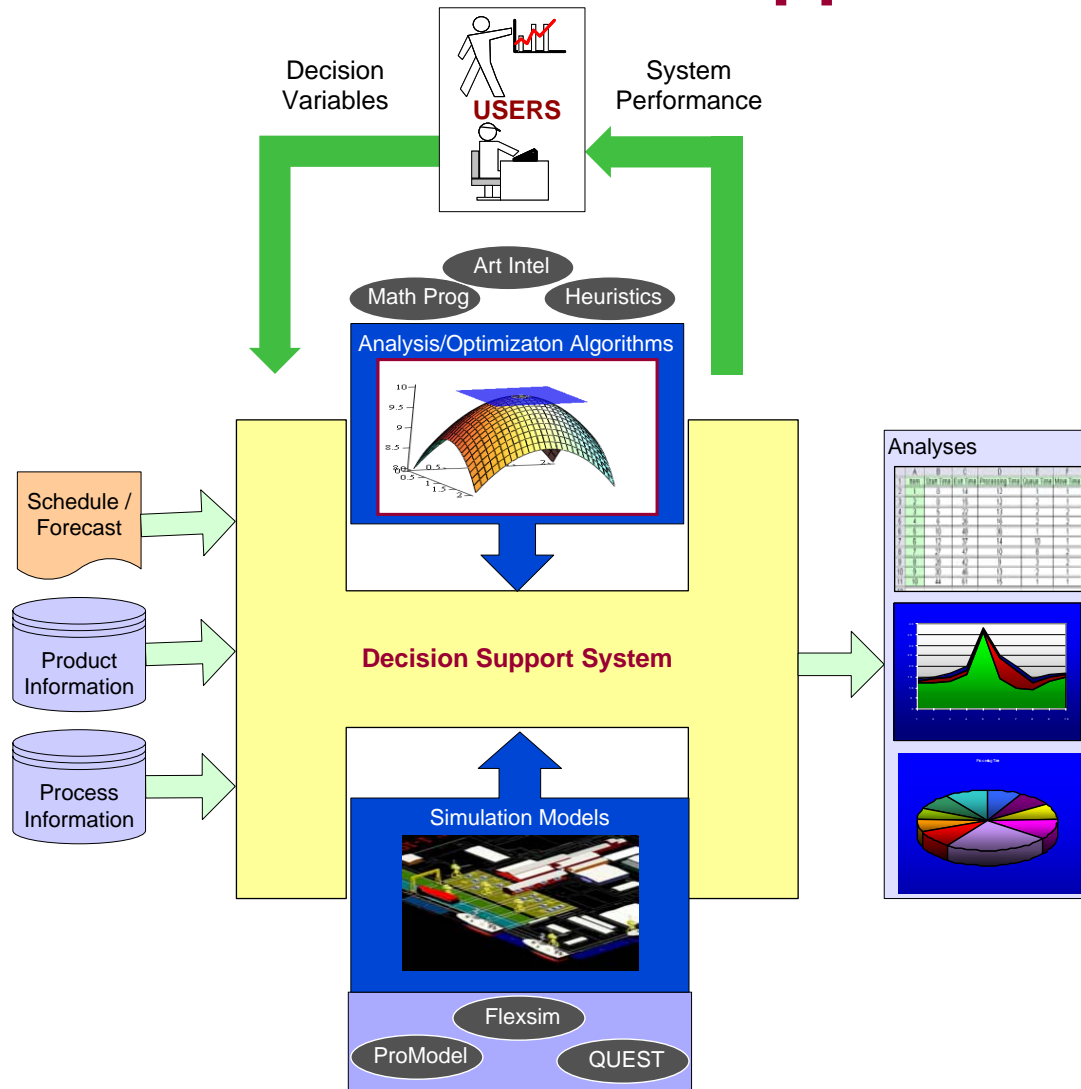
Panel



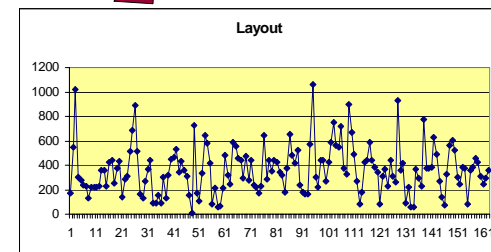
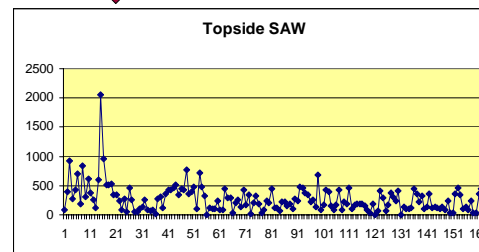
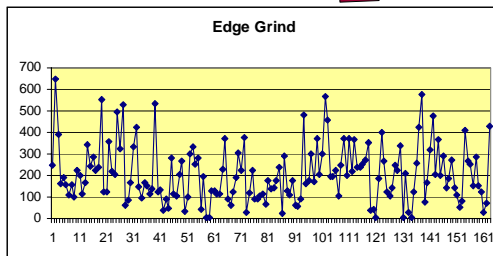
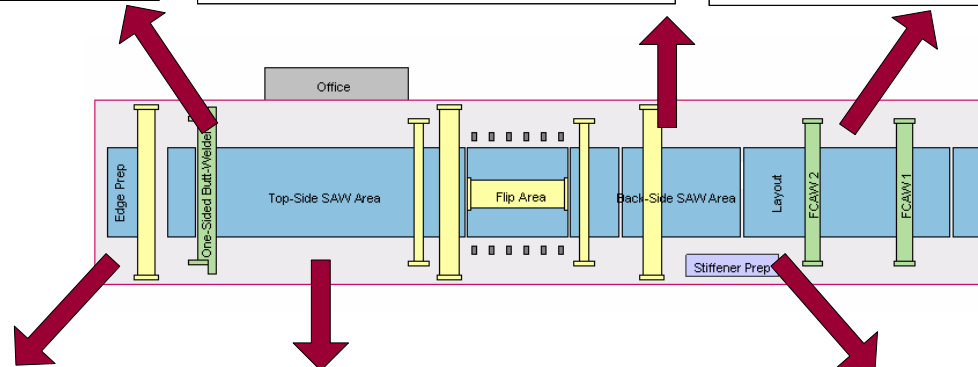
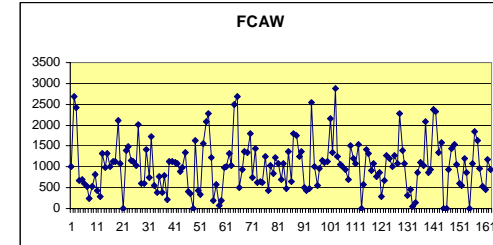
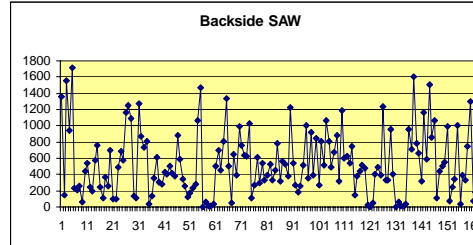
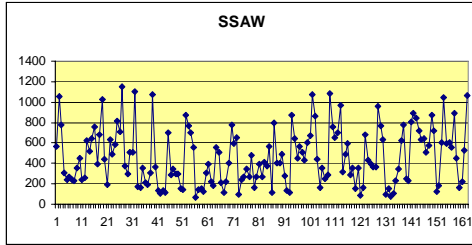
Pipe  
Details




# General MB-DSS Approach



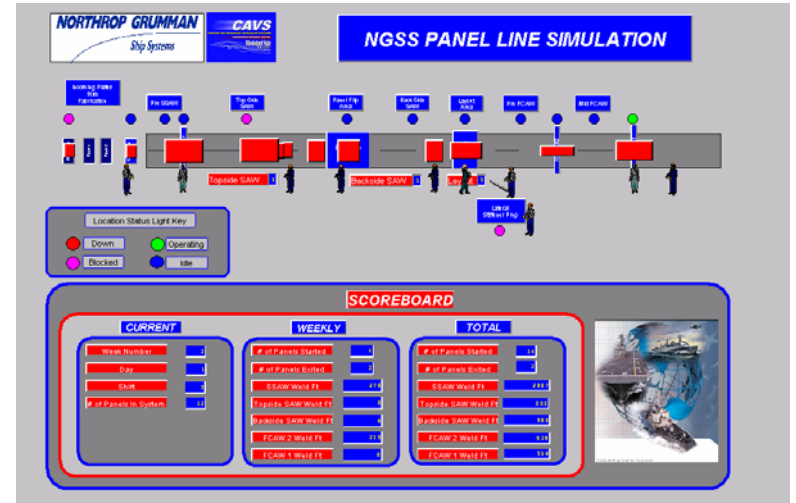
# Panel Shop Problem: Every Panel is Unique → Large variability




# Models Used to Increase Panel Shop Throughput

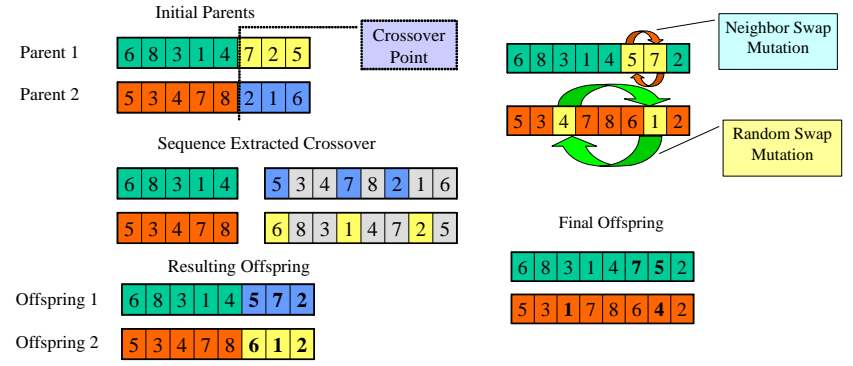

**Simulation** model to represent behavior of production system and evaluate sequence

Model runtime: approximately 5 seconds to process 154 panels (~13 weeks in real time)




**Optimization** algorithm to intelligently generate possible sequences

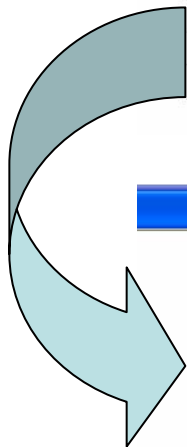
There are 1.3 trillion possible ways to sequence a 15-panel set



## Evolutionary Strategy

# Example Impact – Swapping 1 of 42 Panels

2631	2582	1-A	03/20/06	04/14/06	03/28/06	04/21/06	7.0
2631	2582	3	03/20/06	04/14/06	03/28/06	04/25/06	11.0
2631	2583	M-48	03/20/06	04/14/06	03/30/06	04/20/06	6.0
2631	2583	1	03/20/06	04/14/06	03/30/06	04/26/06	12.0
2631	2583	1-D	03/20/06	04/14/06	03/30/06	04/24/06	10.0
2631	2583	1-C	03/20/06	04/14/06	04/03/06	04/27/06	13.0
2631	2583	1-B	03/20/06	04/14/06	04/03/06	04/26/06	12.0
2631	2583	1-A	03/20/06	04/14/06	04/04/06	05/02/06	18.0
2631	3473	1-B	03/20/06	04/14/06	04/04/06	05/10/06	26.0
2631	3473	1-A	03/20/06	04/14/06	04/04/06	05/09/06	25.0
2631	3473	M-53D	03/20/06	04/14/06	04/05/06	05/11/06	27.0
2631	3473	1-47C	03/20/06	04/14/06	04/05/06	05/11/06	27.0
5215	421	01-01	03/20/06	04/14/06	04/06/06	05/15/06	31.0
							285.00



2631	2582	1-A	03/20/06	04/14/06	03/28/06	04/20/06	6.0
2631	2582	3	03/20/06	04/14/06	03/29/06	04/19/06	5.0
2631	2583	M-48	03/20/06	04/14/06	03/30/06	04/24/06	10.0
2631	2583	1	03/20/06	04/14/06	04/03/06	04/21/06	7.0
2631	2583	1-D	03/20/06	04/14/06	04/03/06	04/20/06	6.0
2631	2583	1-C	03/20/06	04/14/06	04/03/06	04/26/06	12.0
2631	2583	1-B	03/20/06	04/14/06	04/04/06	04/25/06	11.0

**12% improvement**

Similar solution to adding one welder to first shift for TopSide/BackSide

2631	3473	M-53D	03/20/06	04/14/06	04/05/06	05/08/06	24.0
2631	3473	1-47C	03/20/06	04/14/06	04/06/06	05/11/06	27.0
5215	421	01-01	03/20/06	04/14/06	04/06/06	05/15/06	31.0
							251.00

# Intuitive User Interface for Planners & Shop Floor

The screenshot displays the 'Shop Floor - Prototype' software interface. At the top, a menu bar includes 'File', 'Work Mix', 'Simulation', 'Shifts', 'Tools', and 'Help'. A dropdown menu is open, listing options: 'Run Model', 'Stop Model', 'Run Optimizer', 'Recover Optimizer', 'Stop Optimizer', 'View Output', and 'Options'. A red arrow points from a 'Model Selection' callout to a box labeled 'run in ProModel or QUEST'. The main simulation area shows a factory floor layout with stations: 'Edge Prep', 'One-Sided Buff-Weider', 'Top-Side SAW Area', 'Flip Area', 'Back-Side SAW Area', and 'Cut'. A 'SAW' dialog box is open, showing 'Resource Utilization: 90'. A 'Panel selection' callout points to a table of panels to be scheduled. An 'Optimal sequence' callout points to a table of the optimal schedule.

**Model Selection** → run in *ProModel* or *QUEST*

**Operations parameters**

**Panel selection**

Panels to Schedule					
Key	Hull	Unit	SA	220 Scheduled Start	Customer Due Date
1	2486	1270	1A-1	02/02/2004	02/13/2004
2	7208	114	01-01	02/02/2004	02/13/2004
3	7208	119	01-01	02/02/2004	02/13/2004
4	7208	122	01	02/02/2004	02/13/2004
5	7208	123		02/13/2004	
6	7208	208		02/13/2004	
7	7208	208		02/13/2004	
8	7208	330		02/13/2004	
9	7208	410		02/13/2004	
10	7208	411	02-01	02/13/2004	
11	7208	420	01-01	02/02/2004	02/13/2004
12	7208	414	01-01	02/09/2004	02/20/2004
13	7208	414	01-01	02/09/2004	02/20/2004
14	7208	113	01-01	02/16/2004	02/27/2004

**Optimal sequence**

Optimal Schedule					
I	Hull	Unit	SA	Simulated Start Date	Simulated Delivery Date
1	7208	323	01-01	1/5/2004	2/23/2004
2	7208	325	03-01	1/5/2004	2/9/2004
3	7208	326	01-01	1/5/2004	2/9/2004
4	7208	416	04		2/9/2004
5	2486	4720			2/9/2004
6	2486	4721			2/9/2004
7	7208	107			2/9/2004
8	7208	115			2/9/2004
9	7208	116	02-01		2/16/2004
10	2486	1381	1-1	1/12/2004	2/13/2004
11	2486	1380	1-1	1/12/2004	2/13/2004
12	7208	207	01-01	1/12/2004	2/13/2004
13	7208	207	02-01	1/12/2004	2/13/2004
14	7208	408	02-01	1/12/2004	2/13/2004
15	2486	4720	1	1/12/2004	2/13/2004



# Various Output Reports for Planners & Shop Floor

Output Viewer - [Reports: Resource Prescription]

File Graphs Reports Window

MainReport

**NORTHROP GRUMMAN SHIP SYSTEMS**

**Resource Allocation**

**NGSS Panel Level Resource Prescription**

Hull	Unit	SA	Start Date	Exit Date	Edge Grinders Required	SSAW Required	Topside SAW Required	Backside SAW Required	Layout Required	FCAW 2 Required	FCAW 1 Required	Repair Required	Stiffener Required	FCAW Fitter
7208	225	01-01	08/30/04	09/04/04	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
7208	225	02-01	08/30/04	09/05/04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.00
5213	323	01-01	08/30/04	09/07/04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
5213	323	01-02	08/30/04	09/07/04	1.00	1.00	3.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
5213	323	01-03	08/31/04	09/07/04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
7208	341	06	08/31/04	09/08/04	1.00	1.00	3.00	4.00	1.00	1.00	1.00	1.00	0.00	0.00

**Optimal Schedule**

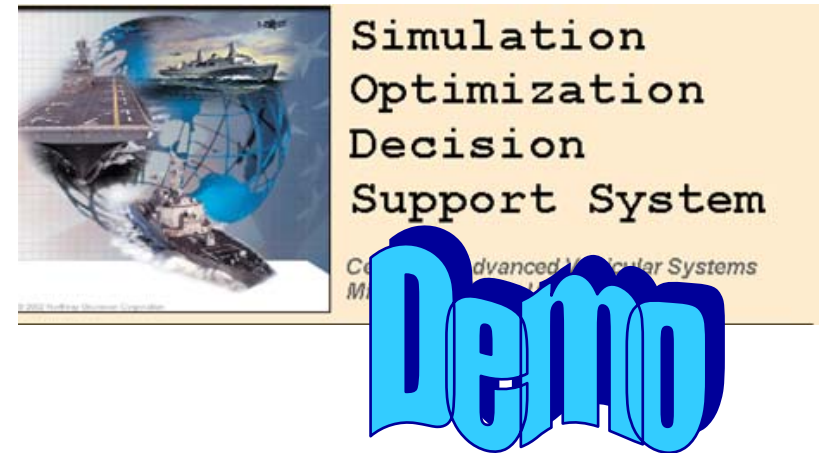
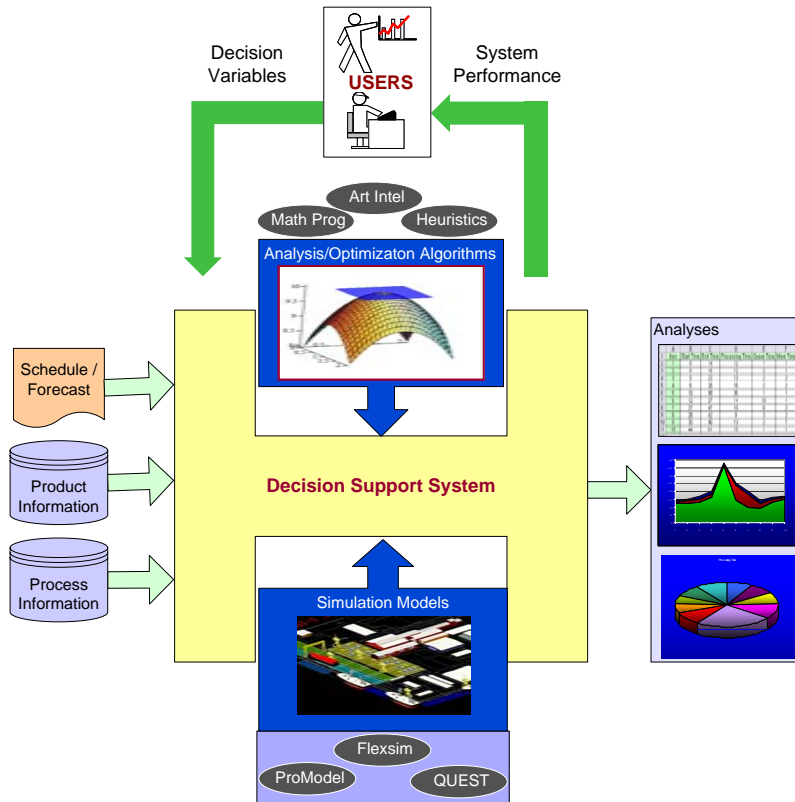
	Hull	Unit	SA	Simulated Start Date	Simulated Delivery Date
1	7208	323	01-01	1/5/2004	2/23/2004
2	7208	325	03-01	1/5/2004	2/9/2004
3	7208	326	01-01	1/5/2004	
4	7208	416	04	1/5/2004	
5	2486	4720	1A-1	1/5/2004	
6	2486	4721	F-1A	1/5/2004	
7	7208	107	01-01	1/12/2004	
8	7208	115	02-01	1/12/2004	2/16/2004
9	7208	116	02-01	1/12/2004	2/16/2004
10	2486	1381	1-1	1/12/2004	2/13/2004
11	2486	1380	1-1	1/12/2004	2/13/2004
12	7208	207	01-01	1/12/2004	2/13/2004
13	7208	207	02-01	1/12/2004	2/13/2004
14	7208	408	02-01	1/12/2004	2/13/2004
15	2486	4720	1	1/12/2004	2/13/2004

**Schedule**

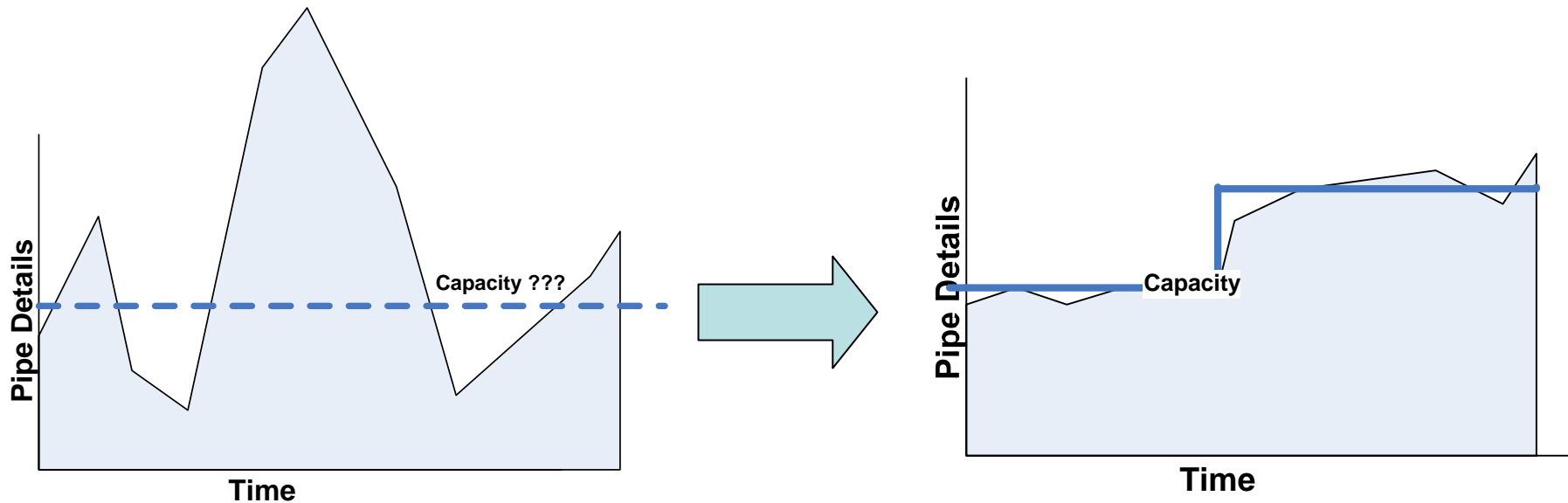


# Panel Shop DSS

## Effectively Links Users With Models & Data

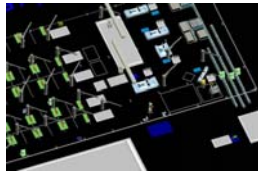


# Pipe Shop Problem: Large Variability in Demand + Unknown Capacity

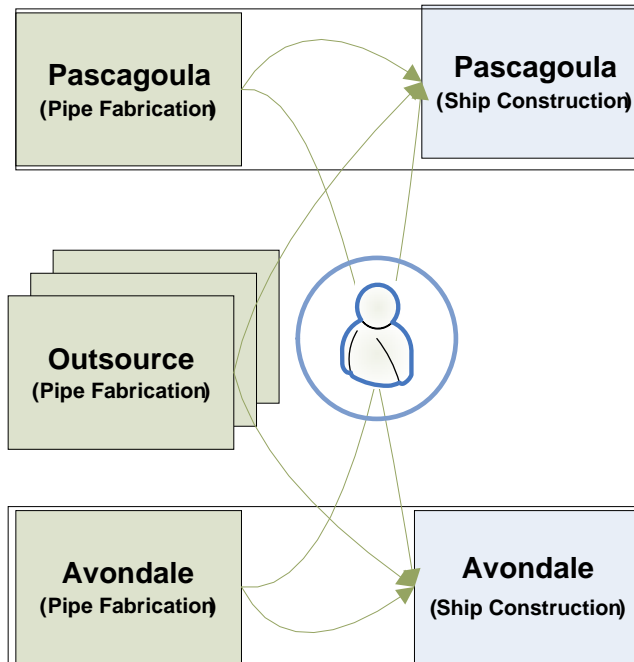
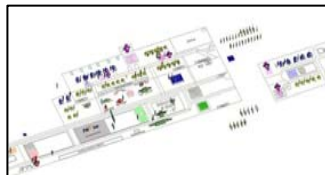


# Basic Issue: What, Where, & When to Produce Each PD with an Effective Use of Resources

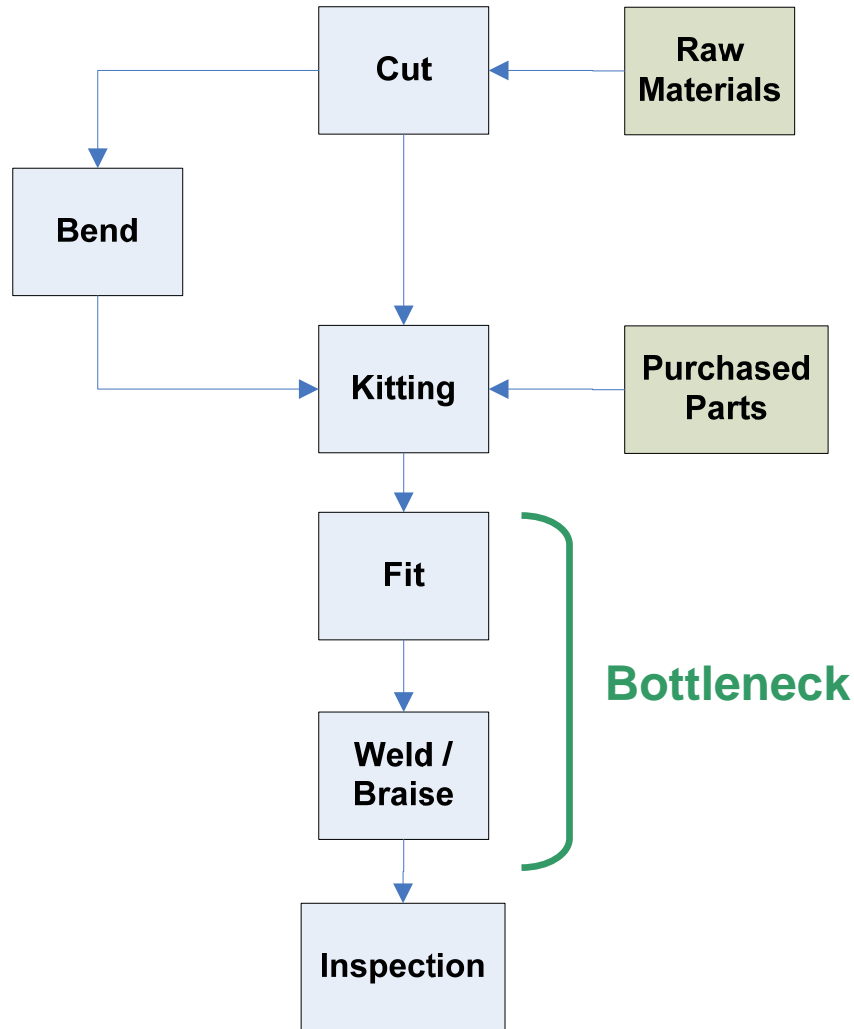
Multiple programs



Multiple yards/shops



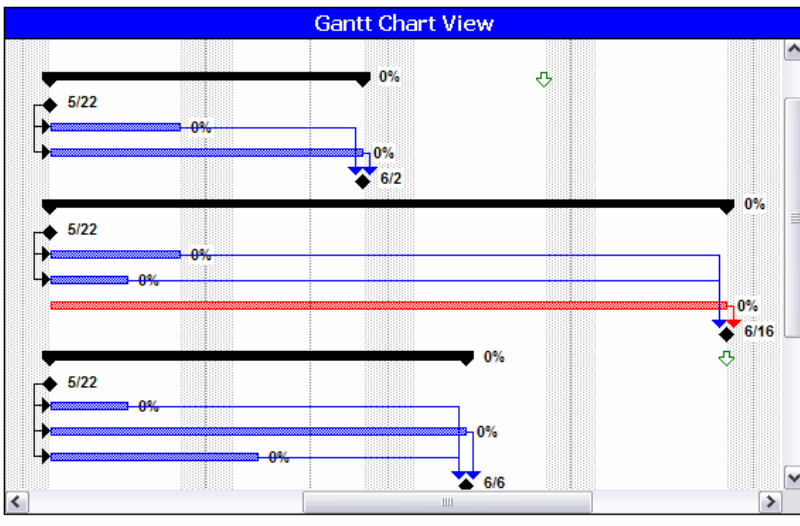
# Pipe Shop Operations & DSS Approach



# DSS Integrates Two-Levels of Models

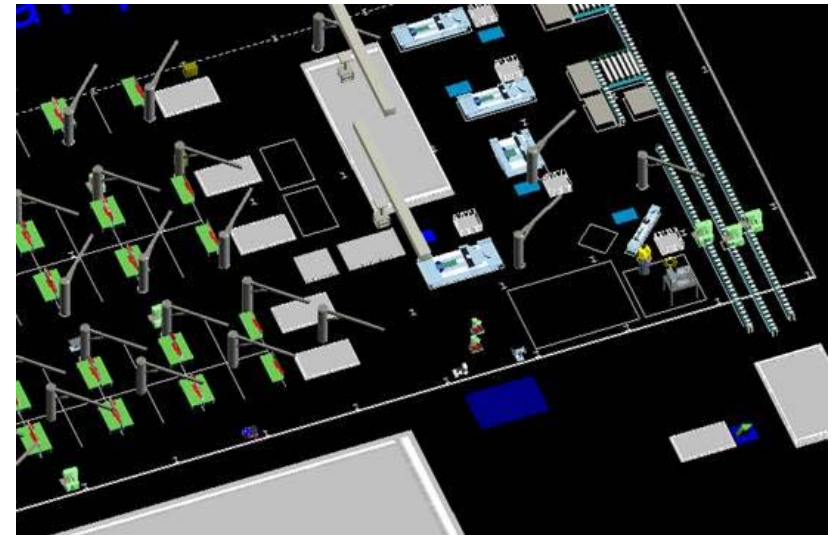
## ❖ **Planning** Model (high-level)

- ❖ for bottleneck capacity planning and analysis
- ❖ high-level operational trade-offs and production decisions
- ❖ considers each PD as a resource-constrained project
- ❖ scheduling using project management methodologies

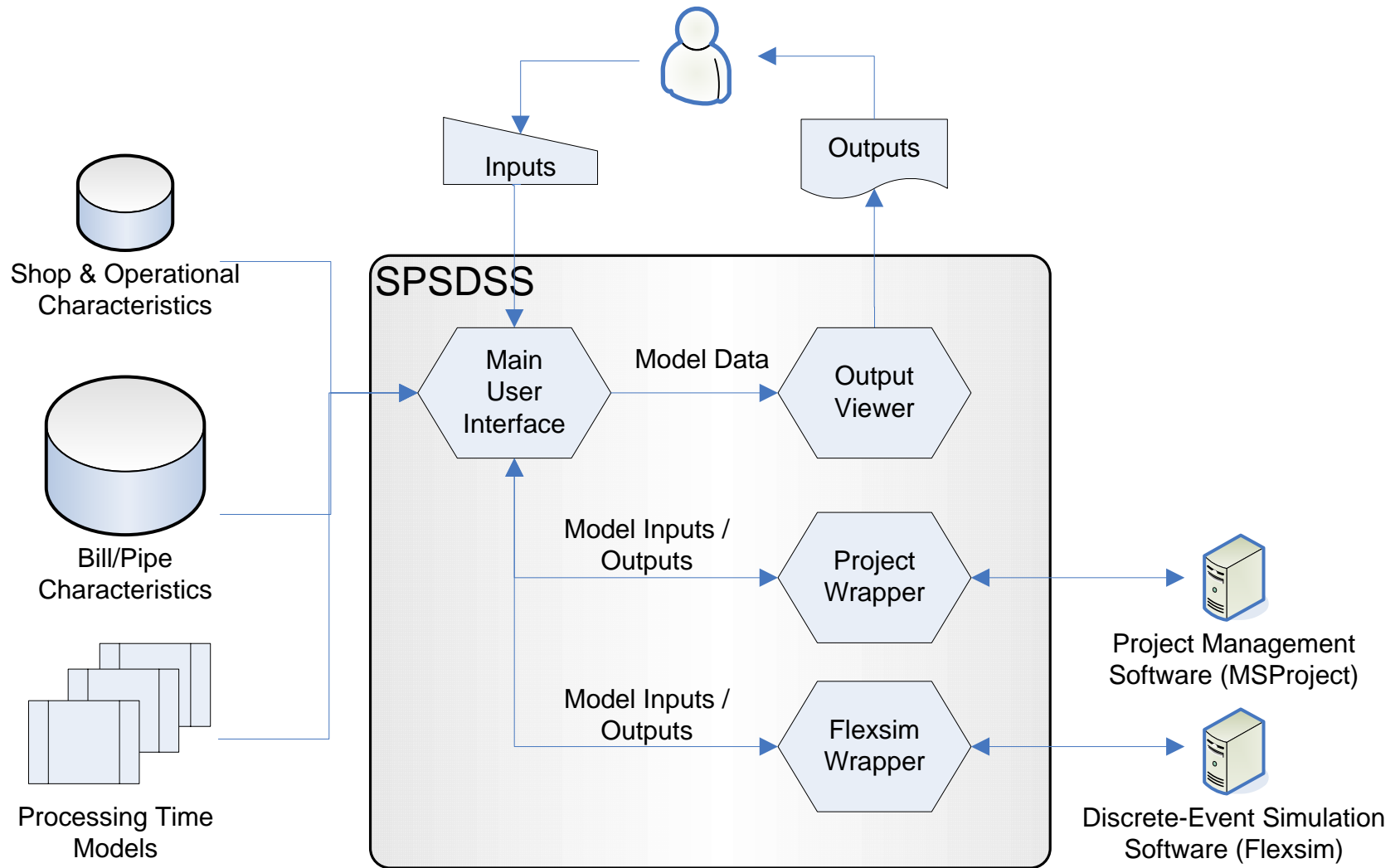


## ❖ **Operations** Model (low-level)

- ❖ assess plan at shop level, including all operations
- ❖ considers interactions, variability, and dynamics
- ❖ establish capacity for high-level model



# Architecture



# Pipe Shop DSS Primary Interface

Current model representation

System inputs

Simulation Model

Basic system outputs

Model chart or graph output

Basic Information Flow

General	Value
Number of PDs:	473
Project Start Date:	9/11/2006
Project End Date:	10/17/2006
Throughput	
Average PDs/Hr:	2.04
Average PDs/Wk:	82.20
Average PDs/Mon:	357.19
Average PDs/Yr:	4,286.30
ManHours	
Average MHours/Hr:	27.76
Average MHours/Wk:	1,117.52
Average MHours/Mon:	4,855.91
Average MHours/Yr:	58,270.94
Utilization	
Cut Area Utilization:	0.04
Bend Area Utilization:	0.05
Fit & Weld Area Utilization:	0.76
Average WIP:	41.95



# Interface to Extract Data from Central Database

The screenshot displays the Pipe Shop Decision Support System v1.0 [Prototype] interface. The main window is titled "Pipe Shop Decision Support System v1.0 [Prototype]" and has a menu bar with "File", "Data", "Models", "Tools", and "Help". The "Data" menu is open, showing options: "Date Range... Ctrl+D", "Labor Settings...", "Resource Settings...", "Lane Selection...", and "Filter". A red arrow points from the "Date Range..." menu item to a dialog box titled "frmDateRange". The dialog box contains the text "Please select a date range for which to load data." and two date input fields, both showing "6/ 5/2006". Below the input fields is a calendar for "June, 2006" with the 5th of June highlighted. The main window also shows a "Sector-Wide" tab selected, a "Gantt Chart View" with task bars, and a "Resource Load" chart. A right-hand panel titled "Outputs" contains the text "Outputs coming soon!".

The Date Range menu item allows users to specify the data to bring into the system.

# Interface to Modify Pipe Detail Attributes

Pipe Shop Decision Support System v1.0 [Prototype]

File Data Models Tools Help

Pascagoula Avondale Tallulah Sector-Wide Outsource

Model Selection  
 High Level Model  
 Low Level Model

Inputs

- Pascagoula
  - 4911
    - 1108-320-A
      - PD01235
      - PD00345
    - 1108-125-Q
      - PD00045
    - 7208
      - 3605-812-F**
        - PD00678**
        - PD00012
        - PD00013
        - PD00014

Gantt Chart View

ID	Task Name	Work	Duration	May 7, '06	May 14, '06	May												
				S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1																		
2																		
3	Bill 1	120 hrs	10 days															
4	Start - Bill 1	0 hrs	0 days															
5	PD1	40 hrs	5 days															

frmBillData

Bill Information

Program: LPD Priority

Hull: 7208

Unit: 234

Bill: 3605-234-D

Unit Build Location: Pascagoula

Schedule Start: 6/ 5/2006

Schedule Complete: 6/30/2006

Work Location: Tallulah

Number of PDs: 3

Update Cancel

Outputs  
Outputs coming soon!

Ready

Double-clicking on an input brings up related information about the selected object.

# Example Output

The screenshot displays the 'Pipe Shop Decision Support System v1.0' interface. A menu is open with 'View Outputs' selected. Two windows are visible: 'frmOutputViewer' showing a 'Bill Report' for 'Low level Tallulah Pipe Shop' and another 'frmOutputViewer' showing a line graph for 'High level Pascagoula Pipe Shop - Number of PDs Per Week'. Red arrows point from the 'View Outputs' menu item to the two windows.

Item	Hull	Unit	Bill	WS (Mod)	Schedule Start	Schedule Complete	Simulated Start	Simulated Complete	Days Late
NSC 4912 6310	5012-038-2	890	9/18/2006	10/27/2006	9/12/2006	9/15/2006	0		
NSC 4912 6310	5011-010-2	890	9/18/2006	10/27/2006	9/12/2006	9/28/2006	0		
NSC 4912 6310	5501-108-2	890	9/18/2006	10/27/2006	9/12/2006	9/13/2006	0		
NSC 4912 6310	5601-019-2	890	9/18/2006	10/27/2006	9/12/2006	10/12/2006	0		
NSC 4912 6110	5103-059-2	890	9/18/2006	10/27/2006	9/14/2006	9/15/2006	0		
NSC 4912 6110	5501-057-2	890	9/18/2006	10/27/2006	9/14/2006	9/15/2006	0		
NSC 4912 6110	5011-013-2	890	9/18/2006	10/27/2006	9/14/2006	9/20/2006	0		
NSC 4912 6110	5601-049-2	890	9/18/2006	10/27/2006	9/14/2006	9/25/2006	0		
NSC 4912 6110	2402-144-2	890	9/18/2006	10/27/2006	9/14/2006	10/19/2006	0		
NSC 4912 6310	3501-136-2	890	9/18/2006	10/27/2006	9/21/2006	9/26/2006	0		
NSC 4912 6310	3506-046-2	890	9/18/2006	10/27/2006	9/22/2006	9/27/2006	0		
NSC 4912 6310	4408-014-2	890	9/18/2006	10/27/2006	9/22/2006	9/25/2006	0		
NSC 4912 6310	5601-064-2	890	9/18/2006	10/27/2006	9/22/2006	9/24/2006	0		
NSC 4912 C130	5903-018-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C130	5011-036-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C140	2306-039-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C130	3506-022-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C140	5901-014-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C140	2401-034-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C140	5903-031-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C130	3505-019-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 B340	2402-077-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C130	2306-035-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 B340	5903-030-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		
NSC 4912 C130	2401-032-2	890	9/18/2006	10/27/2006	9/22/2006	9/23/2006	0		

High level Pascagoula Pipe Shop - Number of PDs Per Week

Time (Wks)	Number of PDs
9/11/2006	150
9/18/2006	280
9/25/2006	350
10/2/2006	220

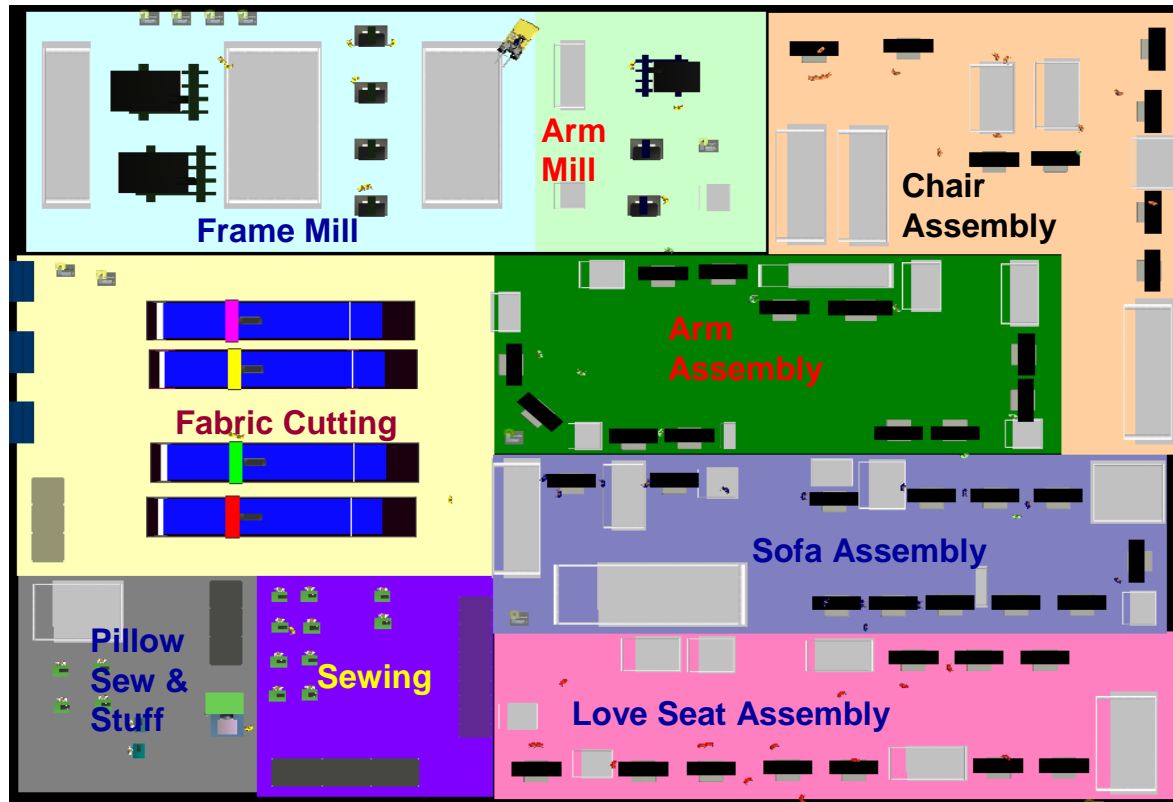
The Output Viewer is used to display all graphs and reports and each are printable and exportable to Excel.

# Lean Manufacturing Flight Simulator

- ✦ **Objective:** Improve *intuition* about the implementation of *lean manufacturing* within the furniture industry. This will be accomplished by ...
  - ✦ Reviewing basic principles of lean manufacturing
  - ✦ Providing the user with the ability to “experiment” with a *simulated plant* (i.e., manufacturing flight simulator).
  - ✦ Enhancing the understanding about relationships between key plant decision variables and performance measures.

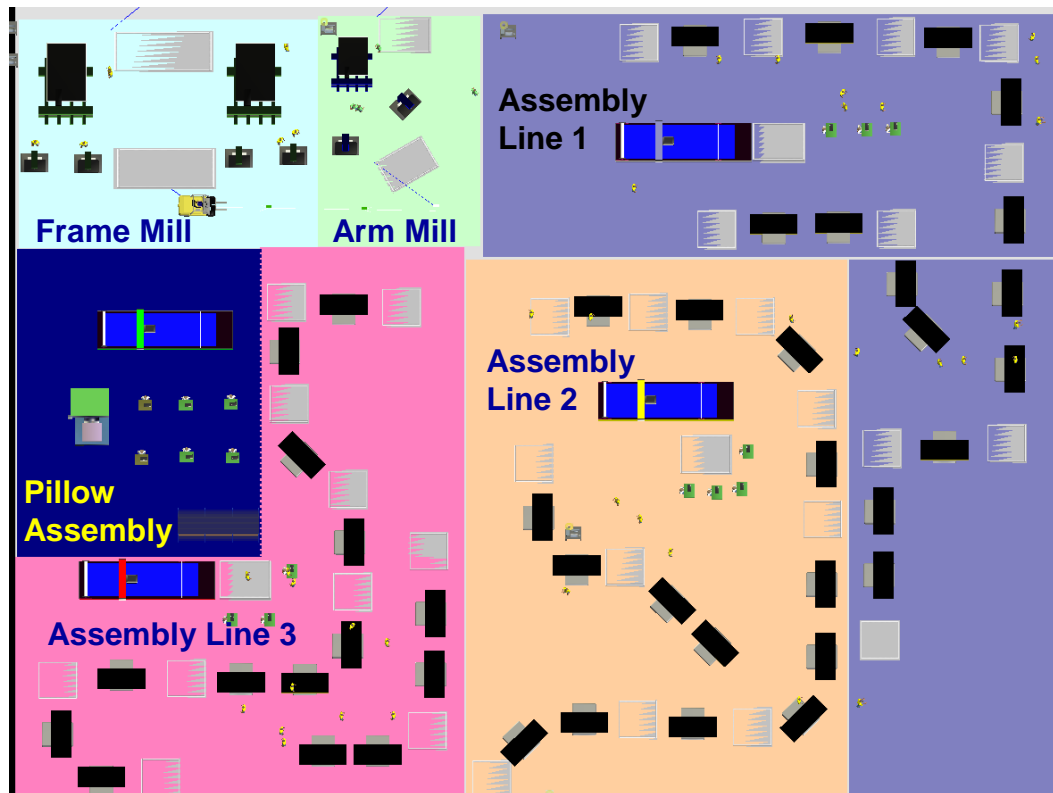
# Characteristics of a Traditional Plant

- ✦ Producing to forecasts and mixes that maximize plant efficiencies.
- ✦ Similar functions grouped together
- ✦ Individual department measures focus on internal efficiencies
- ✦ Quality problems are only detected at inspection stations
- ✦ Set-up times and equipment downtimes are “givens”



# Characteristics of a Lean Plant

- ✦ Focus is on throughput
- ✦ Workers are flexible and move as needed
- ✦ Dependencies between work station are exploited and managed
- ✦ Fabrication & Assembly are managed jointly.
- ✦ Significantly reduced reliance on mechanism for material movement



# Experimentation Parameters

- ✦ **Product Mix** – percentage of the forecast / demand assigned to each product type
- ✦ **Setup Time** – time required to setup between product types
- ✦ **Defect Rate** – percent of products that are defective from a processor
- ✦ **Downtime** – frequency and duration of downtimes
- ✦ **Processing Time** – mean processing time for a given processor
- ✦ **Queue Capacities** – capacity levels of WIP areas

## Performance Measures

- ✦ **WIP** - overall Work-In-Process of the number of units in process
- ✦ **Lead-time** - average time that an order takes to complete all operations
- ✦ **Throughput** - actual production rate in terms of completed units for each hour
- ✦ **Efficiency** - average across all workstations of the percentage of the actual to theoretical production rate
- ✦ **Performance to Schedule** - percentage of scheduled demand achieved
- ✦ **Travel** - average number of feet traveled by each unit produced
- ✦ **First Pass Quality** - percentage of units that complete production with no re-work

# “Points Game”

- ✦ Users are budgeted a given number of points to spend on improving each system.
- ✦ Users can use run experiments to determine where to focus improvement initiatives.
- ✦ Users can apply points to key model areas to:
  - ✦ improve set up time
  - ✦ reduce defect rates
  - ✦ reduce downtime



# Manufacturing Flight Simulator Main Interface

Product Mix Settings

Views and Fly Paths

Model Controls

Status Window

The screenshot shows the 'Manufacturing Flight Simulator' window. It features a menu bar (File, Tools, Help) and several functional panels:

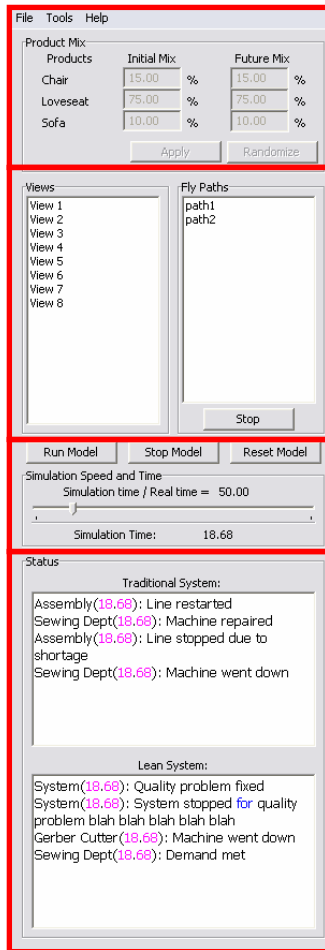
- Product Mix Settings:** A table for 'Product Mix' with columns for 'Initial Mix' and 'Future Mix' for 'Chair', 'Loveseat', and 'Sofa'. It includes 'Apply' and 'Randomize' buttons.
- Views and Fly Paths:** Two lists: 'Views' (View 1-8) and 'Fly Paths' (path1, path2), with a 'Stop' button below.
- Model Controls:** Buttons for 'Run Model', 'Stop Model', and 'Reset Model'. Below is a 'Simulation Speed and Time' section with a slider and 'Simulation Time: 18.68'.
- Status Window:** A text area showing system events like 'Assembly (18.68): Line restarted' and 'Sewing Dept (18.68): Machine repaired'.
- Simulation Model View:** A large 3D rendering of a factory building with a red oval path around it.
- Output Panel:** Contains a 'Model Statistics' table and a 'Throughput Rate vs. Time' graph.

	Traditional	Lean
Space (ft <sup>2</sup> )	50000.00	45000.00
Schedule (%)	31.54	23.12
Travel (ft)	12.34	67.58
Efficiency (%)	9063.73	7549.59
WIP (units/day)	90.34	85.67
Throughput (units/day)	98.78	54.65
Leadtime (days)	63.24	97.21
First Pass Quality (%)	65.98	78.90

Simulation Model View

Output Panel

# Manufacturing Flight Simulator Interface



**Product Mix Settings** – allows users to set the production mix for the simulation model. If the future and initial mix values differ, the model changes the product mix required during the execution of the model.

**Views and Fly Paths** – allows users to maneuver through the simulation model

**Model Controls** – allows users to control the execution of the simulation model

**Status Window** – displays status messages from the simulation (e.g. machine breakdowns, machines coming back online, and whether production was met for the day)

# Simulation Model View

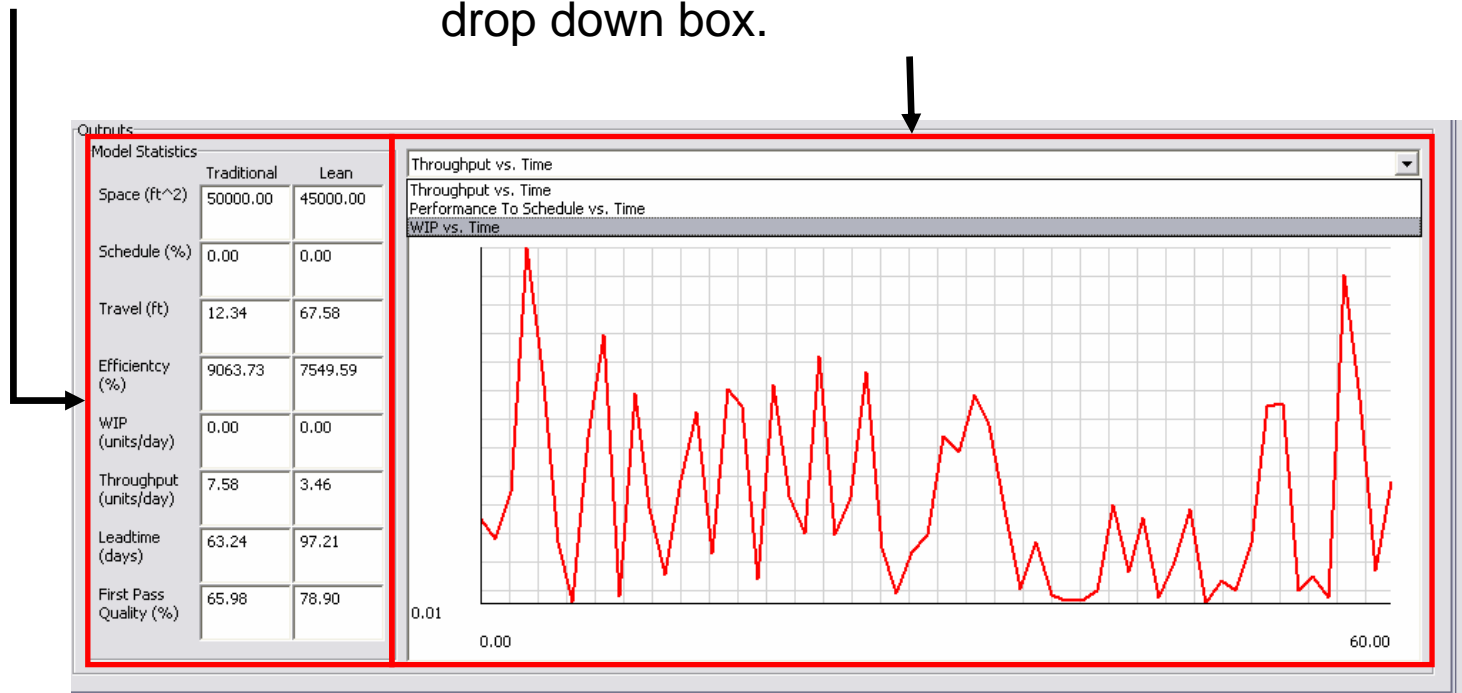
The image displays a 3D simulation of a factory floor. Three configuration windows are overlaid on the scene, each with red arrows pointing to specific areas:

- Traditional Area - pr\_Fram... (Top):** Shows "Average Processing Time (min): 0.00" with "Apply" and "Cancel" buttons.
- Traditional Area... (Left):** Shows "Queue Size: 15.00" with "Apply" and "Cancel" buttons.
- Lean Area - vtAreaL... (Bottom Right):** Shows configuration options:
  - Setup Time: No Change [Cost = 0]
  - Quality Rate: 25% Improvement [Cost = 1]
  - Downtime (duration): 25% Reduction [Cost = 2]
  - Total Cost: 3.00
  - Buttons: Apply, Close

# Output Panel

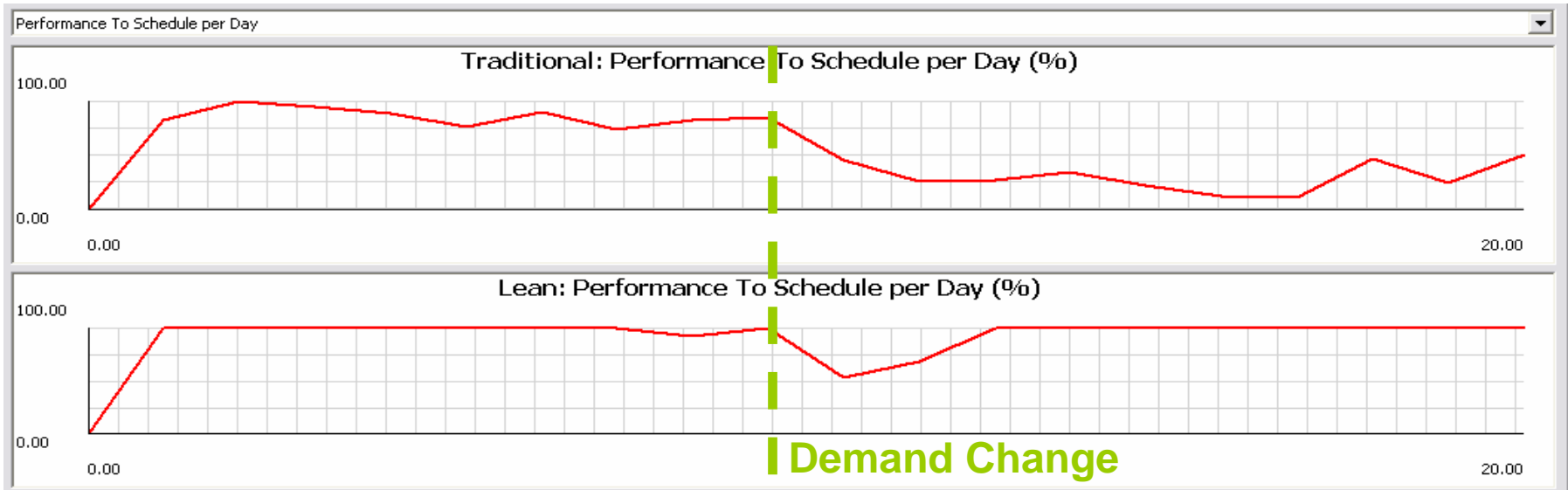
**Model Statistics** – displays summary statistics as the model runs

**Graphical Data** – displays data over time as the model runs. The user can view different graphs by selecting them in the drop down box.



# System Benefits

- Ability to experiment on a more complex system
- Ability to compare global metrics such as equipment efficiency, total WIP and performance to schedule
- Ability to see how the systems react to a major change in demand





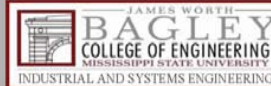
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