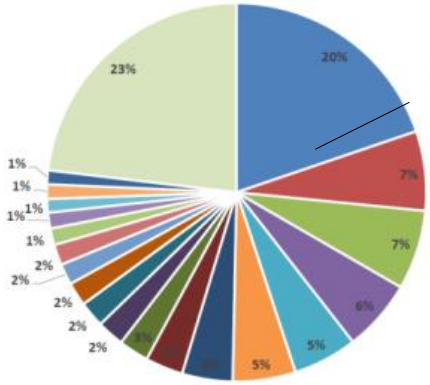
Simio use in Aerospace Technology Development

Chris Tonn – Spirit AeroSystems

May 14th, 2019

Spirit Is the Leading Global Aerostructures Tier 1 Supplier

Global aerostructures leader



Source: Counterpoint

With a balanced aerostructures portfolio

Fuselage (52%)

Propulsion (26%)

Wing (22%)

And an emerging presence in Defense

Sikorsky CH-53K

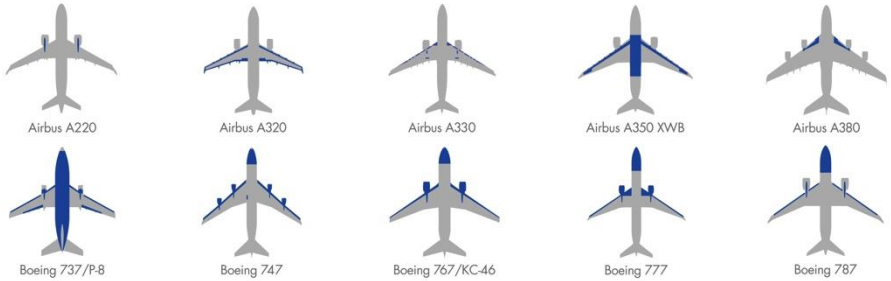
Bell V-280

P-8A, P-8I

KC-46A Tanker

Northrop Grumman B-21

On all of 12,600 Boeing/Airbus backlog



SPR backlog = $47B

Spirit Has a Global Footprint

~15,000 Employees across 15M square feet of facilities

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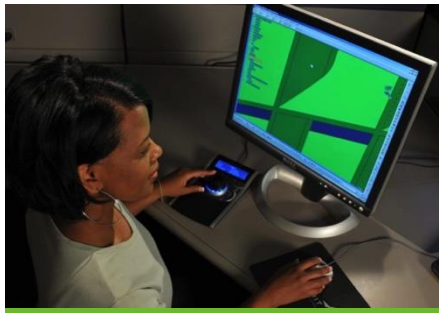
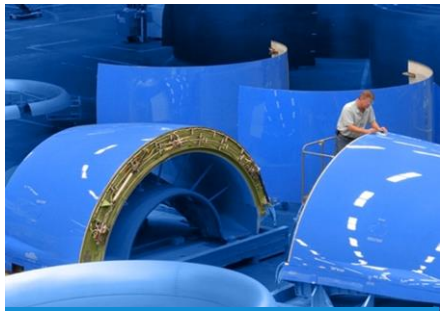
Ensure Spirit's future:
Win spots on future commercial and military aircraft platforms

Spirit Strategic Vision

Innovate in large scale and composite design and manufacturing capabilities to become the leading aerospace structures company


DESIGN


BUILD


SUSTAIN

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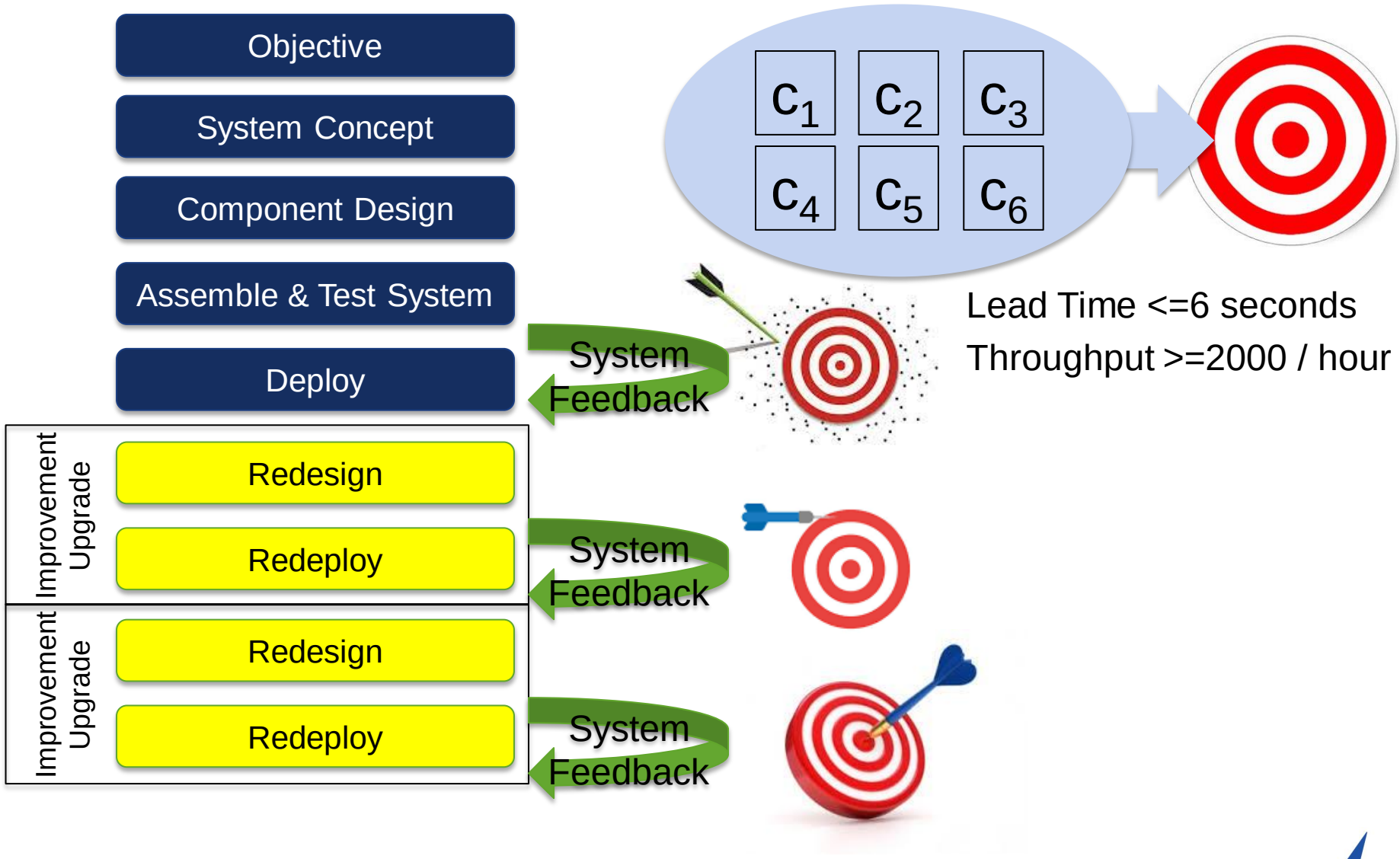
Conventional Technology Development



Late System Feedback Causes Rework

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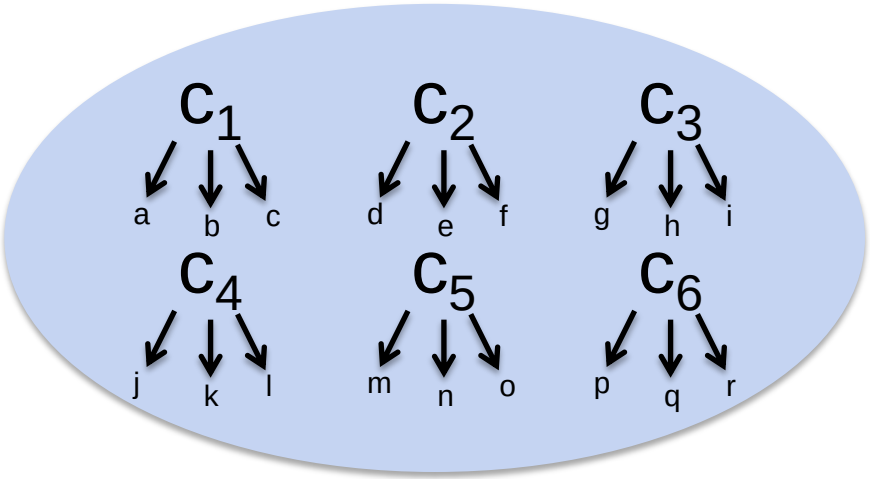
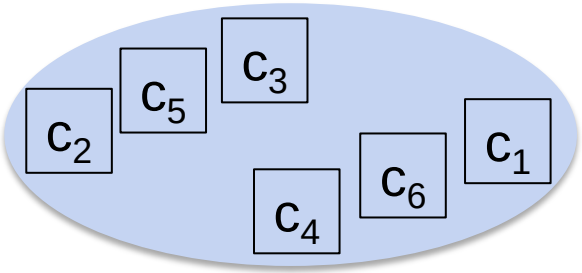
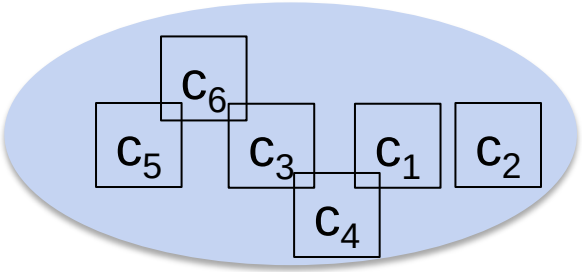
Component Design Decisions



or



or



How many systems combinations exist?

- 6 components
- 3 design options each
- 3 system architectures
- 3 x 3 x 3 x 3 x 3 x 3 = 2,187 combinations
- Which option meets objectives?
- Do any options meet objectives?
- Does one component have more influence on meeting objective than others? Which one?
- Which system architecture delivers most performance?
- When is a component design good enough?

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Conventional Technology Development

Objective

System Concept

Component Design

Assemble & Test System

Deploy

Improvement Upgrade

Redesign

Redeploy

Improvement Upgrade

Redesign

Redeploy

System Feedback

System Feedback

System Feedback

Simulation Assisted Technology Development

Objective

System Concept

Simulate

Component Design

Assemble & Test System

Deploy

System Feedback

System Feedback

Fast forward System Feedback with Simulation

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Simulate Early

Questions

- Does one component have more influence on meeting objectives than other components?
- Which one and by how much?

Develop Generic Model

Design Of Experiments

DOE allows for multiple input factors to be manipulated, determining their effect on a desired output (response), *ASQ.ORG*

BONUS

By manipulating multiple inputs at the same time, DOE can identify important **interactions** that may be missed when experimenting with one factor at a time. *ASQ.ORG*

Which Experimentation Method To Use?

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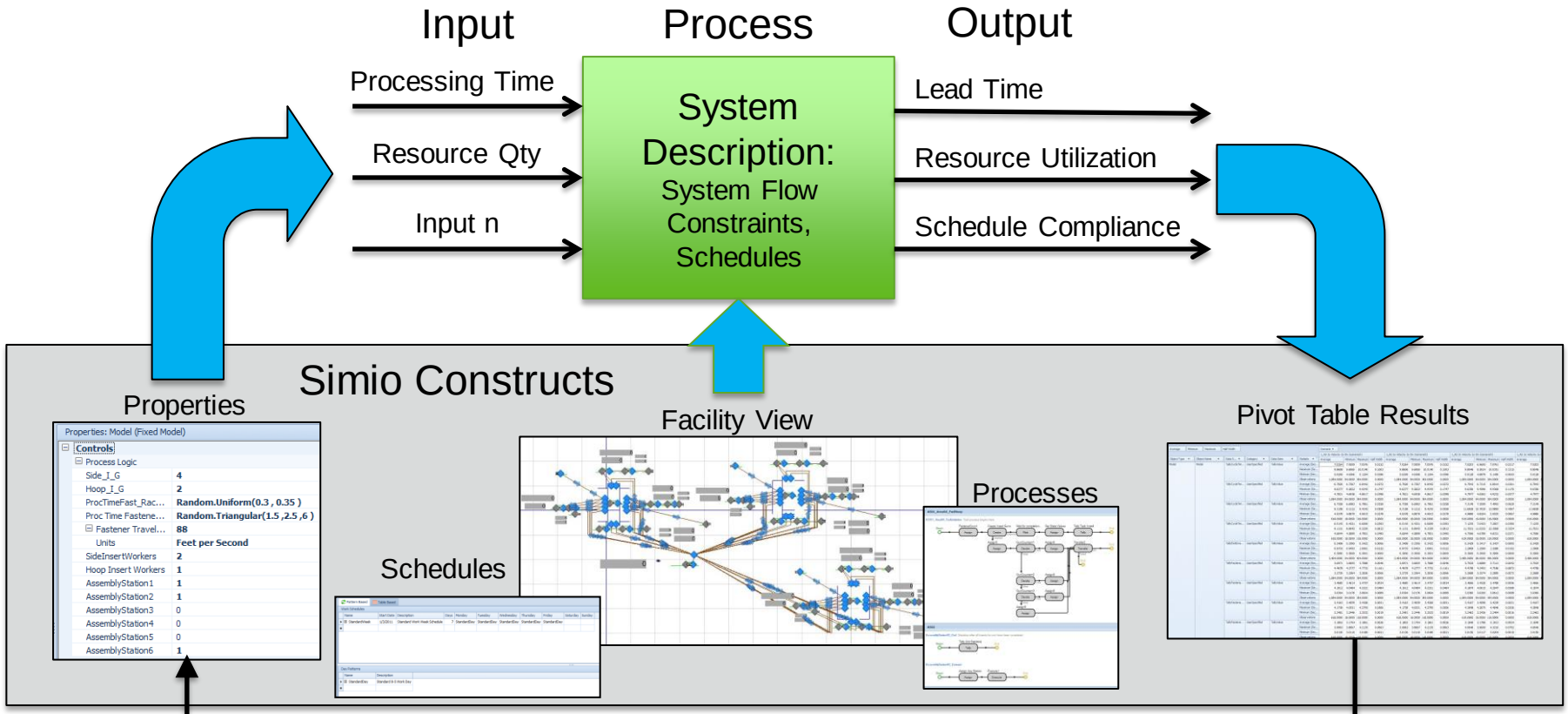
Design Of Experiments



Simio Experimental Design Grid

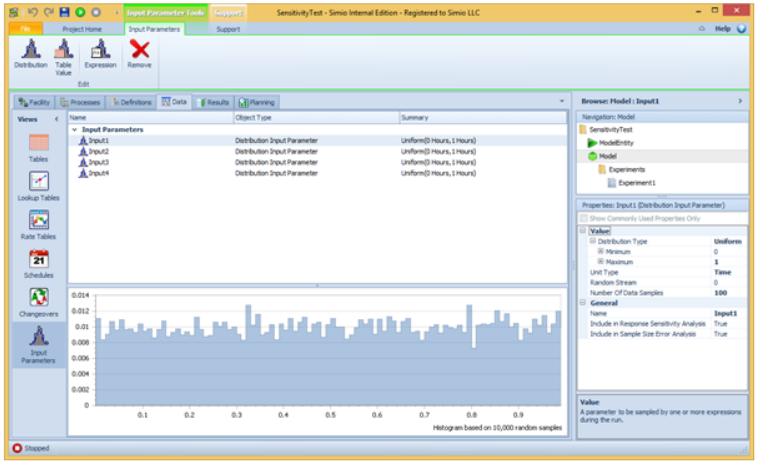
Scenario			Replications		Process Logic - Controls										Responses						
	Name	Status	Required	Completed	SideIn...	Ho...	SideIn...	Hoop I...	Fast...	As...	As...	As...	Ass...	Ass...	Diverter Utilization	Div Time (Seconds)	F Instal...	F Install RH...	F Install Aft Hoo...	F Install Fwd...	Unit Install AS01...
☑	3_AS 3x Velocity 2x Div Scenerio03	Idle	10	10 of 10	1	2	1	1	88	1	1	0	0	0	41.5086	0.431269	3.52699	3.57955	3.27255	3.31317	122.962
☑	3_AS 3x Velocity 2x Div Scenerio04	Idle	10	10 of 10	1	2	2	1	88	1	1	0	0	0	41.5086	0.431269	3.52699	3.57955	3.27255	3.31317	122.962
☑	3_AS 3x Velocity 2x Div Scenerio07	Idle	10	10 of 10	2	2	1	1	88	1	1	0	0	0	69.7028	0.568429	3.67799	3.73288	3.40296	3.40117	74.5264
☑	3_AS 3x Velocity 2x Div Scenerio11	Idle	10	10 of 10	3	2	1	1	88	1	1	0	0	0	69.6171	0.61451	3.73506	3.79061	3.46432	3.3932	74.3937
☑	3_AS 3x Velocity 2x Div Scenerio15	Idle	10	10 of 10	4	2	1	1	88	1	1	0	0	0	69.4884	0.622667	3.74302	3.80256	3.47446	3.39082	74.6929
☑	3_AS 3x Velocity 2x Div Scenerio08	Idle	10	10 of 10	2	2	2	1	88	1	1	0	0	0	69.2618	0.620742	3.74467	3.79277	3.46146	3.40967	74.5921
☑	3_AS 2x Velocity 2x Div Scenerio03	Idle	10	10 of 10	1	2	1	1	58.67	1	1	0	0	0	38.6533	0.425615	3.86253	3.94271	3.60665	3.6766	128.535
☑	3_AS 2x Velocity 2x Div Scenerio04	Idle	10	10 of 10	1	2	2	1	58.67	1	1	0	0	0	38.6533	0.425615	3.86253	3.94271	3.60665	3.6766	128.535
☑	3_AS 2x Velocity 2x Div Scenerio07	Idle	10	10 of 10	2	2	1	1	58.67	1	1	0	0	0	65.9742	0.549205	4.00167	4.07899	3.72893	3.75519	76.4227

Experimental Options In Simio

Input Analysis

- Input parameter (distribution, expression, table value)
- Response Sensitivity shows influence on results for a specific experimental trial

Specifying an Input Parameter of Type Distribution

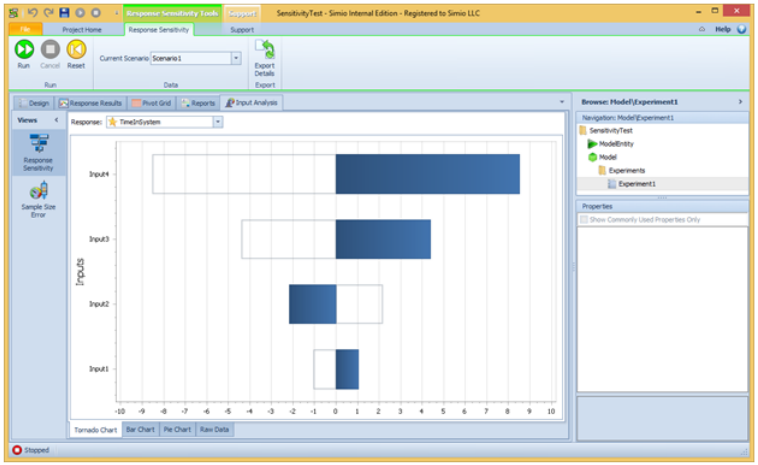


Model>Data>Input Parameters

Challenges

- Difficult to compare outcomes between scenarios

Sample Response Sensitivity Analysis (Tornado Chart)



Experiments > Input Analysis > Response Sensitivity

Not Enough Comparison Power

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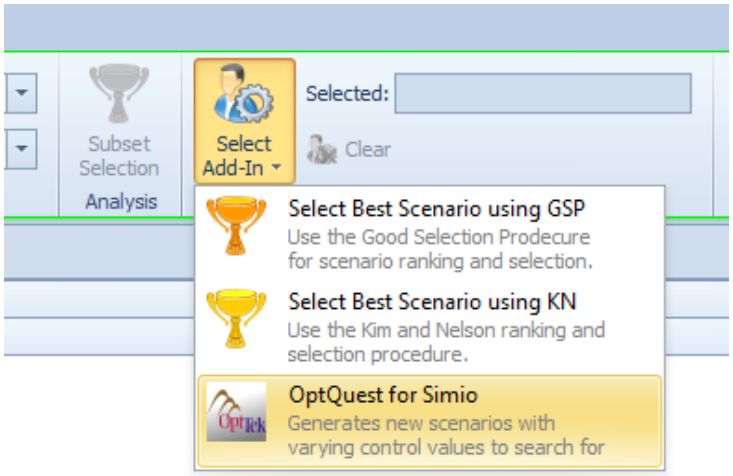
Experimental Options In Simio

Opt Quest

- Easy to use setup
  - Objective type
    - (Single, Multi, or Pattern Frontier)
  - Response objective
    - (None, Maximize or Minimize)
  - User sets values to investigate for each parameter
    - (Minimum, Maximum, Increment)
  - Max number of scenarios
- Automatically searches for optimum objective without much user effort

Challenges

- Not standard part of Simio package
- Parameters can not be expressions. Must be numerical values



Experiments > Select Add In > OptQuest for Simio

Finds Optimum Not Component Significance

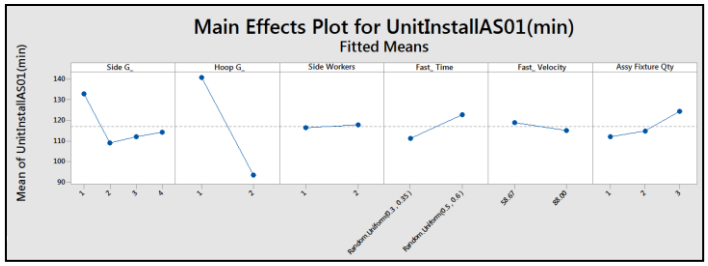
Experimental Options In Simio

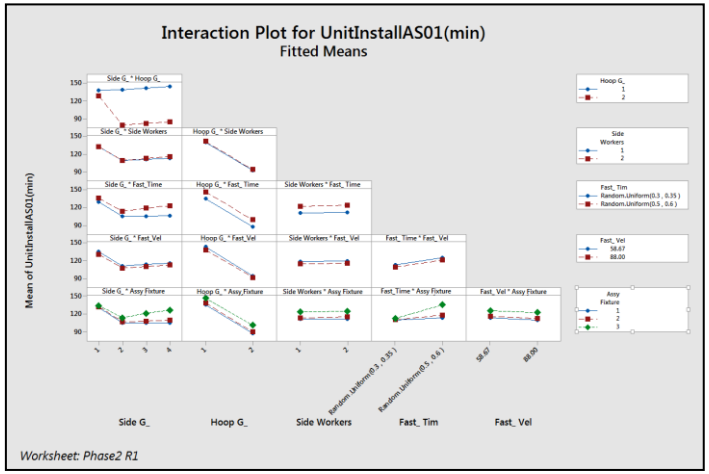
Statistical Software Outside Simio

- Quantifies effect of parameter changes
- Main Effect and Interaction Plots
- F-Value quantifies significance between parameters and combinations of parameters

Challenges

- Difficult to format data to import into statistical software





Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value
Model	99	1678083	16950	15762.35
Linear	9	1375553	152839	142127.38
Side G_	3	167433	55811	51899.31
Hoop G_	1	1080659	1080659	1004920.67
Side Workers	1	728	728	677.12
Fast_ Time	1	64966	64966	60412.43
Fast_ Velocity	1	7141	7141	6640.22
Assy Fixture Qty	2	54627	27313	25399.03
2-Way Interactions	32	288858	9027	8394.17
Side G_*Hoop G_	3	227739	75913	70592.59
Side G_*Side Workers	3	872	291	270.25
Side G_*Fast_ Time	3	7897	2632	2447.72
Side G_*Fast_ Velocity	3	445	148	137.86
Side G_*Assy Fixture Qty	6	17332	2889	2686.18
Hoop G_*Side Workers	1	11	11	10.30
Hoop G_*Fast_ Time	1	5	5	4.47

Everything Needed To Answer Question

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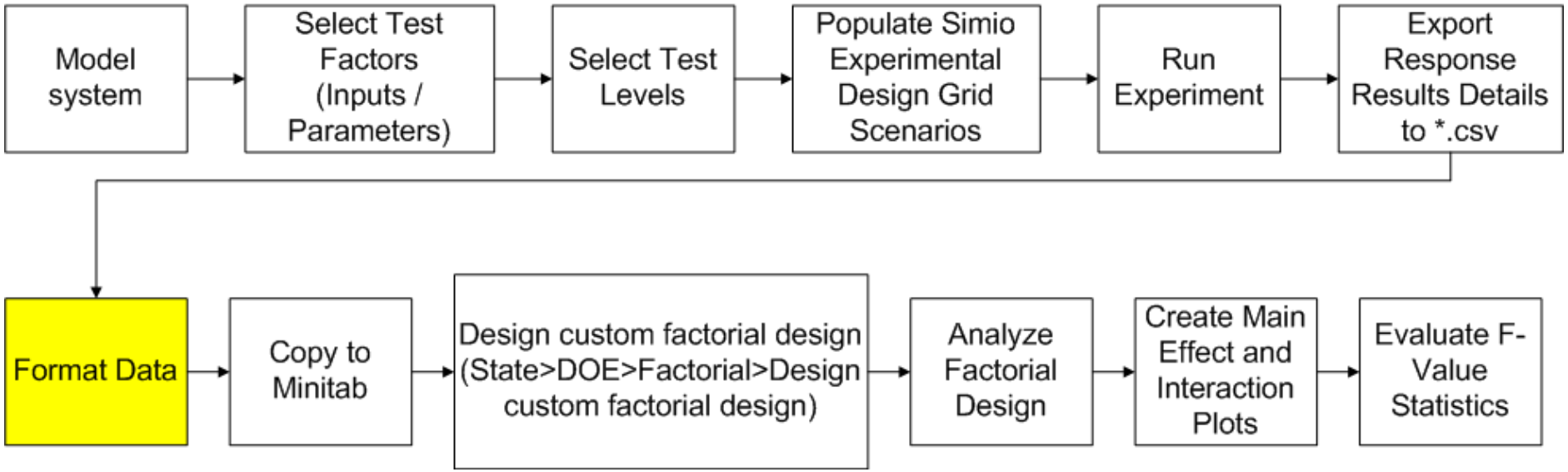
Experimental Options in Simio:



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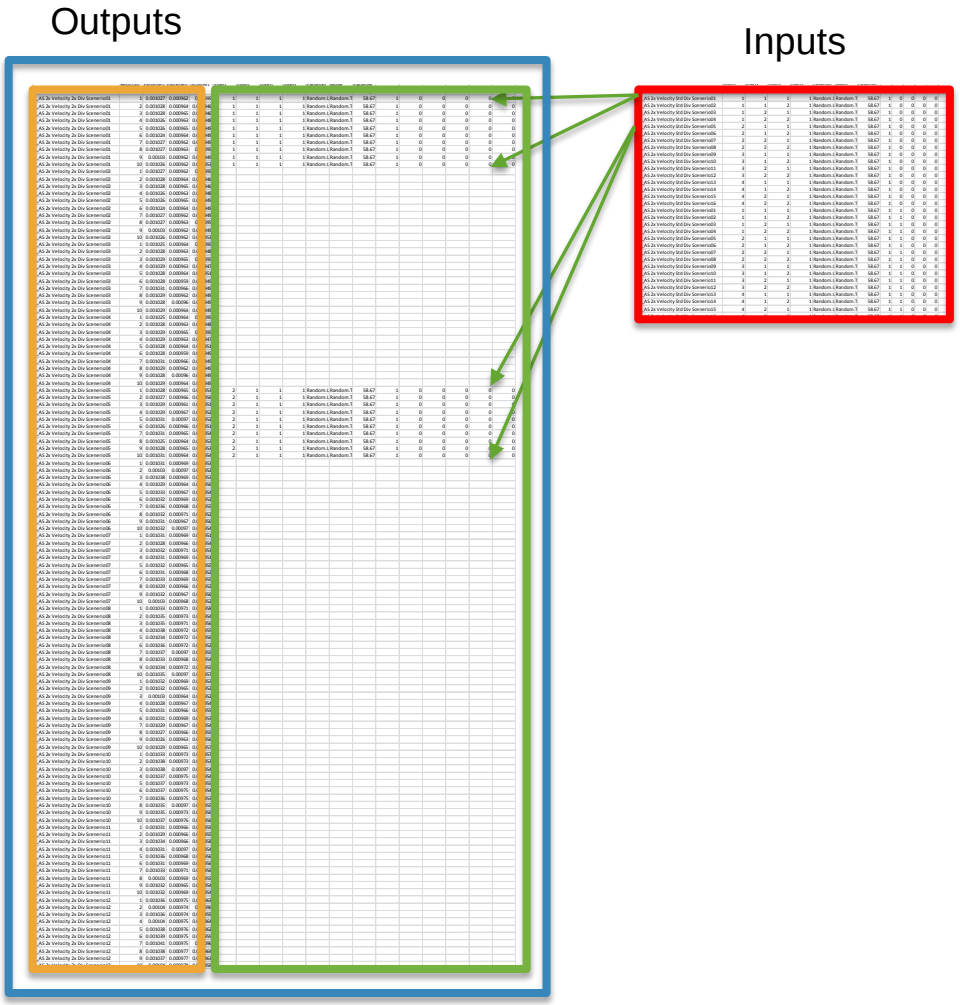
Challenge: Format Data

Format Data



1. Response Results>Export Details to *.csv format
2. Copy Design Grid To Excel and manually type header information
3. Use excel vlookup function to combine experimental outputs with their corresponding inputs into each row (partially complete for presentation purposes)
4. Copy into Minitab

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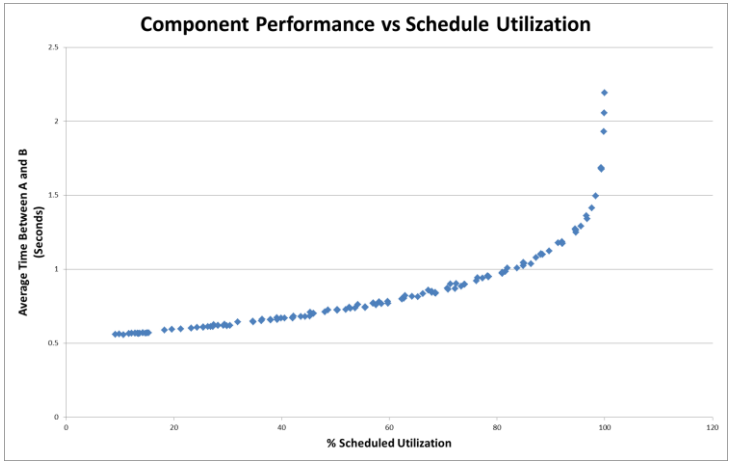
Simulate Early Results

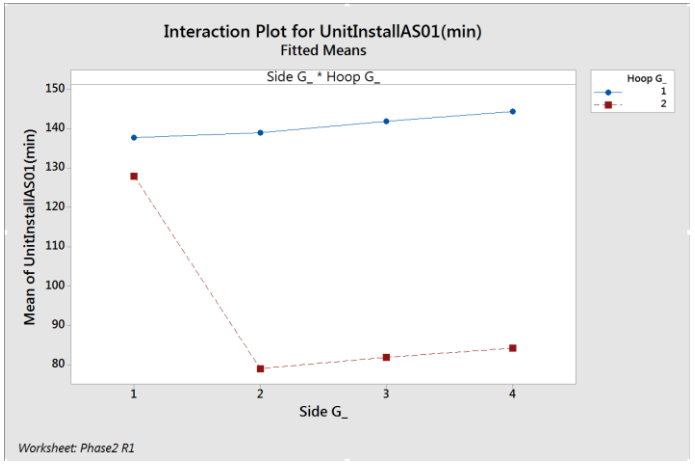
Main Effect Plot and F Values

- Ranked components by their significance to meet objectives
- Spotlighted an under appreciated component as most significant
- Quantified critical component performance as a % of utilization
- Led to system insight and changed direction of development effort

Interaction Plot

- Revealed an unknown method for minimizing unit lead time





Raised New Questions To Answer

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Simulate Early Rev 2

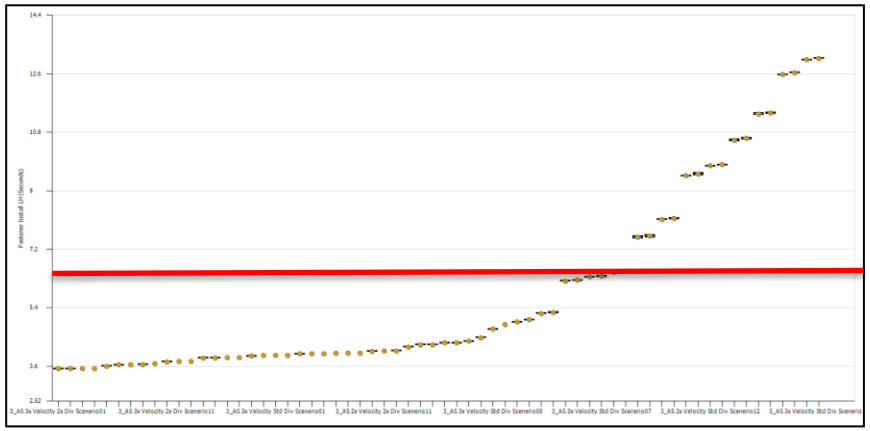
Question

- What if critical component worked differently and drastically better?
- Can model reflect launch customer's installation?

Create Detailed Model

Experimental Design Grid

Simio Response Results Graphs



Challenge

Incorporating both required a new approach to how demand on system was created and how entities were routed to multiple customers.

Results

- Start over with new model
- Eliminated designs that would not meet objectives

Raised More Questions To Answer

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Simulate Early Rev 3

Question

- Which system architecture delivers most performance?

Update Detailed Model

Experimental Design Grid

Simio Response Results Graphs

Excel Graphs

Challenge

How to represent cumulated wait time and compare them

Results

- State Statistic, logged observations, and exported to Excel to plot results
- Further eliminated designs that did not meet objectives or did not increase performance enough for added complexity

Weighing Performance Value vs Complexity

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Simulate Early Rev 4

Question

- When is component design good enough to meet objectives?

Update Detailed Model

Experimental Design Grid

Pivot Grid

Performance Targets

Processing Time: Triangular (1.5, 2.5, 6)

Travel Velocity: 58.67 feet / second

Travel Time			
From	To	Duration	Units
A	B	0.4	seconds
B	C	0.15	seconds

Travel Length

	Area			
Location	X1	X2	X3	X4
1	81	61	81	61
2	61	81	61	81
3	81	61	81	61
4	61	81	61	81
5	119	139	119	139
6	124	144	124	144

Design To Performance Targets

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Replication

- Expect demand to be high for system
  - Improves quality
  - Shortens operator learning curves

- Simulation can model each potential customer's application for:
  - Performance prediction – setting customer expectation
  - Design trade offs
    - System cost
    - Performance

- Simio custom objects will make it simple to build these models

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Conclusions

- Simulate Early and Often – Steer technology development toward target

- With early feedback designers can fast forward improvement upgrades to initial design

- Combining Simio with Design of Experiments
  - Spotlighted an overlooked component with significant influence
  - Revealed a method for minimizing unit lead time
  - Focus development resources on important components

- Several options exist to perform experiments within Simio

- Simio helps Spirit:
  - Innovate
  - Develop distinctive capabilities
  - Replicate deployment of technology

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Thank You





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