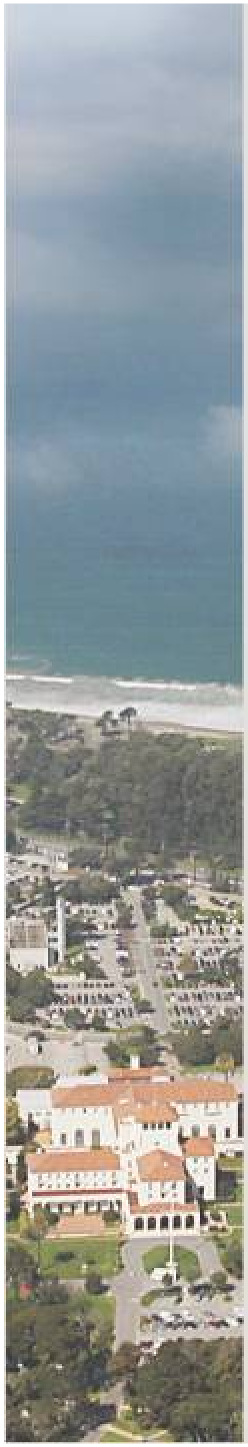
2010-05-12

An information-theoretic approach to software test-retest problems

Karl D. Pfeiffer



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An information-theoretic approach to software test-retest problems

May 13, 2010

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Overview

- Open architectures (OA) and reusable software components offer the promise of more rapid fielding of increments in systems development
- Testing and re-testing these components requires a significant level of effort as new systems are developed and old systems are upgraded
- *How much testing is enough? When can we stop testing?*

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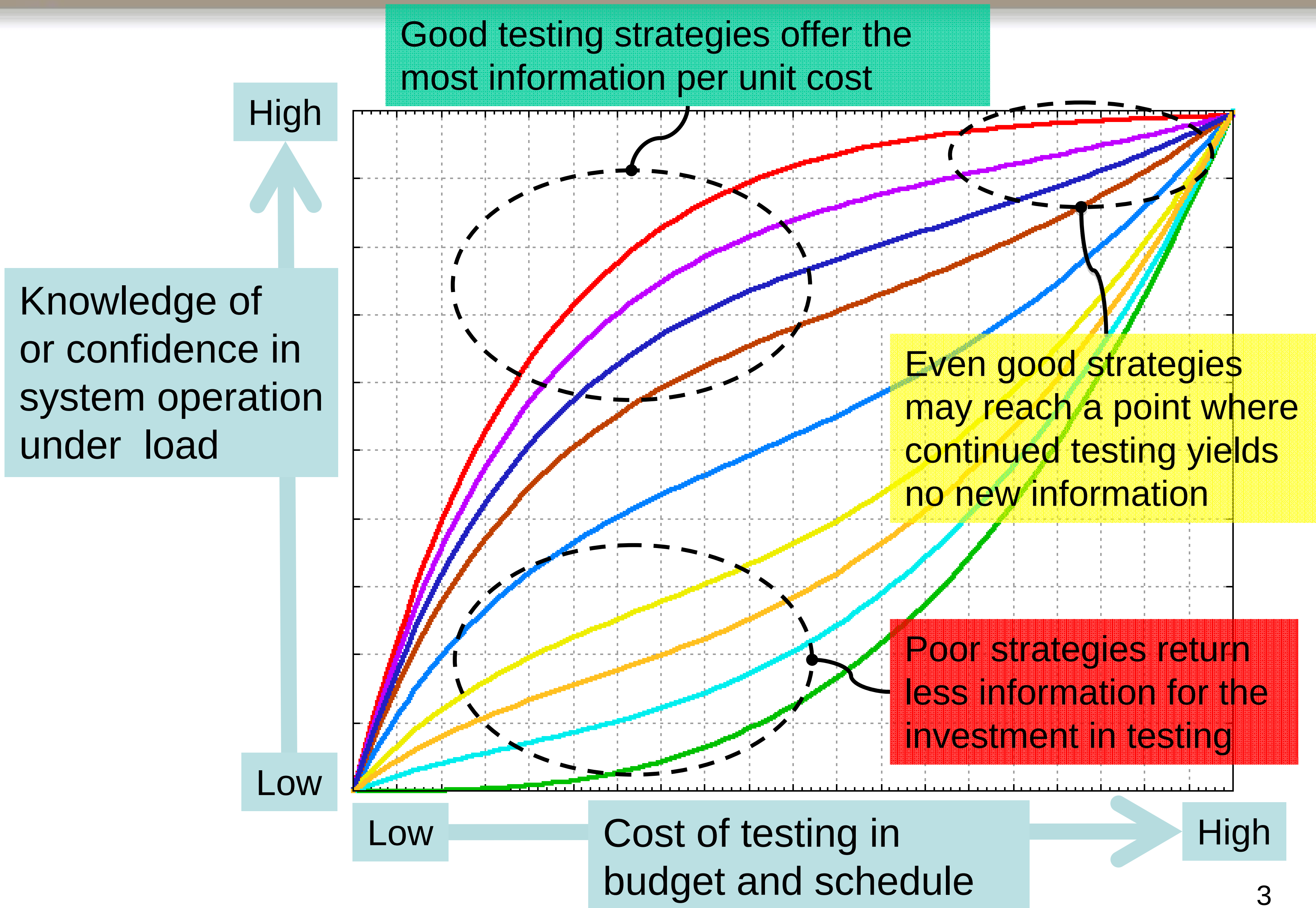
Motivation



Model fundamentals

- We can identify good testing strategies by constructing a simple model of the system, its components, and its attendant test suite

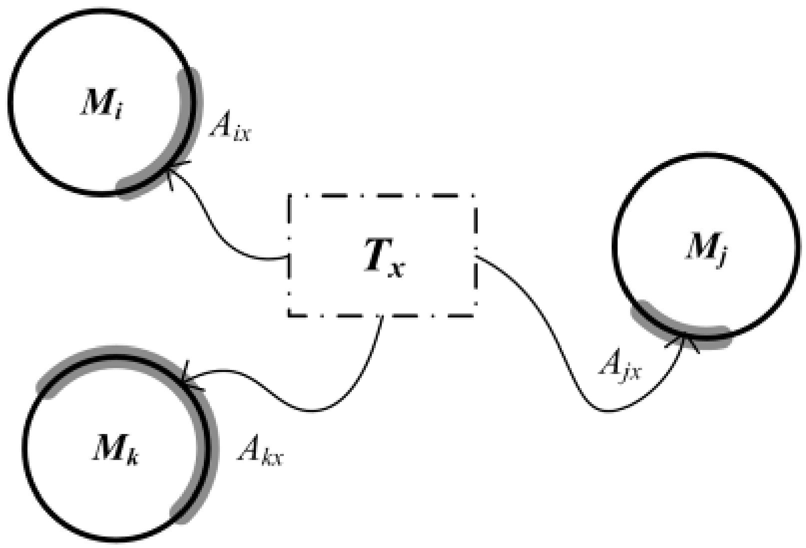
- This model requires
  - Estimates of a prior probability of failure for modules within the system
  - Estimates of the coverage for each test in the suite over these modules

- These estimates need not be precise to make the model useful
  - Monte Carlo simulation can be used to sample around the estimates as means, offering some insight into model sensitivity

Model fundamentals

- This model should help answer questions like:
  - Given a desired level of confidence in system operation, how much testing should we accomplish? How much will this cost?
  - Given a fixed budget for testing, how much confidence in system performance can we achieve through testing?
  - Given a particular test suite, how much information is attainable given infinite resources?

Model fundamentals



- A module M_i is modeled as a unit circle with probability of being defective b_i
- Test T_x exercises region A_{ix} in module M_i
- In general we assume that T_x may exercise several regions across several modules

- A test has two possible outcomes:
  - *PASS* indicates that the test did not *detect* a defect in any of the exercised regions within the modules tested
  - *FAIL* indicates that at least one module exercised is defective, though we may not know which one

Model fundamentals

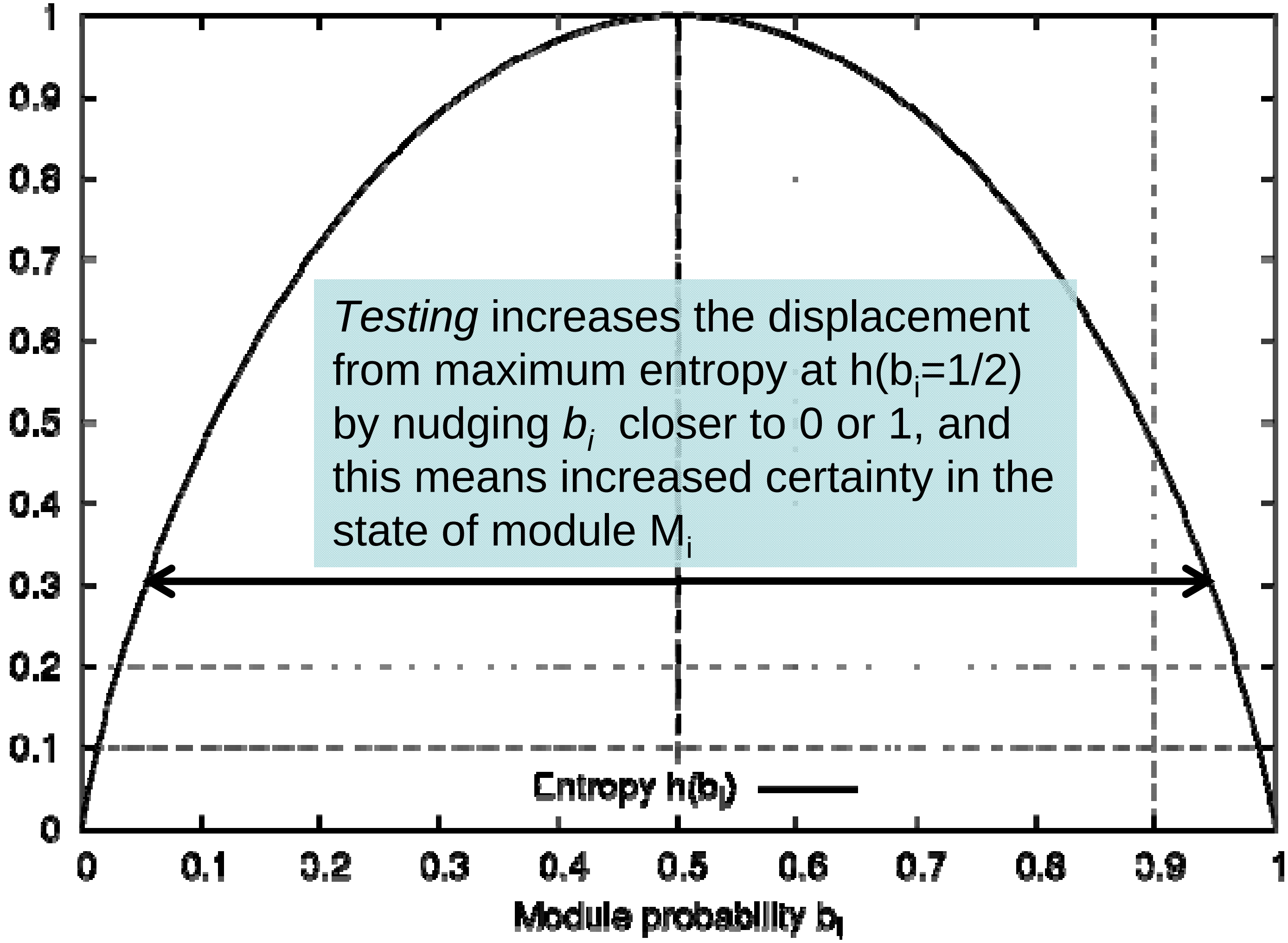
- These ambiguities offer a rich framework for modeling realistic system testing scenarios
  - We need not execute (and pay for) Tx to *forecast* information returned
  - Within this language of expression we can formulate a *quantitative* assessment of the information returned by a test sequence

- Across the system of modules M_i we can measure the information returned by a test using the classic residual entropy for a distribution of probabilities:

$$H = \sum_i h_i = \sum_i -b_i \log_2 b_i - (1-b_i)\log_2(1-b_i)$$

Model fundamentals

At maximum entropy we have a 50/50 chance that our module is good or bad—*we might as well flip a coin*



Testing increases the displacement from maximum entropy at $h(b_i=1/2)$ by nudging b_i closer to 0 or 1, and this means increased certainty in the state of module M_i

Model fundamentals

- From entropy, we derive the forecast measure:

$$Q(T_x) = \sum_i \left(\max(b_i^{fail}, 1 - b_i^{fail}) P(T_x \text{ fails}) + \max(b_i^{pass}, 1 - b_i^{pass}) P(T_x \text{ passes}) \right)$$

- Let c_x be the cost of executing test T_x in appropriate units of time or money (or both) A *good* strategy will sequence the suite of tests such that:

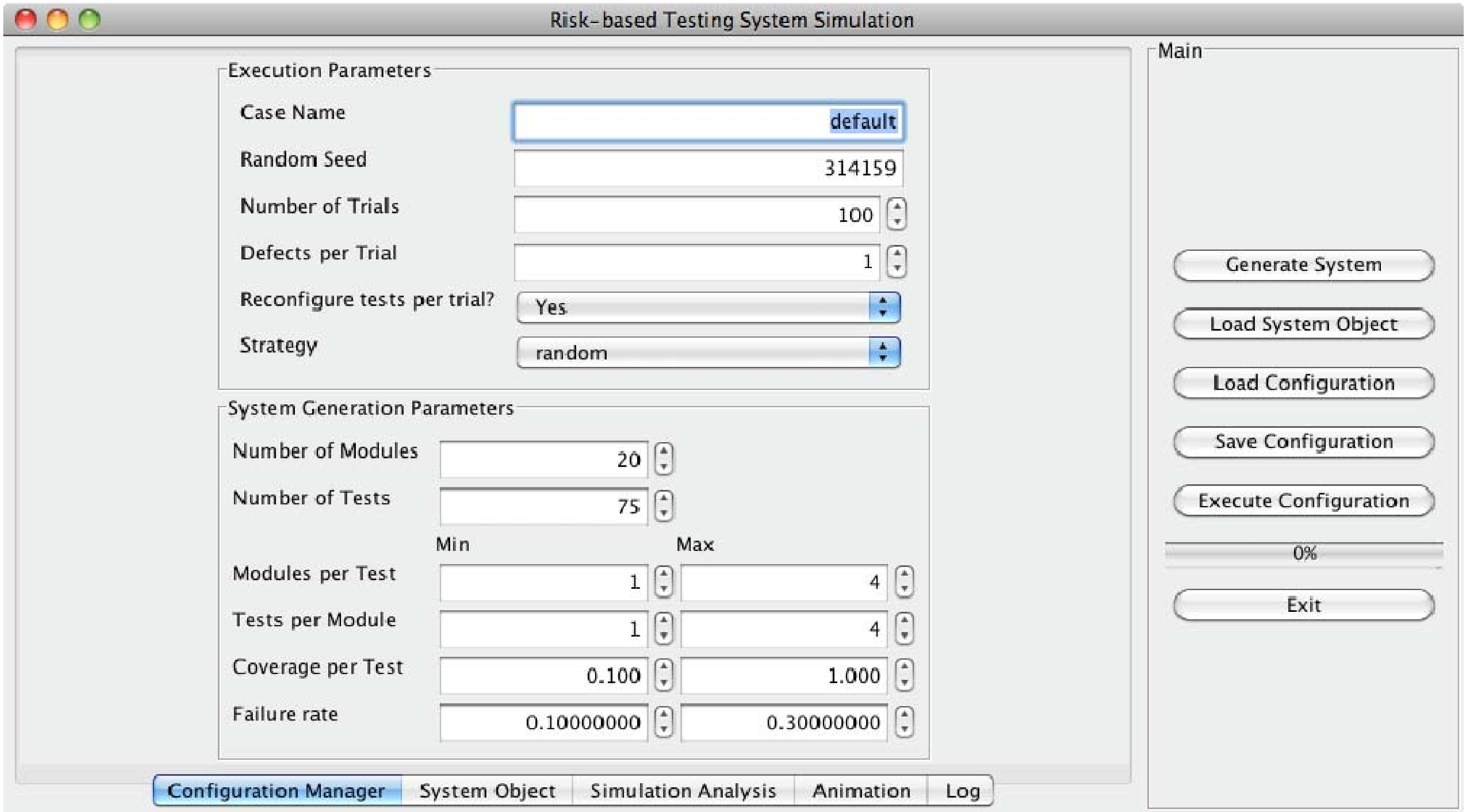
$$\frac{Q(T_{[1]})}{c_{[1]}} \geq \frac{Q(T_{[2]})}{c_{[2]}} \cdots \geq \frac{Q(T_{[m]})}{c_{[m]}}$$

- These ratios represent ***information per unit cost***

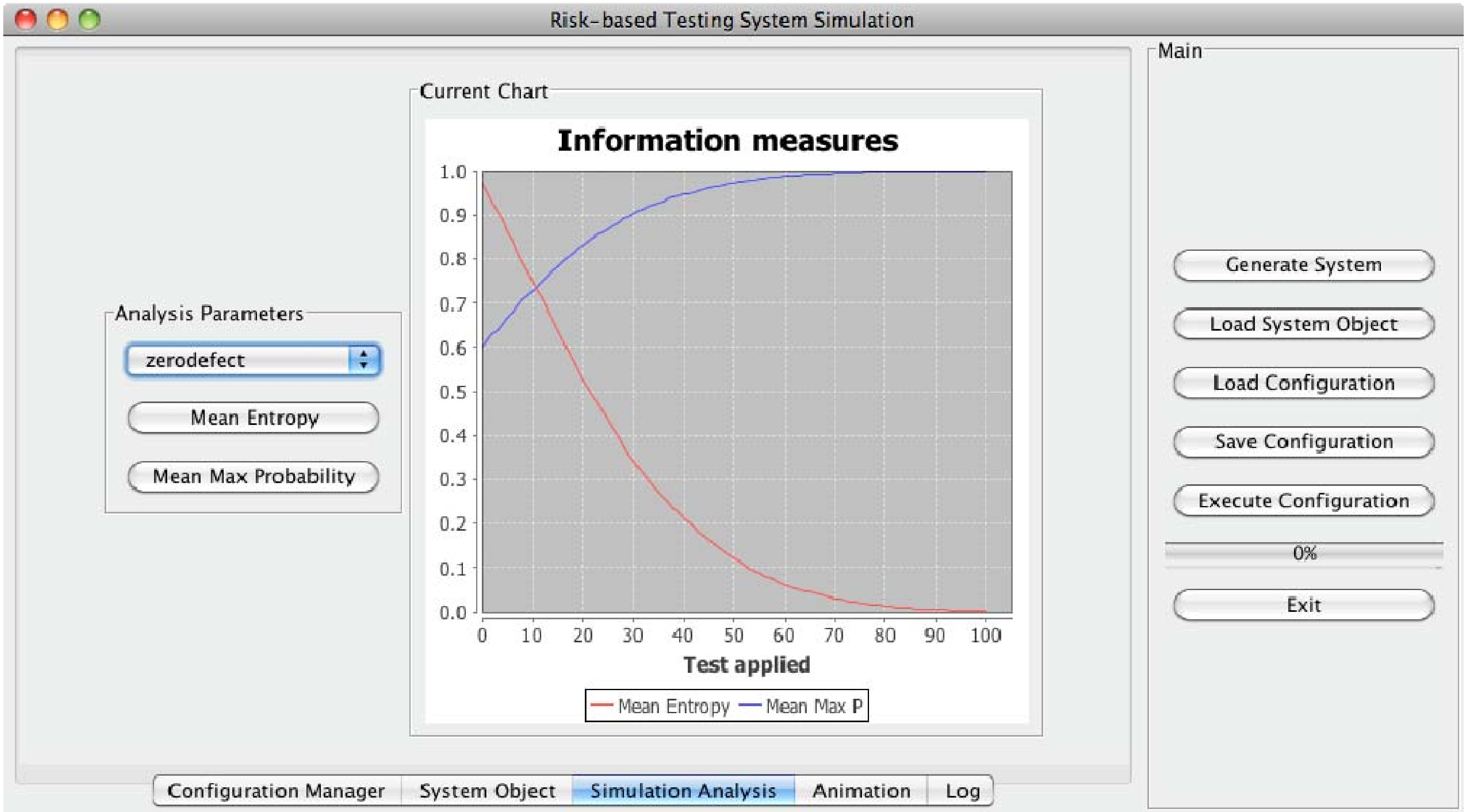
Model implementation

- Within the decision aid, for simple investigations, a fully randomized system can be created with only a few user specified constraints
- If the user has a few system details but only vague insight about others, these aspects can be augmented with randomized parameters (e.g. sizes and number of coverages)
- A system with well-documented interdependencies can be completely specified by the user in terms of modules, tests and coverages

Model implementation



Model implementation



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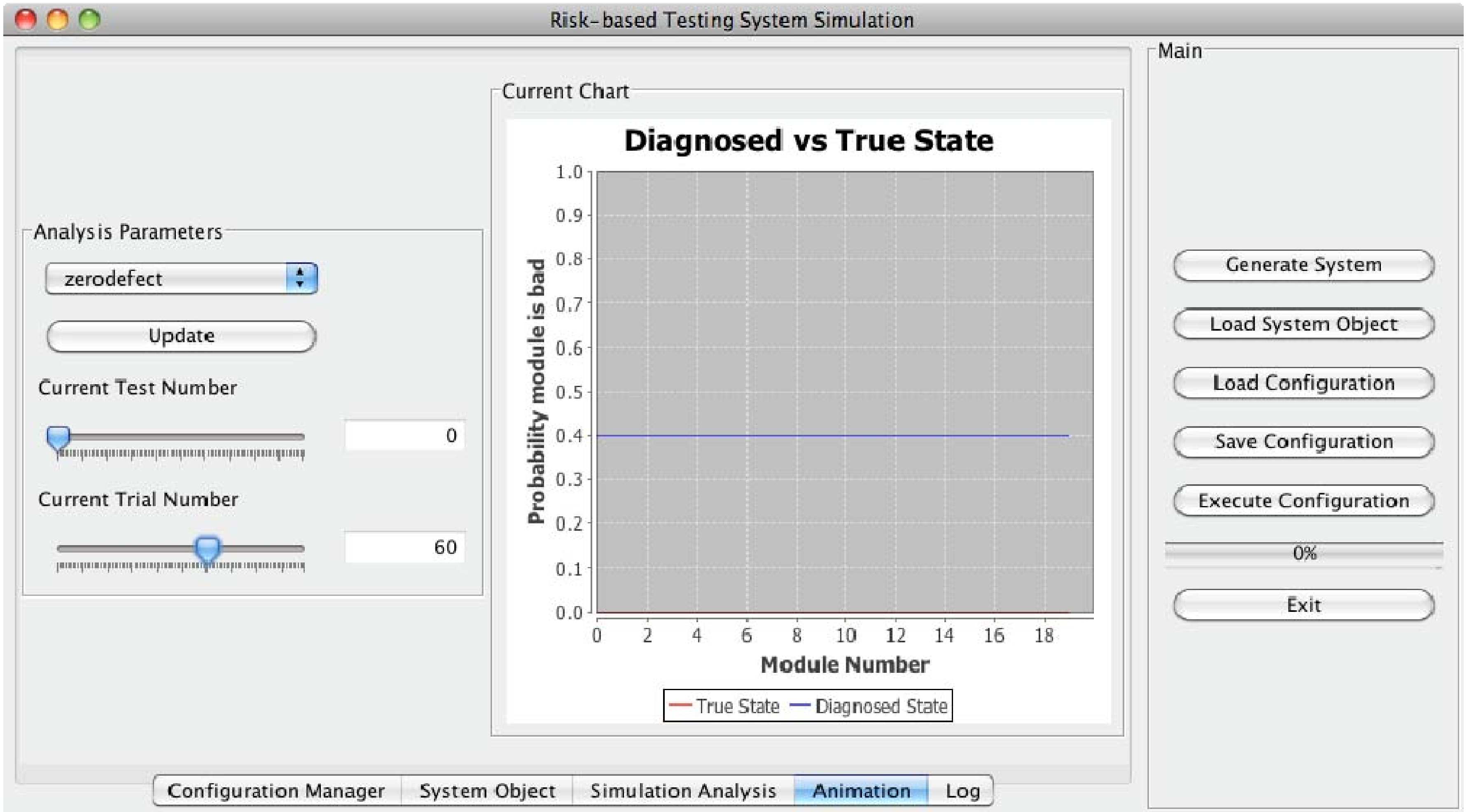

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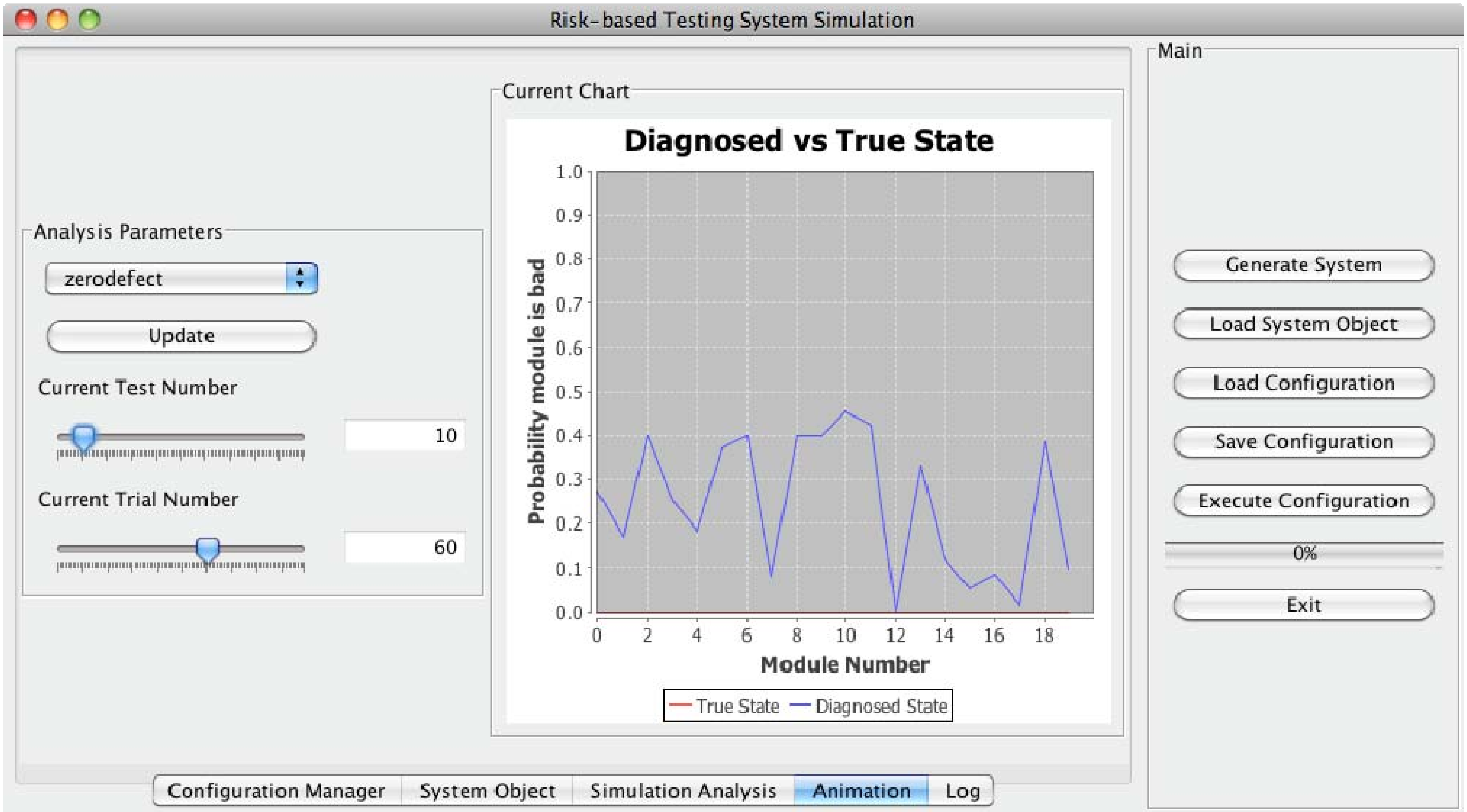

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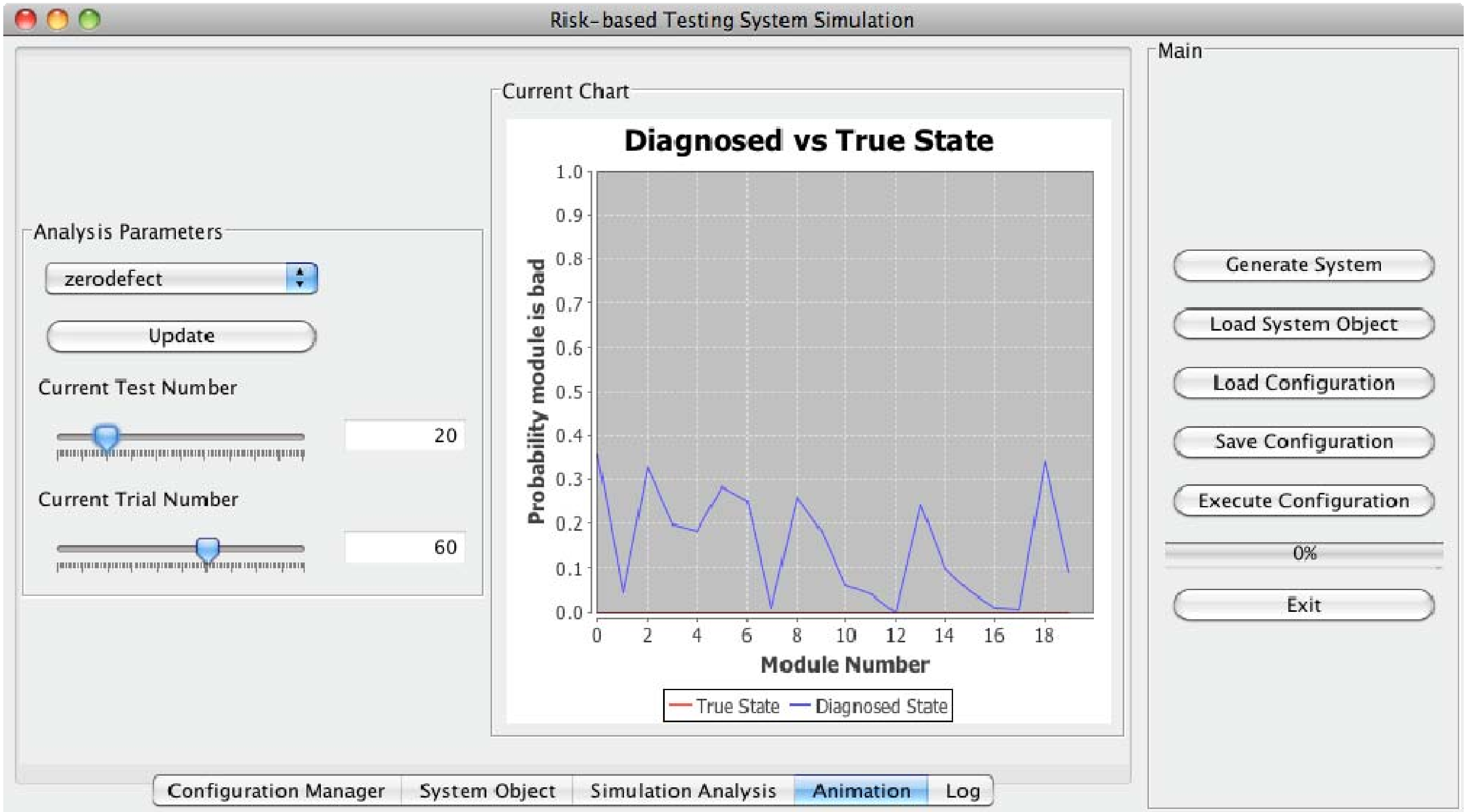

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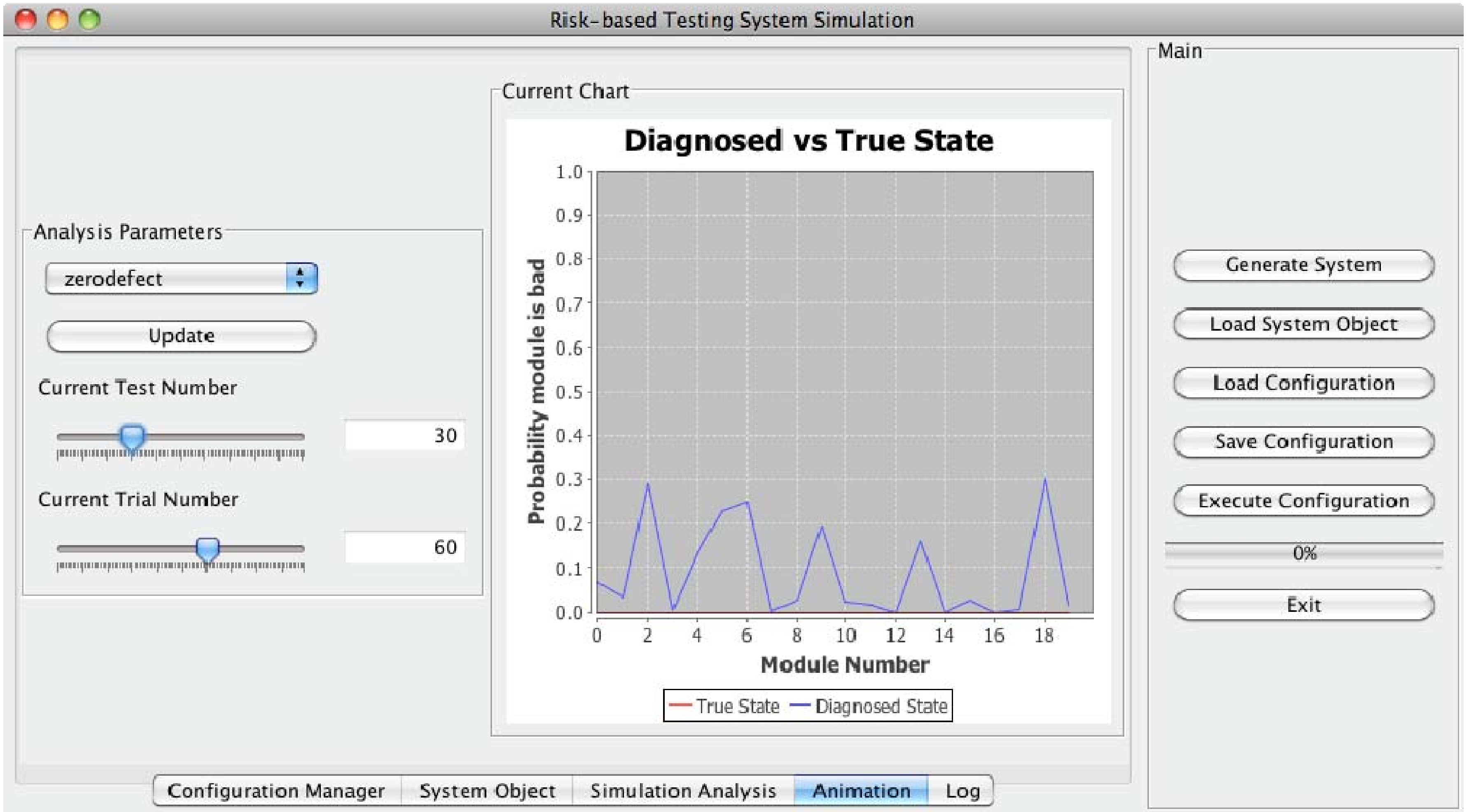

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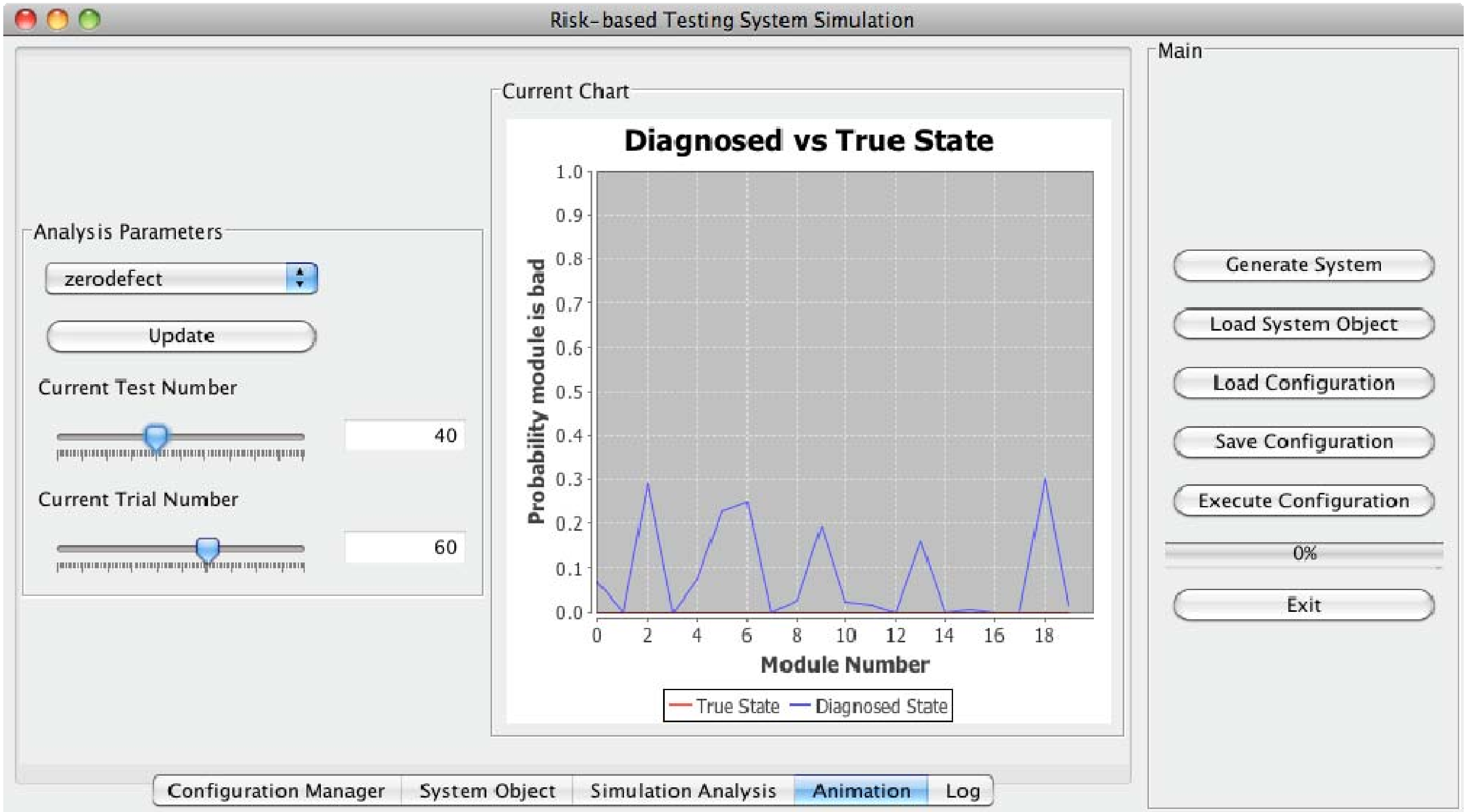

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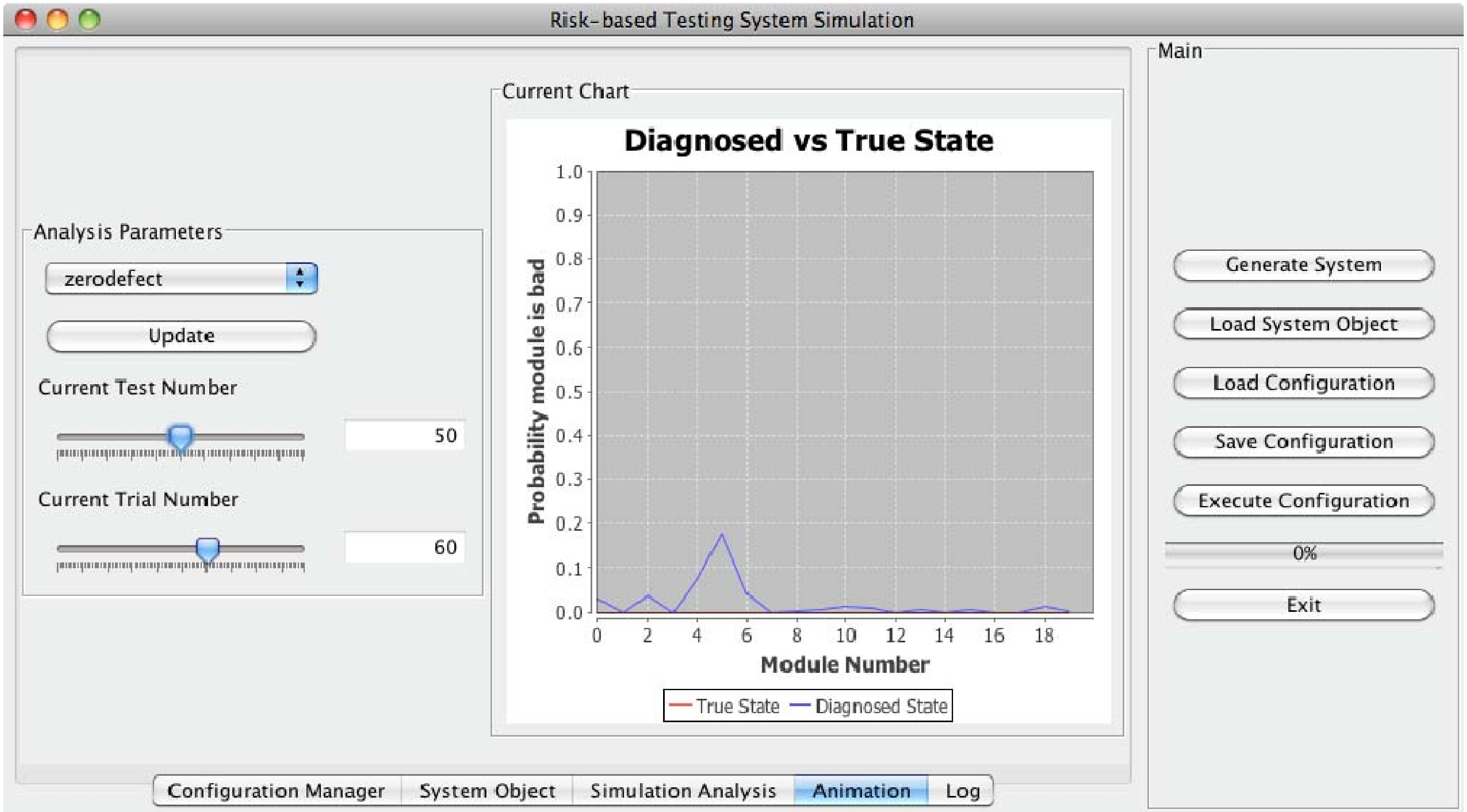

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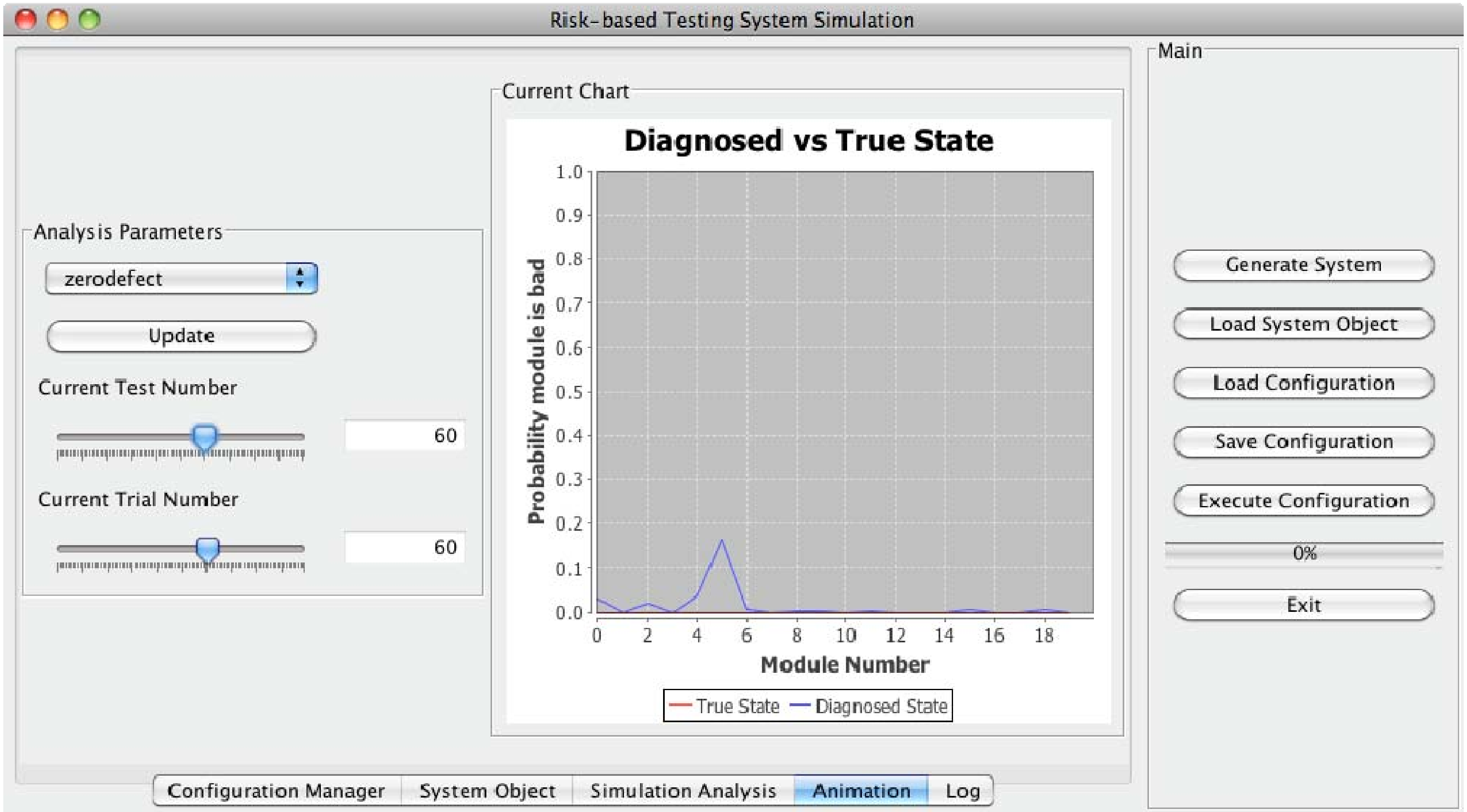

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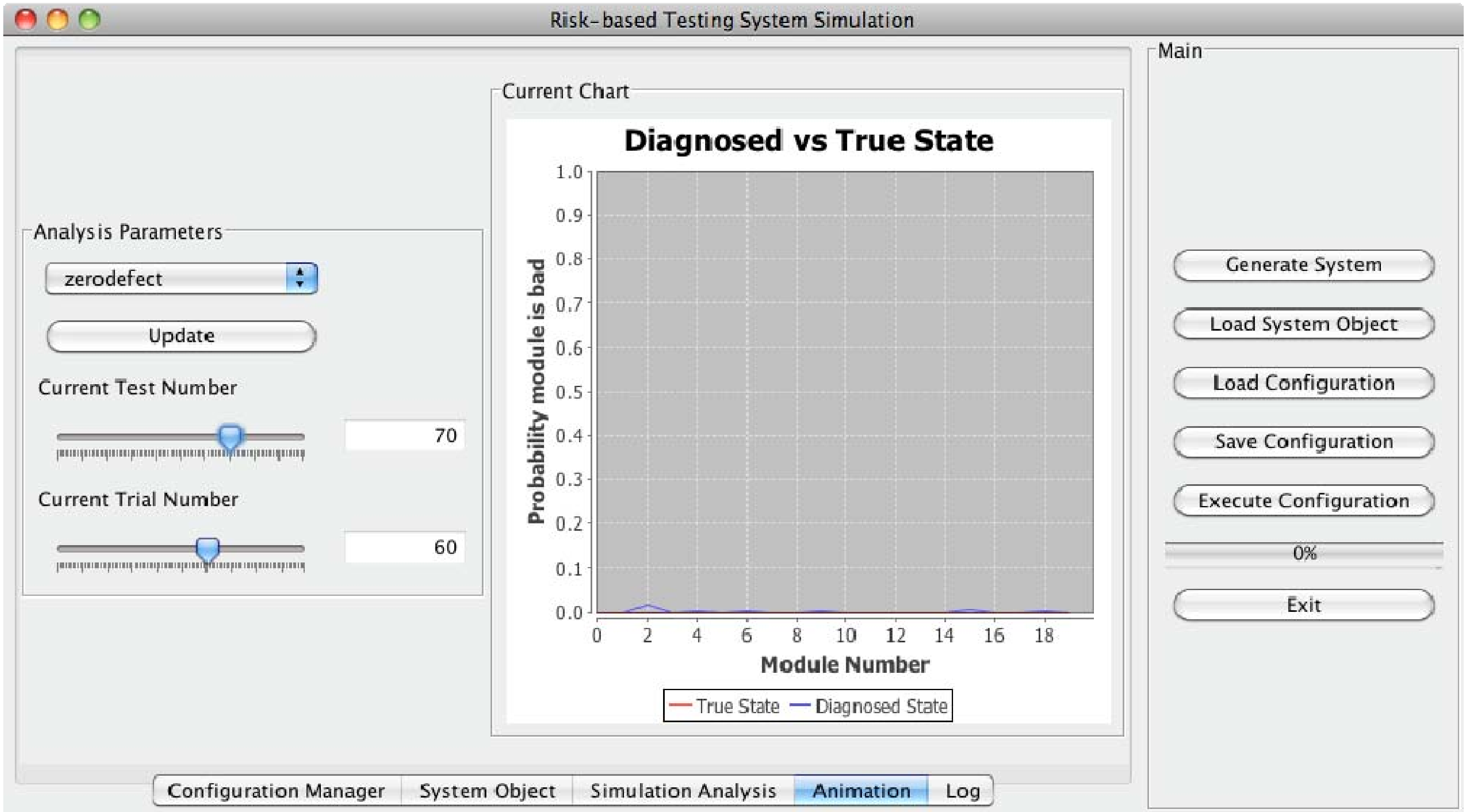

But, what does it all mean?

- *Effective, cost-efficient testing is critical to the long-term success of open architecture programs*

- This model and prototype decision aid provide a rigorous yet tractable way ahead to improve system testing

- Using this framework we can build the tools to:
  - Lower the testing costs for a given level of system reliability
  - Improve the use of existing suites for a given budget or schedule
  - Design better, more targeted test suites to minimize redundancy
  - Provide insight into the power or sensitivity of current test suites