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# A Concept for Optimal Test Article Instrumentation Selection


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# Motivated by Goal to Improve Design for Test Efficiency

- Break Traditional Paradigms
- Minimize Modification of the Tactical Configuration
- Improve System Reliability Expectations
- Increase Design for Manufacturing Assembly
- Enhance Design-to-Cost Goals
- Prognostics Will Become More Prominent in Future Systems
- Apply Statistical Techniques Associated With Design-of-Experiments

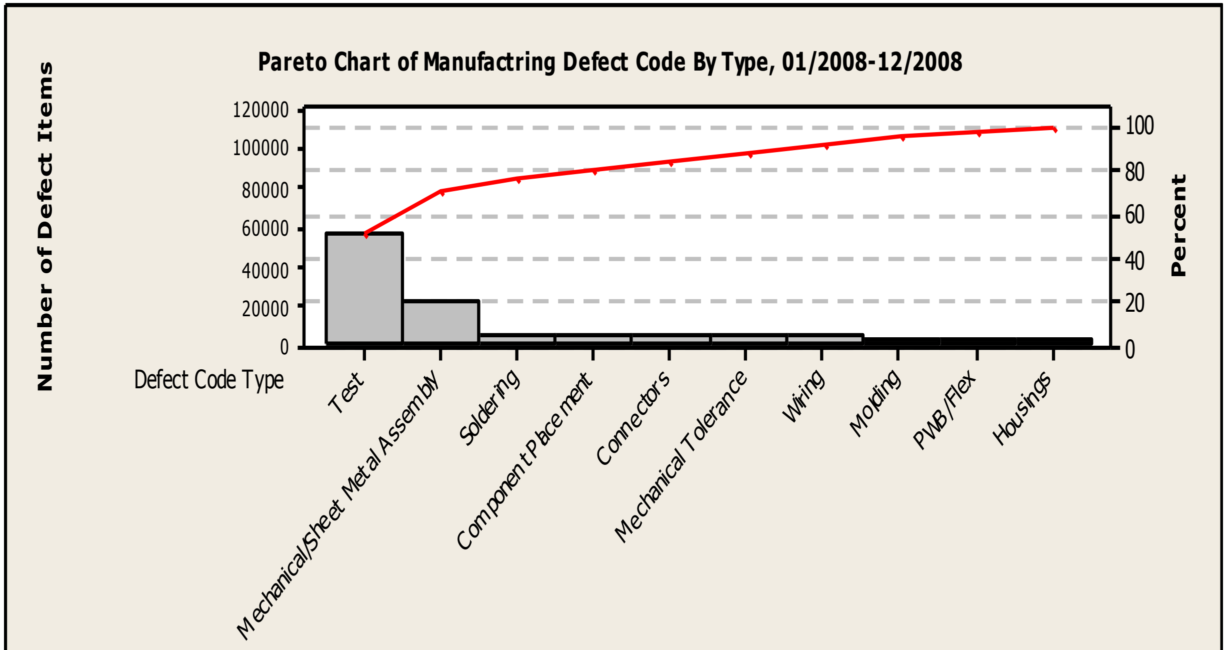
**Concept Focused on Process Improvement with Impact on Product Cost Reduction**

# Test Article Instrumentation Selection Process Needs To Be Refined

- Finite Element Modeling Drives Instrumentation Selection
  - Models Are Required to be High Fidelity
- Engineering Development Follows Conservative Approaches
  - Select Instrumentation Based On Past Experience
- Design Verification Demands High Confidence in Modeling Parameters
  - Instrument Test Article to Improve System Modeling Parameters
- Instrumentation Presence Perturbs the Tactical Configuration
  - Functional Performance May be Limited by Instrumentation Presence

**Develop A Mathematically Justified Process To Improve the Instrumentation Selection Methods and Make Them More Robust**

# Test Is 51.6 % of All Rework*




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of Defect Items | 57424 | 21481 | 5352 | 4934 | 4863 | 4795 | 4181 | 3098 | 2947 | 2225 |
| Percent | 51.6 | 19.3 | 4.8 | 4.4 | 4.4 | 4.3 | 3.8 | 2.8 | 2.6 | 2.0 |
| Cum % | 51.6 | 70.9 | 75.7 | 80.1 | 84.5 | 88.8 | 92.6 | 95.4 | 98.0 | 100.0 |

*Data source: RMS Quality

**Improve Test Efficiency With Refined Instrumentation Groups**

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# A Typical "Real-World" Test Example

- **Primary Test Objective** – To verify product meets its performance requirements while being exposed to a tactical environment.
- **Test Description** – An operational "Timeline" will be performed while product is exposed to the environment. Typical instrumentation consists of instrumentation mounted internally and externally.
- **"Timeline" Description** – Consists of powering up the product and progressing through various modes of operation. Modes of operation exercise product functionality while environment is being applied.
- **Success Criteria** – Product meets its performance requirements while being exposed to the environment.
- **Verification Method** – Success criteria is verified by analyzing data from the product's telemetry and internal/external instrumentation.

**Most Tests Share These Common Characteristics**

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# Test Execution Efficiency Can Be Improved

| Activity | Labor With Conservative Instrumentation Groups | Labor With Optimized Instrumentation Groups |
|---|---|---|
| <u>Test Setup:</u> | | |
| Cable routing, labeling, repair | | |
| Cable connections to data acquisition system (DAS) | | |
| <u>Data Capture:</u> | | |
| Setup DAS to capture accelerometers | | |
| Perform accelerometer "tap-checks", troubleshoot | | |
| <u>Post Test Analysis:</u> | | |
| Compare product's telemetry to performance requirements. Look for anomalies. | | |
| Compare accelerometer data to environment specification. Look for anomalies. | | |
| Conduct Test Data Review. Generate Test Report. | | |

Consider Typical Hours and Associated Cost

Consider Reduced Typical Hours and Associated Cost

**Test Labor Cost Reduced by Using Less Instrumentation**

# Instrumentation Optimization is Critical to Design Evaluation

**Designs are Immature and in the early life-cycle phase when most testing is performed**

- Early life cycle failures are most often caused by:
  - Immature Manufacturing Processes
  - Poor Workmanship
  - Poor Quality Control
  - Insufficient burn-in, de-bugging and/or breaking-in

**Chance Failures may be caused by the interference or overlap of the designed in strength and the experienced stress in operation due to:**

- Designed in stress margins
- Occurrence of higher than expected random modes
- Higher than expected random loads
- Lower than expected random strengths

**Excessive Instrumentation Can Potentially Mask Critical Failure Modes**

# Instrumentation Considerations for the Tactical Configuration

**Limit Trespass on the Tactical Configuration**

- Optimizing Instrumentation is Important for Preserving Tactical Configuration

**Retain Design Performance Characteristics**

- Minimize Instrumentation to Preserve Design Characteristics (e.g. Weight, Modal)
- Dynamic and Thermal Response May Be Affected / Masked With Excessive Instrumentation

**Reduce Errors and/or Failures During Manufacturing**

- Complexity of Instrumentation Can Adversely Affect Both Cost and Schedule

**Retain the Tactical Configuration Throughout the Product Life-cycle**

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# Instrument Design Elements that Drive System Reliability

**Focus on Critical Elements of the Design**

- Use the FMECA and Reliability Predictions to Identify Critical Circuits and Components
- Thermal and Dynamic Models Will Identify Circuit Card Assembly ‘hot-spots’ or High Dynamic Response Areas
- Conduct Electronic Parts/Circuit Tolerance Analysis to Identify Critical Circuits

**Embedded Instrumentation Will be Key to Prognostics**

# Prognostics and Health Management for Future Systems

**What is it?**

**Diagnostics** – The process of Determining the Capability State of a Component to Perform Its Function(s)

**Prognostics** – The Predictive Diagnostics Which Includes Determining the Remaining Useful Life for Proper Operation of a Component

**Health Management** – The Capability to Make Appropriate Decisions About Maintenance Actions Based on Diagnostic / Prognostics Information, Available Resources and Operational Demand

**What will it do for us?**

- Provide a Foundation for Mission Assurance

**How do we do it?**

- Assess Opportunities for Embedded Sensors to Provide Prognostics Data
- Implement Robust Embedded Test (RET) Data Collection and Processing Capability

**Improved Life-cycle Performance for the Tactical Product**

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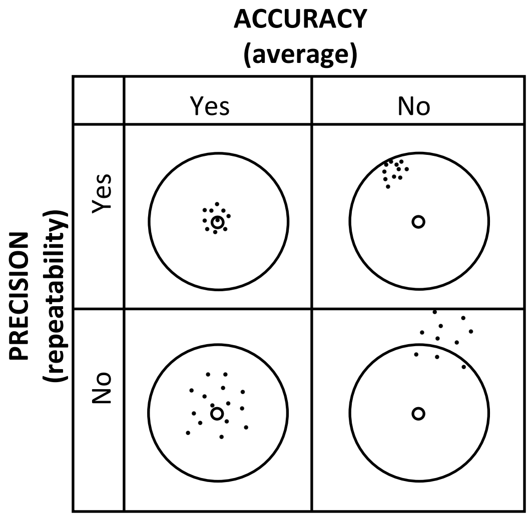
# Desired Properties of A Measurement System

- Accuracy – Ability to produce an average measured value which agrees with the true value or standard being used
- Precision – Ability to repeatedly measure the same product or service and obtain the same results
- Stability – Ability to repeatedly measure the same product or service over time and obtain the same average measured value




**Optimize Each Element of A Measurement System**

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# Considerations for the Use of Design-of-Experiments Techniques for Optimizing the Instrumentation Selection Process

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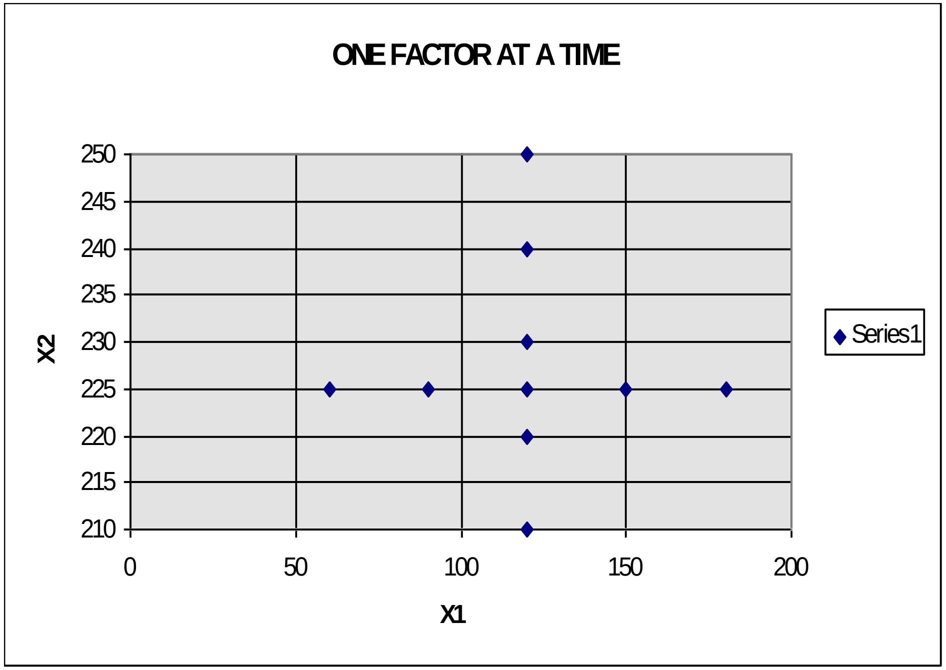
# Consider the A Traditional Design Space

- Many Experiments are executed using a method which holds all but one factor at nominal and varying only one factor
- One factor at a time does not cover much design space
- It is a poor substitute for a more rigorous orthogonal design




**A One Factor at a Time Design Space Will Not Discover Parameter Interactions**

# Consider a 3-factor, 5-level Full Factorial Design Space

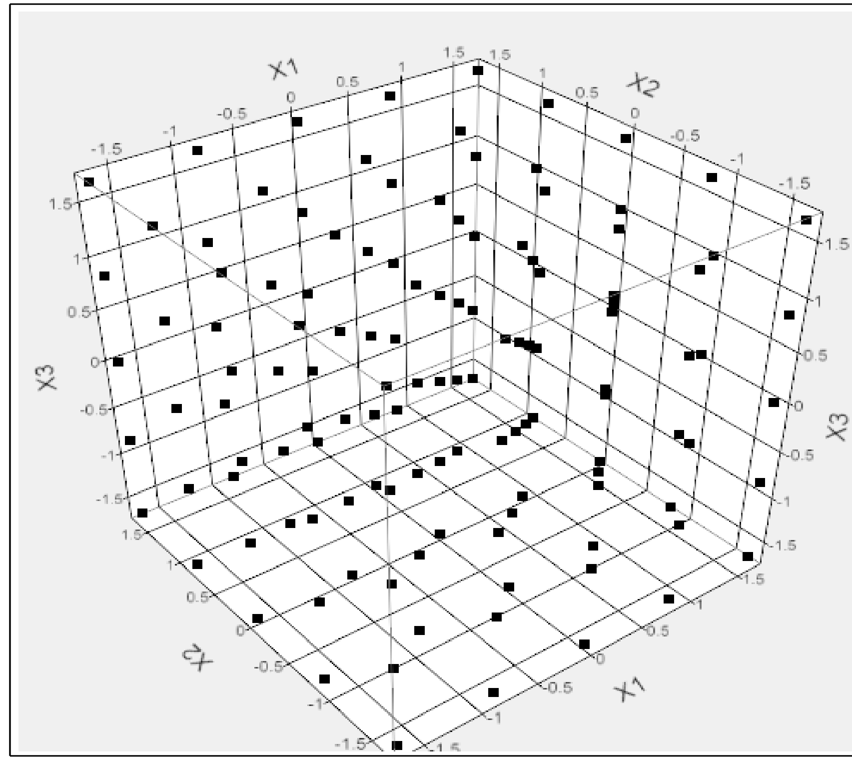
- A 5 level full factorial explores the design space very thoroughly
- It allows you to discover two factor, three factor and higher interactions
- It allows you to discover quadratic, cubic and higher order effects

**This Design Uses 125 Combinations Which May Be Cost Prohibitive**

| 5 LEVEL 3 FACTOR DESIGN | | | |
|---|---|---|---|
| RUN | X1 | X2 | X3 |
| 1 | -0.84 | 0.84 | 0 |
| 2 | 0.84 | -1.68 | 1.68 |
| 3 | 0 | 1.68 | -1.68 |
| 4 | 0.84 | 0 | 0 |
| 5 | -1.68 | 0.84 | 0 |
| 6 | -1.68 | 0 | -0.84 |
| 7 | -0.84 | 0 | 0 |
| 8 | -0.84 | 1.68 | 0 |
| 9 | -0.84 | 0 | -0.84 |
| 10 | -1.68 | 0 | 1.68 |
| 11 | -1.68 | 1.68 | 0.84 |
| 12 | 0 | -0.84 | 0.84 |
| 13 | 0.84 | 0.84 | 1.68 |
| 14 | 0.84 | 1.68 | 0 |
| 15 | 0.84 | 1.68 | -0.84 |
| 16 | 0 | -0.84 | -1.68 |
| 17 | 1.68 | 0 | -0.84 |
| 18 | 1.68 | -0.84 | 1.68 |
| 19 | 0 | 0 | 0.84 |
| 20 | -1.68 | -0.84 | 0 |
| 21 | -1.68 | 1.68 | -1.68 |
| 22 | -0.84 | 1.68 | -1.68 |
| 23 | -1.68 | 0 | 0 |
| 24 | -0.84 | 1.68 | 1.68 |
| * | 0.84 | 0 | -0.84 |
| * | 0.84 | 0 | 0.84 |
| * | 1.68 | 1.68 | 1.68 |
| 125 | 0.84 | 1.68 | -1.68 |

# Design Space Thoroughly Explored Using a 3-factor, 5-level Full Factorial Design

The 3-factor, 5-level full factorial design is described by a cube with the three factors on the X, Y and Z axis




**Full Factorial Designs Will Drive The Cost of the Experimental Execution**

# Consider A Central Composite Design Space

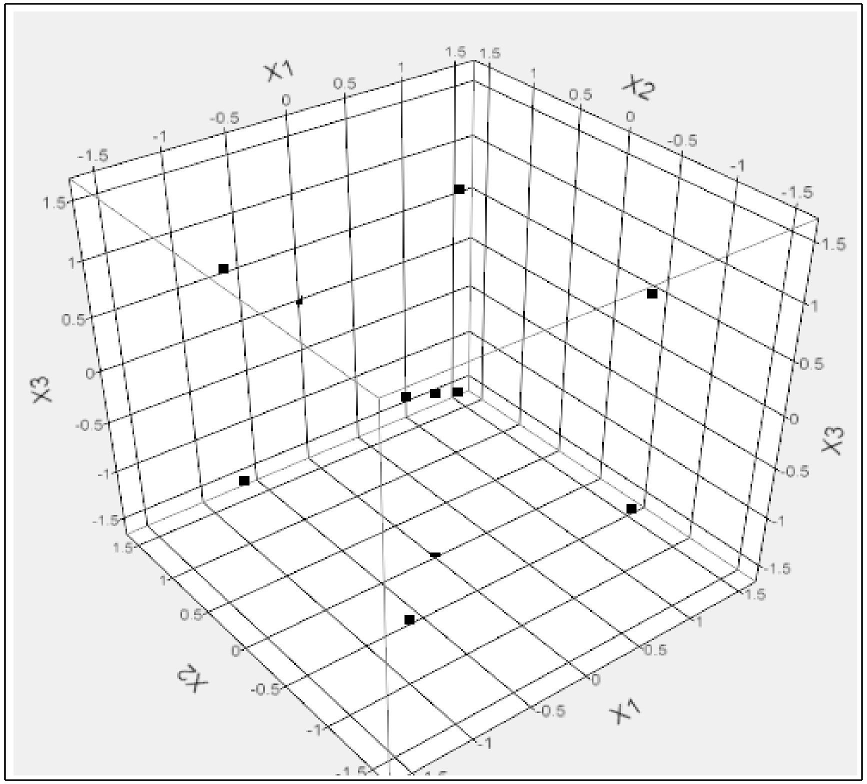
- We can accomplish the same five levels identified for a full factorial design with a central composite design
- It is a much smaller sub-set of the full factorial
- It does not explore the design space as rigorously as the full factorial

| 5-LEVEL 3-FACTOR CENTRAL COMPOSITE DESIGN | | | |
|---|---|---|---|
| RUN | X1 | X2 | X3 |
| 1 | 1 | -1 | 1 |
| 2 | 0 | 0 | 0 |
| 3 | -1 | 1 | 1 |
| 4 | -1.68 | 0 | 0 |
| 5 | -1 | -1 | 1 |
| 6 | 1 | 1 | 1 |
| 7 | 1 | 1 | -1 |
| 8 | -1 | -1 | -1 |
| 9 | 0 | 1.68 | 0 |
| 10 | 0 | -1.68 | 0 |
| 11 | -1 | 1 | -1 |
| 12 | 0 | 0 | 1.68 |
| 13 | 0 | 0 | 0 |
| 14 | 1 | -1 | -1 |
| 15 | 0 | 0 | -1.68 |
| 16 | 1.68 | 0 | 0 |

**Design Uses 16 Combinations - Efficient and Cost Effective**

# Central Composite Designs Are Efficient

The 3-factor 5-level Central Composite Design is described by a cube with the three factors on the X, Y and Z axis




**Central Composite Design - Efficient and Cost Effective**

# The Use of Design-of-Experiments Techniques for Optimizing the Instrumentation Selection Process Has Potential

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# Instrumentation Optimization Has Significant Benefits

- Improved Reliability by Reducing Complexity
  - Less Instrumentation
- Reduced Manufacturing Cycle Time
  - Lower Test Set-up Time
  - Fewer Labor Hours
  - Test Conduct Time Shortened
  - Post Test Analysis Diminished
- Reduced Special Test Equipment Cost
- Less Handling of Hardware, Fewer Opportunities for Induced Failures
- Minimize Opportunities for False Failures and Associated Trouble-shooting and Resulting Failure Investigation
- Embedded Instrumentation for Prognostics Will Effectively Evaluate the Design Space

**Design-of-Experiments Techniques Show Potential for Improving the Instrumentation Selection Process**