DOE as a Tool within the Development Process

Minnesota Quality Conference

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Agenda

- DOE definition and tool description
- Development process and how DOE fits in
- How to get started using DOE

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DOE Definition and Tool Description

It is only a tool – and not always the right choice

Understand Variable Relationships

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DOE Definitions

- **DOE organizes the collection of development test data to determine the most statistically confident relationship between inputs and outputs.**
  - **Complexity of the relationship is chosen by the user.**

- **DOE is a tool to assist in the process of understanding a system**

Provides understanding
- equation
- priority
- area of interest

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Process Development

- **Goal: Reduce rework, amount of coating used, amount of coating wasted and cost of coating process**
- **Response: Achieve vendor recommended thickness and customer required visual quality**
- **Approach: Use DOE in lab environment to determine air pressure and flow rate settings while a new production line is being set up**
- **Result: Achieved a significant reduction in cost and defined settings quickly for a high quality finish**

Office Process Development

- **Goal: Accelerate time to market**
- **Response: Approval time of engineering changes**
- **Approach: Use DOE to assess factors influencing sign-off. Submitter experience, approver experience, and change complexity are example variables.**
- **Result: Identified a training issue which would reduce approval iterations and improve sign-off by an average of several weeks.**

Product Development

- **Goal: Evaluate battery design options**
- **Response: Battery size and longevity**
- **Approach: Use DOE with a simulation to assess design and modeling factors influencing performance.**
- **Result: Understood sensitivities such that detailed design decisions could be made quickly and with certainty.**

St. Thomas Projects

- Welding, web processes, heat treat, stamping
- Molding plastic and rubber, foaming (gaskets, diaphragms and piece parts)
- Adhesive in assembly, epoxy curative reaction, powder coating colorization, adhesive delivery
- Plating, vapor deposition, cleaning, soldering, polishing
- Laser cutting, drilling and surface grinding equipment
- Medical fluid sampling equipment
- Electronics, composites, food
- Seal repeatability, product durability/ reliability
- Office process flow, process waste, mfg sim.
- Analysis of hydraulic, thermal & molding

90 of these projects saved an estimated $4,184,000 thru Spring 2001.

Medical Development DOE Application Ideas

- Performance modeling
- Environmental Exposure
- Process validations
- Seal integrity
- Adhesive connections
- Electrical isolation
- Polishing operations

Can be used anywhere but not everywhere

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Tools

- **Factorial Designs**
  - Full and Fractional
  - Taguchi - maximum assumptions
- **Advanced Designs (Response Surface Methods)**
  - 3 and 5 level
  - Optimization
- **Related Statistical Tools**
  - Statistical Process Control (SPC)
  - Probabilistic Failure Assessment (PFA)

Organizing the collection of data to determine the most statistically confident relationship

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Tool Comparison / Typical Equations

OFAT or Taguchi typical output (main effects)

$$y = z + a*A + b*B + c*C$$

More information (fine tuning) is achieved as progress to more rigorous tools

Factorial typical output (main and interactions)

$$y = z + a*A + b*B + c*C + d*A*B + e*A*C + f*B*C + g*A*B*C$$

Response Surface typical output (main, interactions, quadratic)

$$y = z + a*A + b*B + c*C + d[A]^2 + e[B]^2 + f[C]^2 + g[AB] + h[AC] + i[BC] + j[ABC] + p[A]^3 + q[B]^3 + r[C]^3 + s[A^2B] + t[AB^2] + u[A^2C] + v[AC^2] + w[B^2C] + x[BC^2]$$

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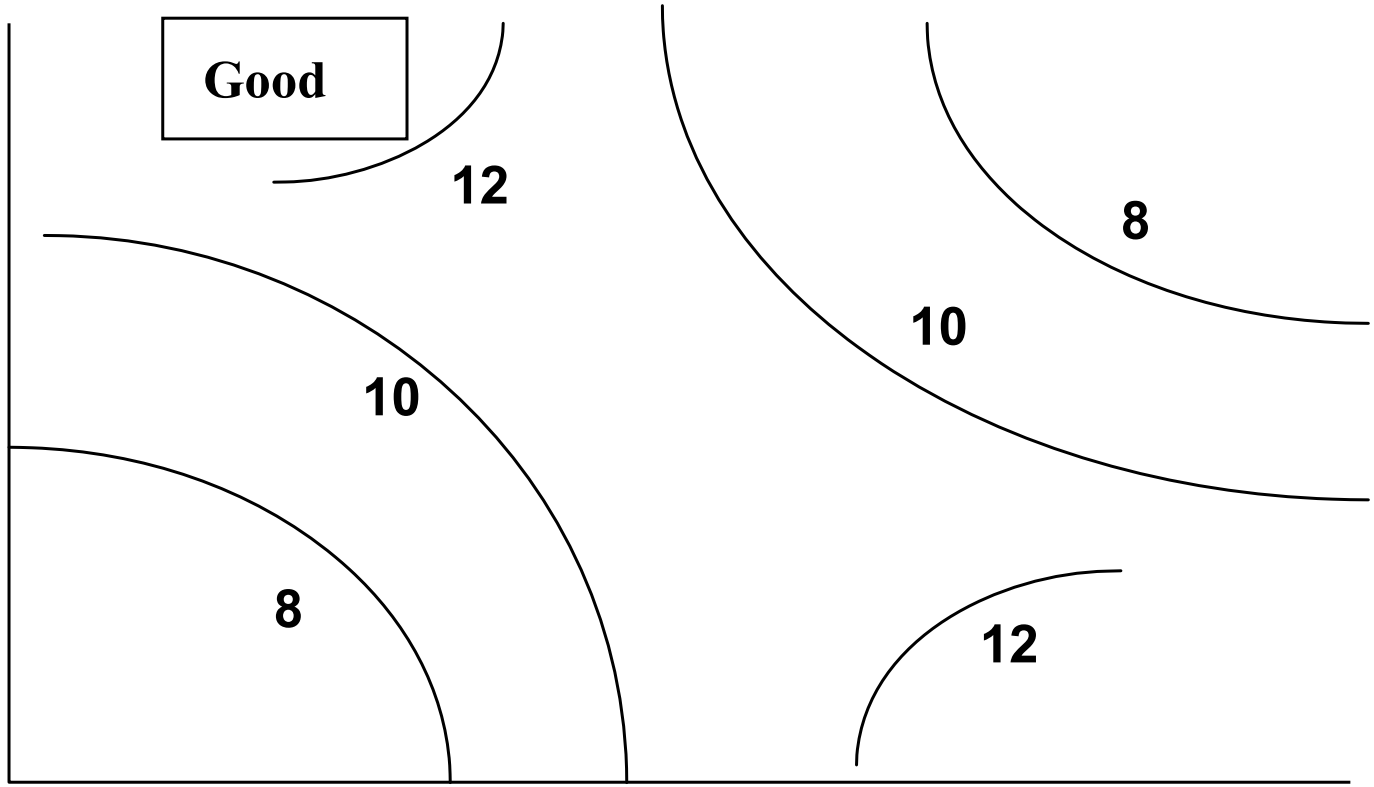
RSM, Postage Stamp



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DOE and the Development Process

“DOE – It’s not just for hardware anymore…”

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Types of Testing in Development Process

- Thought Experiments * (concepting stage simulation and trade studies)
- Development * (subsystem, components, validation)
- Verification (composite system or subsystem, hypothesis testing)
- Qualification (composite system or subsystem, clinicals)
- Problem Resolution * (manufacturing, and post-implementation field issues)

* These are the areas where DOE is used

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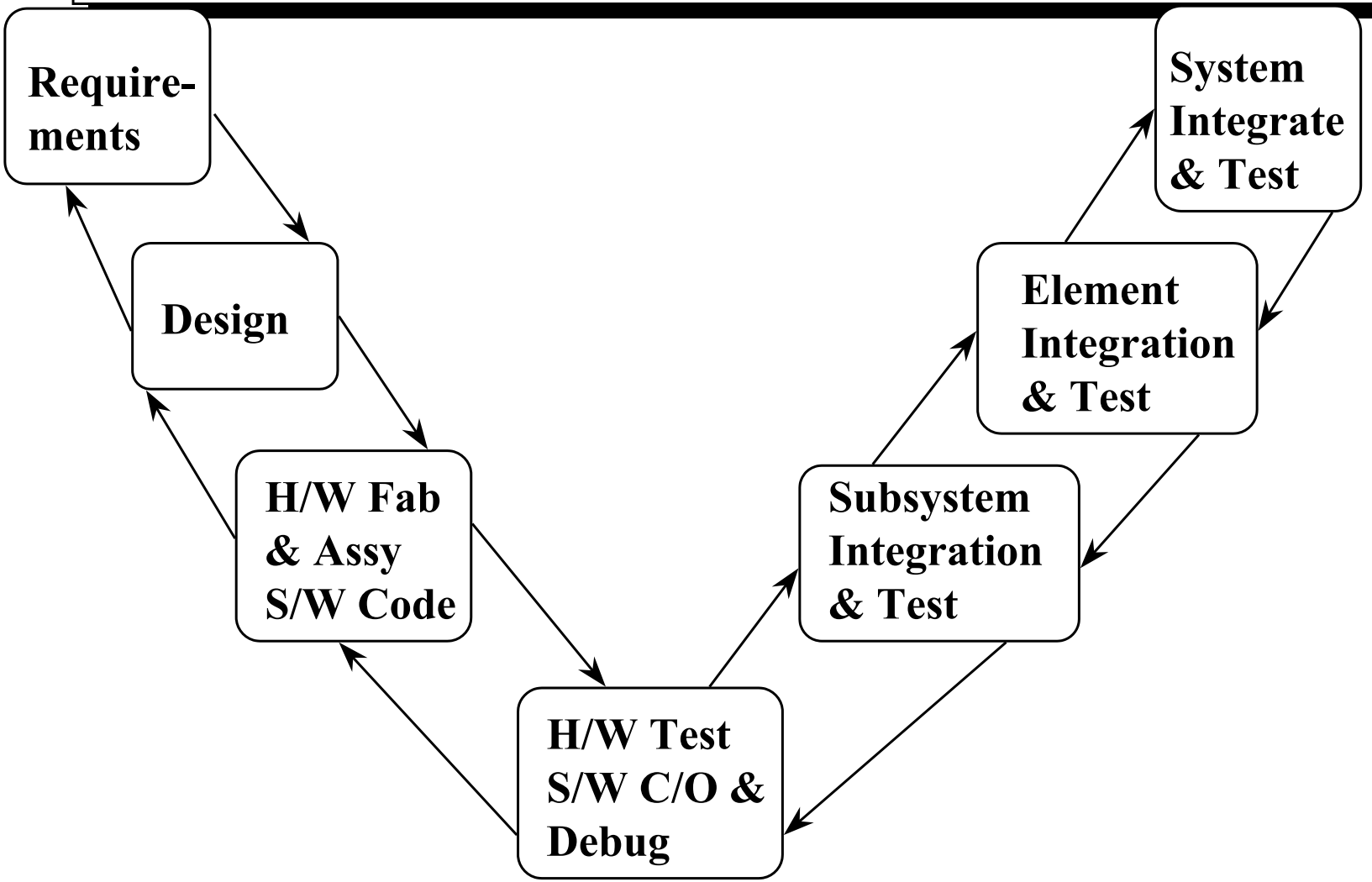
System Life Cycle "V" Model



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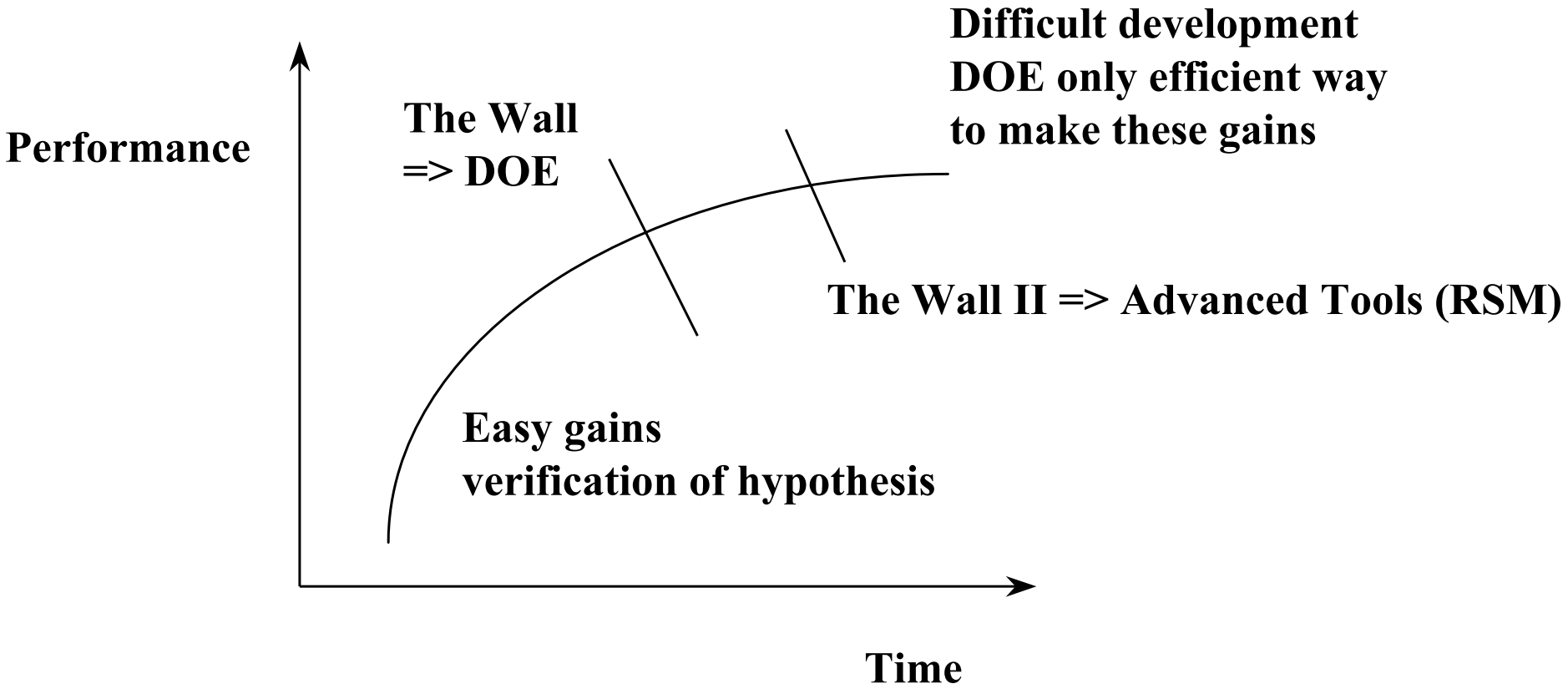
Development Stages



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Development Process Benefits

- Schedule acceleration
- Can consider more variables
- Optimize variable settings by analysis versus prototypes
- Organized and efficient test approach to characterize actual performance of prototype hardware, production hardware and processes
- Design flexible prototypes for test to reduce cost
- Goes beyond factors-of-safety approach on critical components to reduce weight

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DOE Process

- Define goal - need
- Define response(s) to measure progress to goal
- List all variables and down select to "key" variables using engineering judgment
- Select appropriate design matrix - approach *
- Select safe/consistent test levels for variables
- Address tradeoffs between responses
- Perform test
- Analyze results *
- Discuss next step

* Where DOE software helps

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Keys for Development Application

- Ingenuity for Defining the Goal appropriately
- Defining and applying appropriate measurement techniques
- Reducing the complexity down to the critical few factors for DOE evaluation
- Choosing an appropriate approach
- Being rigorous enough in testing to be “in-control”
- Determining “when is it optimized enough?”
- Selling to the “old school”
- Obtain quick, confident, and more improvement

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Getting Started with DOE

“This person sitting beside me could probably do this…”

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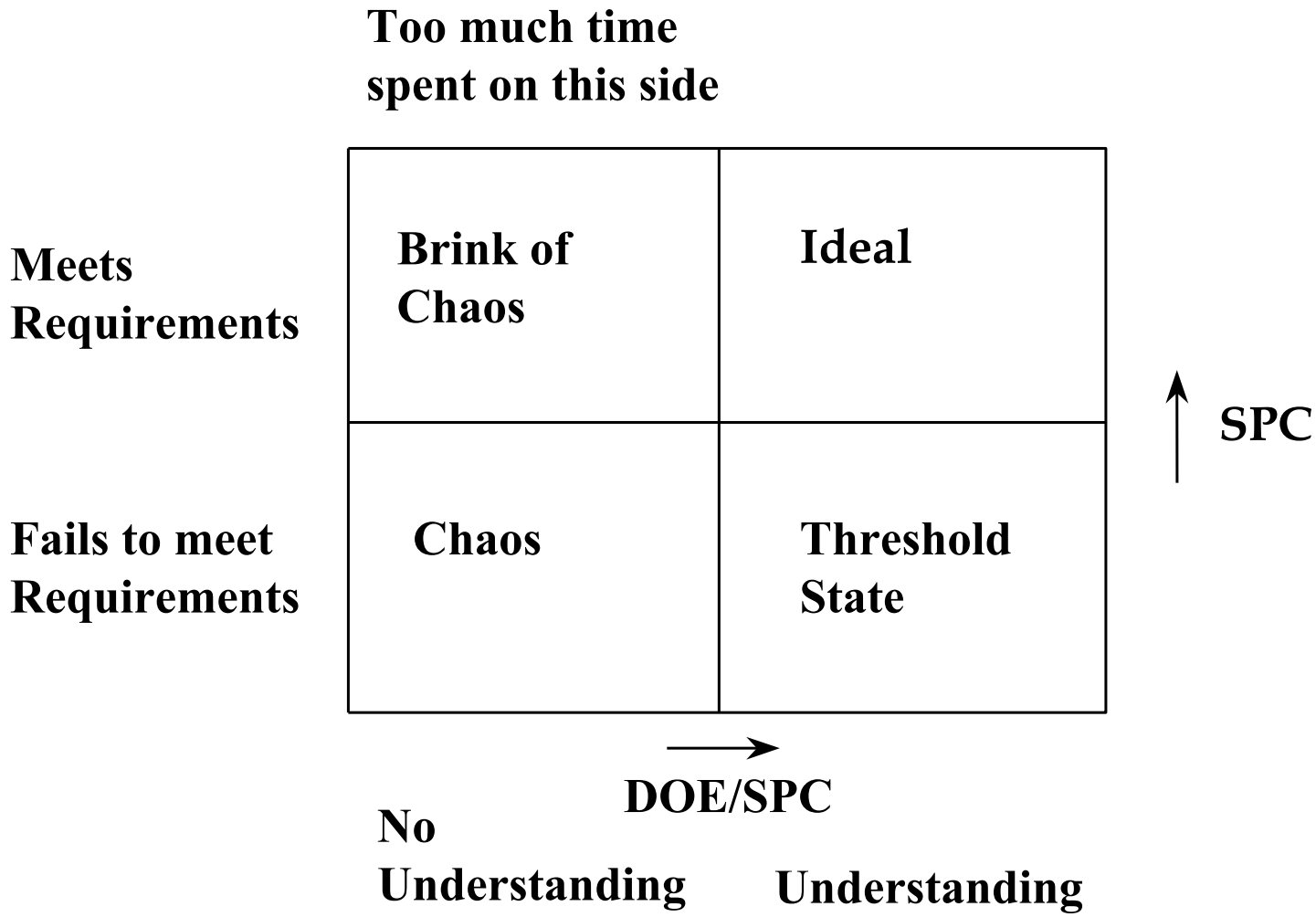
Chaos Chart



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How to Start Applying DOE

- Receive training in tool and process
- Select small low risk project with a small team now
- Get wins under your belt
  - Document savings
- Expect learning, mistakes or delays as you get started
  - However, benefits can be obtained on the first project.
- Use these projects to build on and to gain manager approval for future work and larger impact projects/tests

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