

DOE as a Tool within the Development Process

Minnesota Quality Conference

Perry Parendo

Medtronic Energy and Component Center

University of St. Thomas

Agenda

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

DOE Definition and Tool Description

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

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**

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.

Understand Variable Relationships

July 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**

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

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

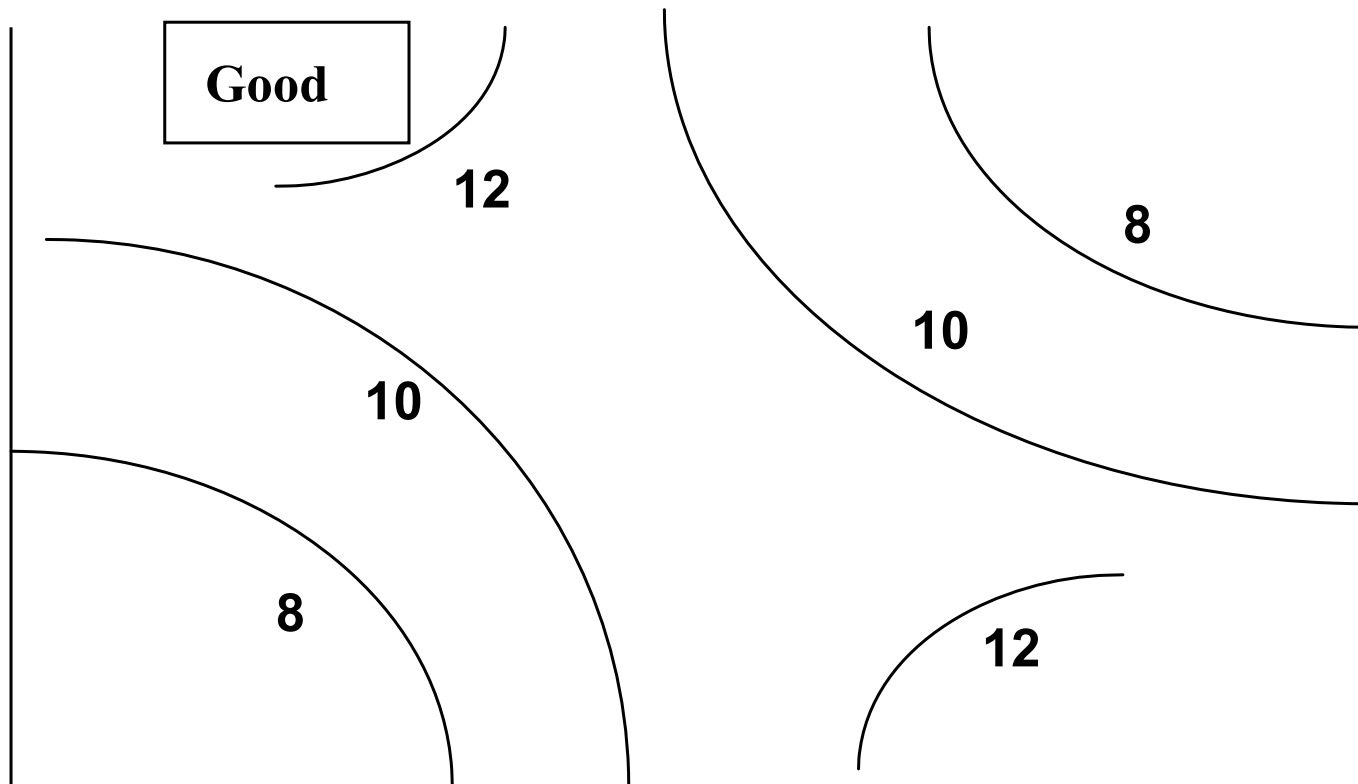
Factorial typical output (main and interactions)

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

Response Surface typical output (main, interactions, quadratic)

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

RSM, Postage Stamp



DOE and the Development Process

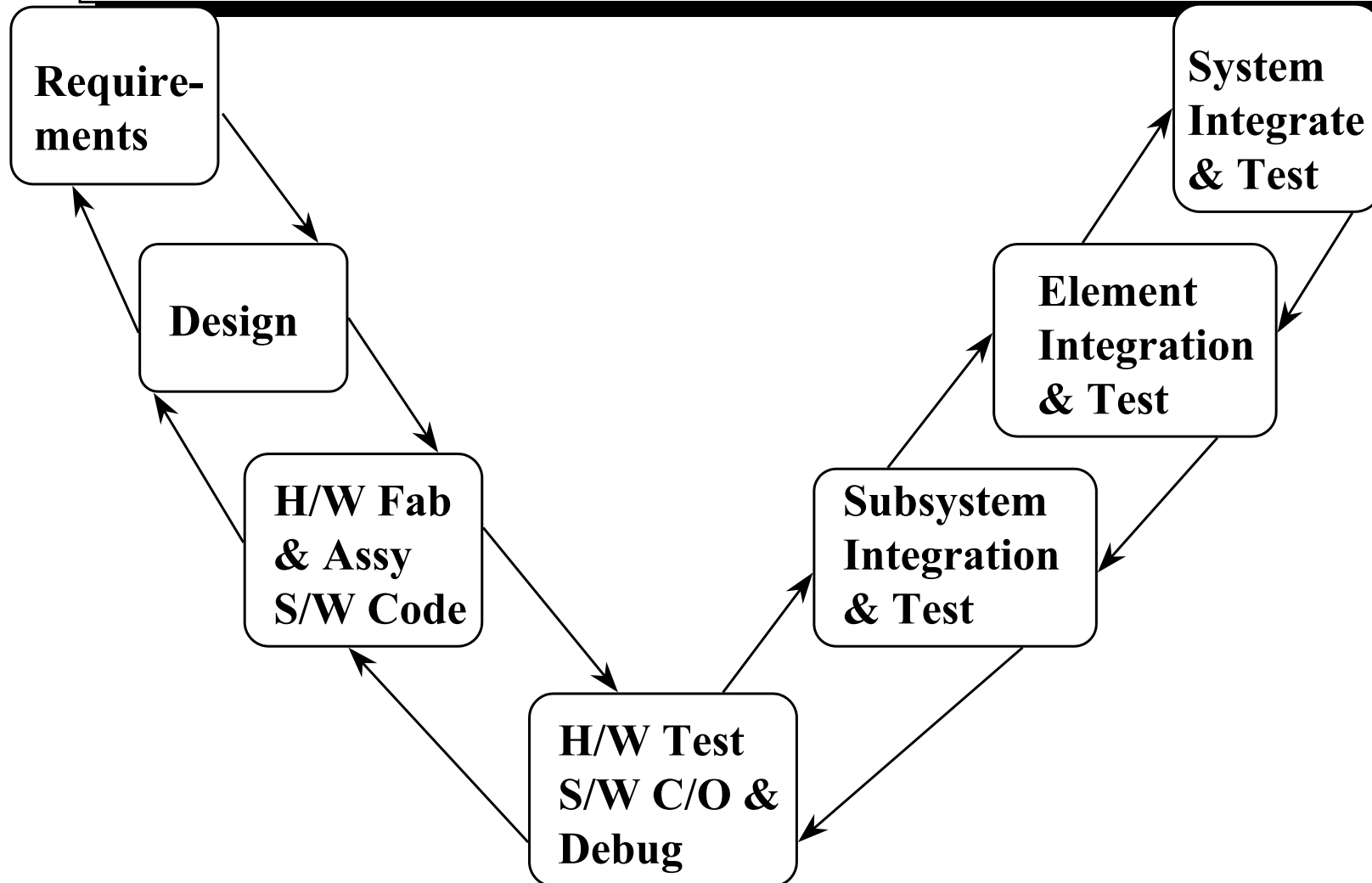
“DOE – It’s not just for hardware anymore...”

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

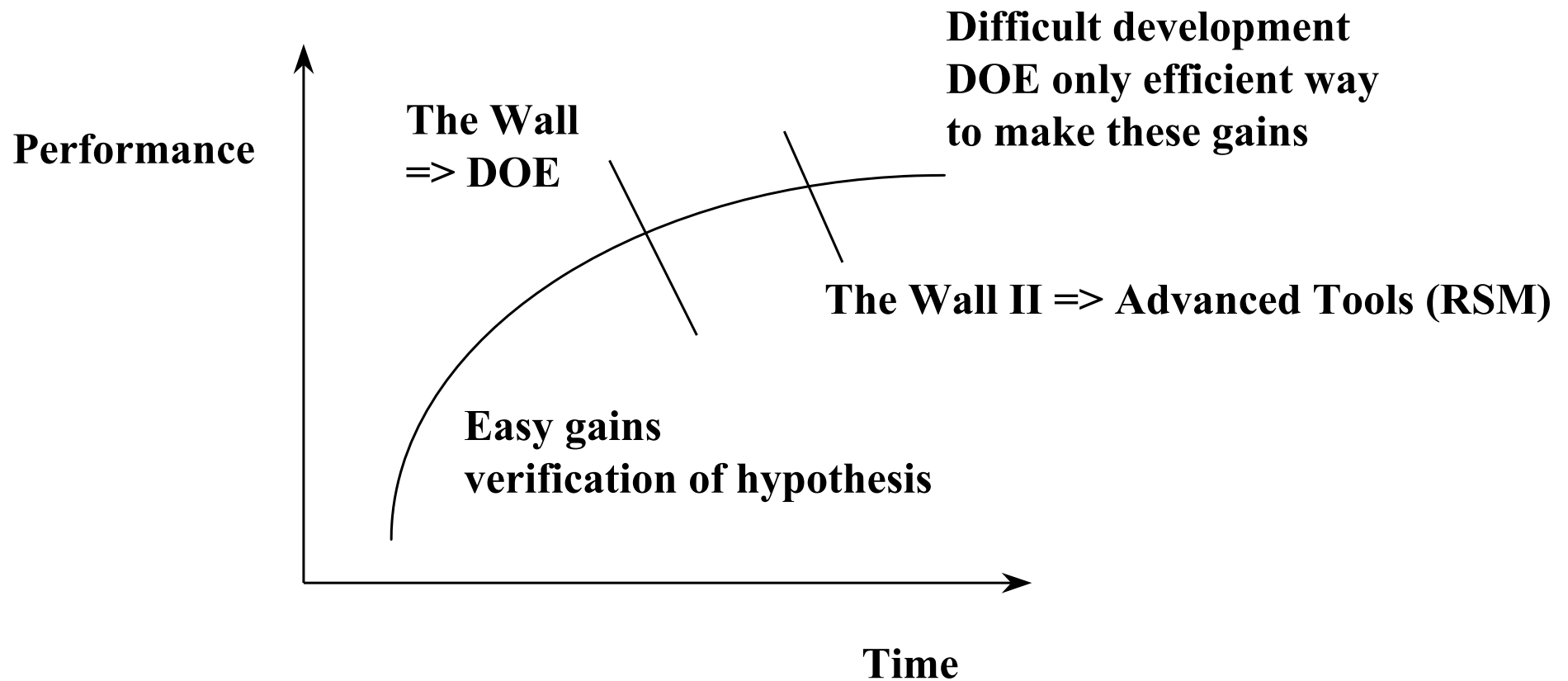
System Life Cycle “V” Model



Understand Variable Relationships

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Development Stages



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**

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 * * Where DOE software helps
- Discuss next step

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

Getting Started with DOE

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

Chaos Chart

Too much time
spent on this side

Meets
Requirements

Brink of
Chaos

Ideal

Fails to meet
Requirements

Chaos

Threshold
State

↑ SPC

→
DOE/SPC

No

Understanding

Understanding

Understand Variable Relationships

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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**

Current Contact Information

- Perry Parendo
- 651-230-3861
- Perry@PerrysSolutions.com
- www.PerrysSolutions.com

