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A Priori Factor Validation and Use Case Analysis for Effective DoE Application

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This Presentation contains no technical data as defined under ITAR 120.10

Applying DoE effectively

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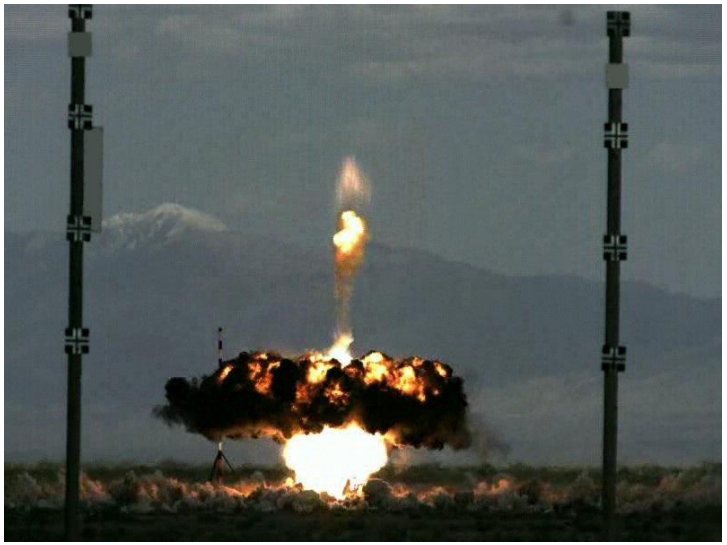
Design of Experiments (DoE) provides tremendous benefit:

- Optimizing test programs
- Reducing costs
- Evaluating data
- Design space exploration
- Failure investigation
- Profound understanding of a system



Effective DoE conduct is crucial, requiring optimal design and set-up

Two key areas to aid optimal DoE conduct

- Identifying relevant factors
- Understand DoE Use Cases

Effective factor identification and use case understanding aids implementation

DoE Perspective

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DoE Approach

- General methods of Design of Experiments (DoE) are understood
  - A response or effect is identified (i.e. accuracy)
  - Several factors or variables effect the response
  - An efficient way of sorting and understanding the variables' effect on a response is desired
- Once response and factors are identified, the DoE can be designed
  - Full Factorial
  - Fraction Factorial
  - Optimal Designs
  - Many other's

The ultimate outcome of the DoE is the generation of an equation which clearly identifies variable or combination of variables effect on the response, with enough fidelity to predict the outcome within the tested design space.

DoE aids understanding a system better

Critical Initial DoE Steps

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1. The response must be identified

- Important first step which sets the “tone” for the entire DoE Design
- Often easy to identify the response
- Examples: Miss Distance, Accuracy, MTBF

2. The factors which can effect the response must be identified

- New experiments or tests may have many possible factors
- Similar types of tests often provide legacy factors which may effect the response

3. Sort through the identified factors

- Important step to focus on critical factors which effect the response
- Need to “weed out”
  - ➢ duplicate factors
  - ➢ ineffective factors

Rigorous planning of a DoE leads to success

Methods for Sorting Factors

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Deductive Reasoning

- Often data being captured is important, but is very similar and does not require identifying a separate factors
- Example: Charge and muzzle velocity

Screening Experiments

- Well known method of identifying critical Factors
  - ➢ May Add crucial time to tight schedules
  - ➢ Adds cost to programs
- May be unavoidable on new projects or programs

Proper factor identification is critical

Methods for Sorting Factors (Cont)

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Utilize statistical analysis to identify largest contributing factors

- New variants, block upgrades, or similar programs can utilize this method
- A plethora of data exist in Flight Test Databases, Program Databases, or in Program Data Repositories
- Utilize standard statistical methods (i.e. Analysis of Variance (ANOVA) and T-Test, etc.) to analyze data

Keys for successful sorting of factors

- Need to understand the data captured in the data base
  - How to filter for accurate factor analysis
  - Identify missing data that can skew data
- Ensure the identified factors really have an effect on the response
- Identify factor limitations, i.e. where factor level combinations may be impossible

Sorting or screening factors is vital for valid DoE

What may be revealed

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Statistical analysis may reveal

- Some critical factors which were obvious
- Some factors thought to be obviously critical, that really have no effect
- Perhaps some factors thought to be not critical, are critical
- Some factors may not have enough data to determine whether they are critical

Caution using Statistical Analysis for Factor identification

- Be sensitive to how comparable data is to the DoE wanting to conduct
  - ➢ Is the system to be tested similar enough to the system tested
  - ➢ Is the new system being utilized in a similar manner
- Utilize common sense
  - ➢ If unsure of statistically irrelevant factor, that seems to be obviously critical, then include them

Statistical analysis provide great insight but common sense must prevail

What is a DoE Use Case

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Why the need for defining DoE use cases?

- Helps further define how DoE can be used
- Helps explain the correct use of DoE
- Helps reduce confusion of DoE application

A DoE Use Case is …

- A defined group of DoE's with a common purpose
- Differentiates between how DoE's are applied and what is emphasized
- Enough description to explain it, but not too defined to limit possible cases that could benefit from DoE
- Provides an explanation of how a DoE can be used in each use case

DoE use cases we will explore

- System Design Space Exploration
- Failure Investigation
- Cost Improvement

Use cases can help avoid confusion when applying/executing DoE

Use Case: System Design Space Exploration

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Use Case Purpose

- Provide a better understanding of the entire design space rather than only areas of interest

Use Case Explanation

- Understand the corner or edges of the design space
  - Will typically be at spec limits
  - Greater than spec limits if looking at margin
- The regression equation identifies how the system works within the design space
- Identify variables or combination of variables which effect the response most

Use Case Application

- Component Level (CCA, Battery, etc.)
- Sub System Level (Guidance System, Control Actuators, etc.)
- System Level (Missile Level, Aircraft, Ground Vehicle)

System Design Space can be understood better with DoE

Use Case: Failure Investigation

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Use Case Purpose

- Identify the failure cause or contributing factors
  - Single variable
  - Combination of variables

Use Case Explanation

- Identify which variable or combined variables caused the failure
  - This is very difficult, if not impossible to identify with standard OFAT Test
- Identifies the regression equation for the contributing factors to failure modes
- Using DoE can aid in not misdiagnosing failures or corrective action

Use Case Application

- Response and variables should be identified in conjunction with a Failure Investigation Team
- Tests at component, sub-system level, system level, depending on Failure Investigation Team findings

Failure Investigations can be more accurately diagnosed with DoE

Use Case: Cost Improvement

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Use Case Purpose

- Evaluate/Identify areas where cost savings can be realized

Use Case Explanation

- Utilize DoE to identify areas to reduce cost
  - ➢ Key on the level of the factors relative to the response
- Identifies the regression equation for the contribution of variables to cost
- Identify variables or combination of variables which effect the response most

Use Case Application

- Process Improvements
- Widening or narrowing spec limits
- Identifying areas to reduce waste
- Identifying areas in the design space where an item works better
- Many more …

Cost improvements can be realized quickly with DoE

Conclusion

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Statistical analysis provides insight for choosing valid factors

- A plethora of data exists, benefit from it
- Data analysis can be used as guidance for similar types of programs
- Trust the statistics and use common sense

Use Cases definition helps with DoE application

- Use case categorization is new, and therefore many more use case types are out there
- The intent with use case identification is to guide implementation and avoid confusion of how DoE's are implemented
- It is critical to not attempt to span use cases; the inevitable effect will be confusion and frustration

It is imperative we understand and implement DoE on programs

- Implement it in all phases
  - Bench tests, small integration tests, full system tests
  - Preliminary Design, Critical Design, Operational Test, Production
- Don't just implement because we have been directed too
- Implement because it makes sense and helps us understand our products better

Tremendous value can be gained through effective DoE implementation