

# Interaction Effects in the Design of Computer Simulation Experiments for Architecting Systems-of-Systems

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## ABSTRACT

This paper demonstrates the applicability and benefits of optimal design of experiments (ODOE) for architecting systems-of-systems (SoSs). All experiments depend on appropriate models for their design and analysis. In keeping with the sparsity-of-effects principle, a general linear model with main-effects-plus-two-factor-interactions (MEPTFI) is assumed to realistically characterize the relationship between the SoS elements and the response of interest. The designed experiment requires additional simulations to account for the two-factor interaction effects, and the main effects cannot be interpreted as defining the optimal solution. The optimal performance architecture is determined by optimizing the fitted MEPTFI model. The proposed method is applied to the problem of architecting a SoS to protect against small boat attacks. A statistical analysis confirms that the MEPTFI model has excellent predictive capability. It also proves the fallacy of the applicability of the standard Taguchi method for architecting SoSs by demonstrating that it gives misleading results because of the omission of active interactions. The ODOE method can be implemented using commercially available general-purpose statistics software. Given its mathematical formulation, it can be generalized to solve systems engineering and architecting problems that require complex models beyond the MEPTFI model. © 2014 Wiley Periodicals, Inc. *Syst Eng* 17: 426–441, 2014

**Key words:** interaction effects; maritime terrorism; optimal design of experiments; orthogonal array experiment; system-of-systems architecting; Taguchi method

## 1. INTRODUCTION

Design of experiments (DOE) is a structured approach to designing and analyzing experiments in which purposeful changes are made to multiple input variables (or factors) to efficiently investigate the effects on an output variable (or

response) [Kleijnen et al., 2005]. It has a long and illustrious history since Fisher [1926] founded the underlying principles of design and statistical analysis of designed experiments in the 1920s and early 1930s. Montgomery [2012: 22] notes that “There is not a single area of science and engineering that has not successfully employed statistically designed experiments.” The early applications principally used 2-level full factorial and fractional factorial designs (FFDs). Full factorial designs consider all combinations of factors and an experiment with  $k$  2-level factors require  $2^k$  runs. FFDs drop some of the factorial combinations to reduce the number of runs,

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### **Table of Contents The Design Of Computer Simulation Experiments Papers**

1. Understanding the eBook The Design Of Computer Simulation Experiments Papers
  - The Rise of Digital Reading The Design Of Computer Simulation Experiments Papers
  - Advantages of eBooks Over Traditional Books
2. Identifying The Design Of Computer Simulation Experiments Papers
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an The Design Of Computer Simulation Experiments Papers
  - User-Friendly Interface
4. Exploring eBook Recommendations from The Design Of Computer Simulation Experiments Papers
  - Personalized Recommendations
  - The Design Of Computer Simulation Experiments Papers User Reviews and Ratings
  - The Design Of Computer Simulation Experiments Papers and Bestseller Lists

5. Accessing The Design Of Computer Simulation Experiments Papers Free and Paid eBooks
  - The Design Of Computer Simulation Experiments Papers Public Domain eBooks
  - The Design Of Computer Simulation Experiments Papers eBook Subscription Services
  - The Design Of Computer Simulation Experiments Papers Budget-Friendly Options
6. Navigating The Design Of Computer Simulation Experiments Papers eBook Formats
  - ePub, PDF, MOBI, and More
  - The Design Of Computer Simulation Experiments Papers Compatibility with Devices
  - The Design Of Computer Simulation Experiments Papers Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of The Design Of Computer Simulation Experiments Papers
  - Highlighting and Note-Taking The Design Of Computer Simulation Experiments Papers
  - Interactive Elements The Design Of Computer Simulation Experiments Papers
8. Staying Engaged with The Design Of Computer Simulation Experiments Papers
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers The Design Of Computer Simulation Experiments Papers
9. Balancing eBooks and Physical Books The Design Of Computer Simulation Experiments Papers
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection The Design Of Computer Simulation Experiments Papers
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine The Design Of Computer Simulation Experiments Papers
  - Setting Reading Goals The Design Of Computer Simulation Experiments Papers
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of The Design Of Computer Simulation Experiments Papers
  - Fact-Checking eBook Content of The Design Of Computer Simulation Experiments Papers
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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