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LAWRENCE LIVERMORE LABORATORY
University of California/Livermore, California

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ATTRIBUTES OF SYSTEM TESTING WHICH PROMOTE COST-EFFECTIVENESS

L. C. Martin

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ATTRIBUTES OF SYSTEM TESTING WHICH PROMOTE COST-EFFECTIVENESS*

L. C. Martin
Lawrence Livermore Laboratory
University of California
Livermore, California

Abstract

A brief overview of conventional EMP testing activity examines attributes of overall systems tests which promote cost-effectiveness. The general framework represents an EMP-oriented systems test as a portion of a planned program to design, produce, and field system elements. As such, all so-called system tests should play appropriate cost-effective roles in this program, and the objective here is to disclose such roles. The intrinsic worth of such tests depends not only upon placing proper values on the outcomes, but also upon the possible eventual consequences of not doing tests. A relative worth measure is required. This paper reviews and examines attributes of EMP system testing over the range of potential activity which encompasses research and development, production, field handling, verification, evaluation, and others. Thus, the relative worth, in a cost-effective sense, is provided by relating such attributes to the overall program objectives so that values can be placed on the outcomes for tradeoff purposes.

Introduction

Various types of tests constitute an essential portion of overall nuclear hardening activities. In electromagnetic pulse (EMP) programs,[1] such testing activities play a significant role in many areas. One of the most complex involves EMP testing of a complete system, where the scope, effort, and equipment required could reach gigantic proportions. This paper presents first a brief overview of types of conventional EMP testing and then reviews attributes which promote

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cost-effectiveness in the system test area. The framework here includes an EMP-oriented systems test as a portion of a planned program consisting of research, development, design, production, and use cycles.

Overview of Testing

An examination of the testing activity associated with the overall EMP problem will disclose a variety of tests at different levels of interest.[2] Categorization of tests can be made in many ways, of which the following are a few more likely arrangements:

A. Hierarchical Structure
  - Systems
  - Subsystems
  - Circuits
  - Components

B. Program Objectives
  - New Designs
  - Retrofits or Upgrades
  - Vulnerability Studies
  - Research and Development of Techniques

C. Types of Simulators or Levels
  - Alecs, Ares, Temps, etc.
  - High or Low Level, Pulse or CW

D. Type of System
  - Airborne
  - Missile
  - Satellite, Shipboard, Ground Installation

Examples of specific types of tests include those which to some measure evaluate the following:

- response and overload tolerance of components
- ESA performance

survey of sites for variations in coupling
transients on cables
shielding effectiveness
connector filter performance
conductive epoxy
bonding resistance
transients in semiconductor devices
insulation breakdown
closure of seals
system vulnerability
low level coupling

This list could be extended considerably, since all phases of engineering activity are involved to some extent.

Cost-Effectiveness

Before examining systems tests and some of their features which provide a favorable outlook from a cost-effective viewpoint, some discussion of cost-effectiveness is necessary. First, what is cost-effectiveness in the present context? The general subject of cost-effectiveness in engineering endeavors goes back centuries,[3] but in more recent times has evolved from an early engineering economy viewpoint of return on investment and comparison of alternative schemes.[4] Clearly one has limited resources. Cost-effectiveness compares actions or alternatives in terms of their costs and their effectiveness in reaching a goal. Costs are expressed in dollars, time, or resources. Effectiveness is expressed as benefits obtained from achieving a goal. Benefits obtained will depend on the desired goal. The concept of cost-effectiveness as herein employed represents some judicious element of balance among the three usually conflicting areas of

economics,
technology
and operations.

These areas are identified briefly as follows:

Operations	Technology	Economics
Levels of information obtained with constraints imposed on system operational alternatives	Levels of engineering predictions available and testing complexities required	Costs in terms of money, time, and resources expended
1.	1.	1.
2.	2.	2.
3.	3.	3.
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There should be correspondence and tradeoff balance between appropriately valued operations and requirements in the other areas.

The crucial cost question is, of course, "Is a systems test really necessary?" Usually this has an affirmative answer; almost unequivocally, arguments for some type of system-oriented test are presented. The cost-effective problem now becomes that of determining which is best approach to develop.

System Testing

At the systems level there are several stages of activity where EMP testing occurs. The following identifies four main phases of activity and lists some of the types of testing performed:

1. Engineering Models
   - Coupling Investigations
   - Cable Studies
   - Shielding Evaluation
   - Configuration Studies
2. Functional Prototypes
   - Subsystem Performance

Design Compatibilities
Test and Modify Cycles

3. Production Models
   Verification of Design
   Proof of Hardness
   Evaluation of Design

4. Fielded Systems
   Hardness Determination
   As-Built Configuration Evaluation
   Hardness Integrity Checks

Some of the cost-related features of system testing are depicted in Figure 1. In general, as one proceeds from an injected, general purpose, and localized test signal to a radiated, specific, and full scale threat simulation, costs increase. In addition, an increasing amplitude level of test signals also implies increased costs. Investment in multiuse simulators has alleviated some of the equipment money and time costs.

Survey of Testing

In order to identify and to establish at least a relative worth measure of attributes of system testing, details of several tests were examined. Below are listed condensations of both objectives and results for a number of systems tests. These are presented in a simplified nonspecific system manner (labeled A, B, C,...), without the usual qualifiers and details in order to focus on what are believed to be the essential features.

Test	Objectives	Results
A	Determine damaging or disruptive effects and recommend corrective measures	Examined grounding and shielding Compared polarizations

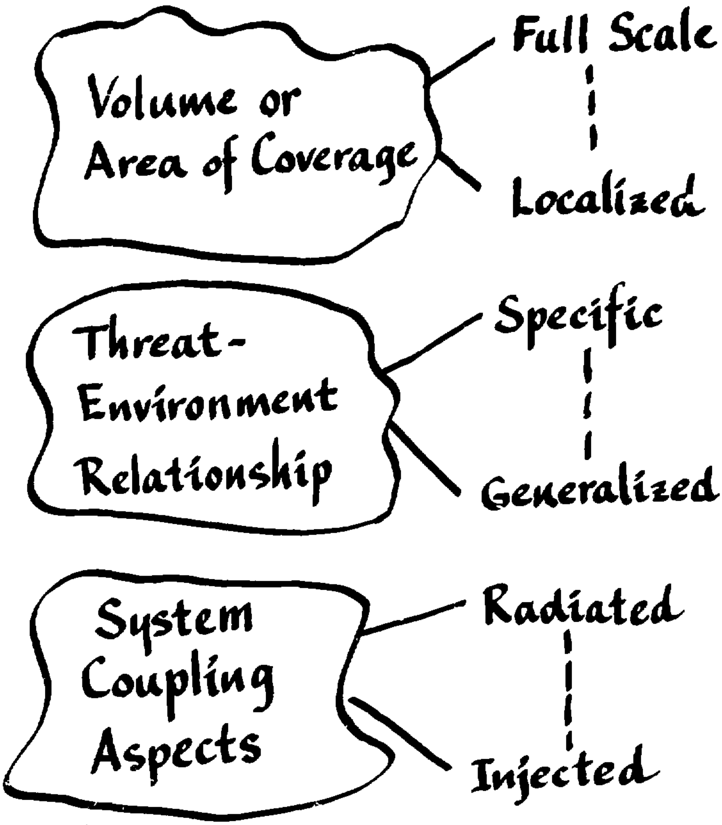

Figure 1. Some Cost-Related Features of System Testing

		Noted Disruptive effects Made some correlations with previous tests
B	Evaluate existing design and identify necessary changes	Orientation study for maximum cable response Bulk current measurements Individual wire currents Hardware modification eval. Configuration studies
C	Data to validate analytical model Verify design solution Provide data for extra-polation	Model which predicts current distributions verified Test calibrates injection testing Hardening concepts verified Variations in vulnerabil-ity, protection not well known
D	Determine effect of EMP on system components	Measured induced voltages and currents Varied configurations Monitored test points Checked for failures Identified most suscept-ible configurations
E	Determine capability to function in EMP environment Identify anomalies, non-linear response and evaluate corrective actions Provide data to evaluate vulnerability	Nature of distribution of currents Susceptibility and function-related measurements Variations in configura-tions and points of entry

F	Compare responses (other tests) Investigate several modes of operation for failures Observe nonlinearities Collect data for vulnerability assessment Measure transient currents to support lab tests	Variations noted Upsets/failures noted Anomalies observed Made necessary measurements
G	Assess hardness of critical facilities by site tests, lab tests and analysis	Equipment responses upset/failure thresholds Penetrations noted Current levels measured Bases for equipment modifications, selections and operations

Conclusions

From considerations of the objectives and results of the preceding tests and qualitative comparisons with the ingredients of what is meant by cost-effectiveness, the following are presented as system-related experimental attributes which promote cost-effectiveness. Benefits implied are also listed.

Attributes:

- Nature of distribution of currents in system
- Susceptibility thresholds
  - Upset - more apt determined at system level test
  - Burnout - less apt for complex systems at systems level test
- Functional measurements and modes of operation for upset or degradation
- Configuration and sensitivity studies
- Points-of-entry or penetration studies

- Induced voltage and current levels of critical points
- Anomalies and surprises uncovered
- Hardening and protection evaluations

Benefits:

- Validate theoretical models
- Disclose unexpected weaknesses
- Provide data for specification development
- Make more accurate assessments
- Establish baselines for design changes

The above list is not meant to be exhaustive, but it does represent what experience has indicated.

In summary, in order to lead to a summary of attributes of system testing which promote cost-effectiveness, an overview of the general EMP testing area was presented. This was followed by a brief discussion of cost-effectiveness and the basic nature and categories of systems test. Finally, a survey was performed on a number of test programs to disclose such attributes.

Acknowledgment

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