About the presenter

- Experience
  - Corporate
    - Large and Small projects
    - Including International
  - Consulting
    - Leader and team member
- Education
  - BSME (University of Minnesota)

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What this presentation will cover

- Product Development Flow
- The Point Solution Problem
- Design of Experiments Solution

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Product Development Flow

What happens?

Product Development Flow

- Requirements
- Concept
- Proof of concept
- Key variables
- Sensitivity analysis
- Learning/ recommendations
- Final Design
- Validation

Avoid jumping ahead

Applies to product and process design

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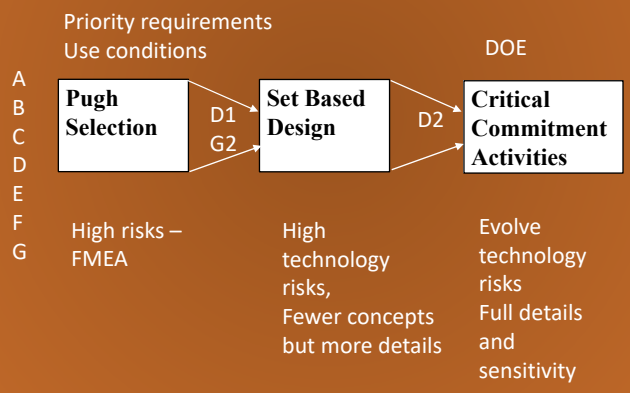
Convergent/ Divergent Concept



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The Point Solution Problem

- Missing Potential
  - Stuck at preliminary design
- Likely no stability
- Likely more expensive than needed
- Can it be scaled?
- Impact on validation and end of development schedule
- Impacts Design Culture/ Behaviors

Stability

- Consistency
- With material variation
- With design variation
- With process variation
- With environment variation

- Know of places to open tolerances
- Know where to improve process controls

Can also look at cost and schedule sensitivity

Intro to DOE Solution

- A tool to identify relationships between multiple input and multiple output variables
- Common window is 3-7 inputs but phased approach is common
- Outputs – unlimited, but solution becomes less intuitive with larger quantities
  - Include competing requirements
  - Always a cost trade off
- Additional depth is important to increase confidence
  - Residual analysis is core approach which also provides additional learning

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Typical DOE Test Table

Test #	Variable			Response			
	A	B	C	1	2	3	4
1	-	-	-				
2	+	-	-				
3	-	+	-				
4	+	+	-				
5	-	-	+				
6	+	-	+				
7	-	+	+				
8	+	+	+				

This is the most simple case. Can add more inputs and outputs. Do not have to test every combination.
This case is often evaluated at 3 conditions, leading to 27 tests.

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Dealing with Sensitivity Information

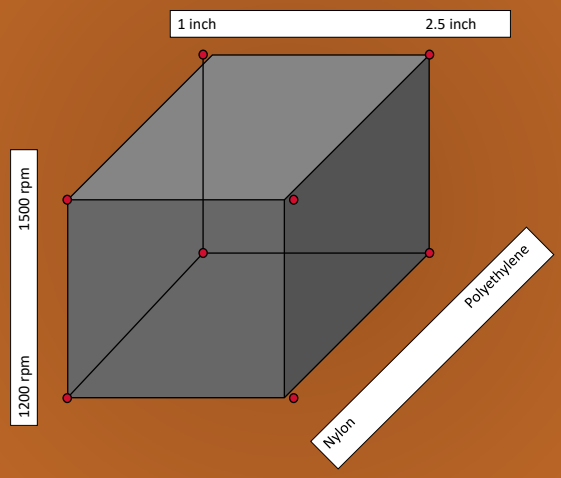
- Based on the sensitivity, can we determine a new solution
- A balance of the levels we previously tested at
  - Do not need to select corners of the cube. We can pick the interior
- For example, if we did a temperature of 70 and 150, maybe we can determine a level of 90 may be our “sweet spot”

Design of Experiments (DOE)

- How do we find an ideal sweet spot?
- Simultaneous, strategic changing of variable settings and multiple output measurements
- Confident prediction to speed decision making

May be useful for feasibility but certainly an advantage for development

Design of Experiments - Product



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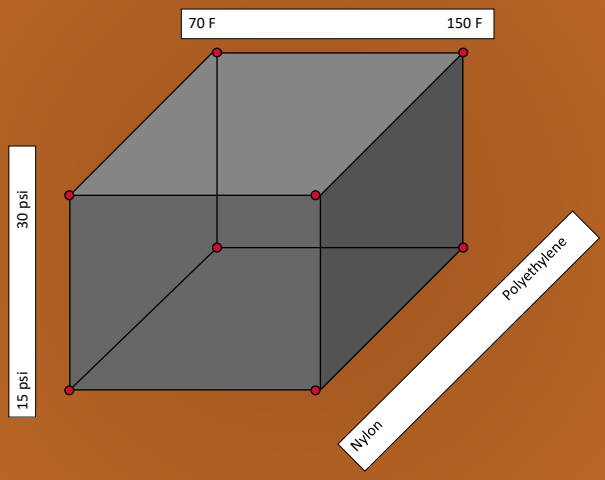
Design of Experiments - Process



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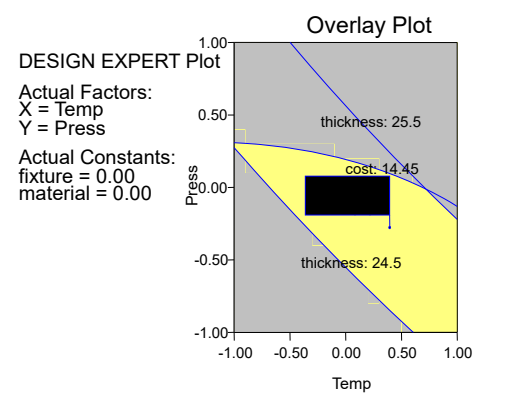
DOE Testing

- DOE can explore extremes and avoid all of the middle values
  - Interpolation often matches quite well

Optimization



Example Equation

- Y = z + a*[A] + b*[B] + c*[C] + d*[A*B]
- Y = z + 15*[A] + 8*[B] + 1*[C] + 8*[A*B]
  - A is key variable
  - C tolerance can be opened up

Next Step

- Another test?
  - Change ranges
  - New variables to replace less important ones
  - Add responses/ outputs
- Finalize design
  - Confirm and then move to validation

Key takeaways

- As we advance our designs, knowledge and understanding shapes our decisions
  - More knowledge means more predictability
- If we stop with a preliminary design, the instability causes development delays and cost impacts.
- Doing sensitivity analysis well, accelerates the end of the development process

Thank you for attending!!!

For more information feel free to contact me:

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