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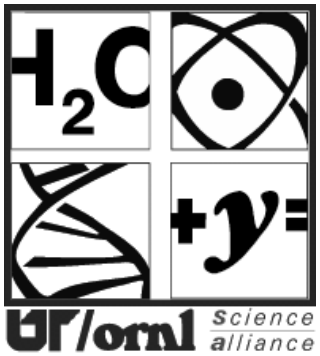

Model Based Testing: Opportunity for VV&A

Presentation to NAVSMO VV&A TWG

March 20, 2002

Telcordia Technologies/SAIC

An SAIC Company

University of Tennessee

Model Based Testing

- Software Testing consumes 1/3 of total development budget
- Model based testing a new technology- for efficient and effective testing
- Has uses in V&V
- Key idea: Create a model of test scenarios and generate test cases as needed
  - Easy to maintain
  - Quick to generate many test cases
  - Discovers anomalies quickly
  - Supports automated testing
- Two methods for efficient testing:
  - Markov Chain Usage Models: University of Tennessee
  - Combinatorial Design Method: AETG System from Telcordia/SAIC
- When you have tested enough?

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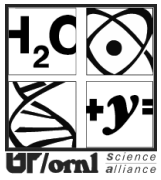
Model Based Testing: Markov Chain Usage Models

Developed at the University of Tennessee

Available from UT:

- research papers
- support tools
- training
- application support



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Major Users of Markov Chain Usage Models

- Raytheon (Dallas)
- IBM Storage Systems Division (Tucson)
- Microsoft (Seattle)
- US Army TACOM (Warren)
- CTI-PET Systems
- FAA Tech Center
- Ericsson
- Nortel
- Alcatel

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Essence of Method

- Identify *states of use* and *possible transitions*
- Construct directed graph
- Derive/assign probabilities to arcs (Markov chain)
- Use statistics of MC to validate and plan
- Test (use) cases are paths from source to sink
- Generate test cases by graph methods
- Generate random test cases per exp design
- Test and evaluate stopping criteria

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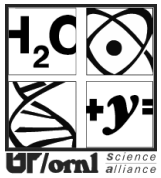
Benefits of Method

- Model construction & validation reveal errors
  - much rework avoidance if modeling precedes system development
- More effective testing
- More effective test management
- Shorter testing time, less cost
- Directly supports automated testing



Raytheon Experience, Multiple Projects

Phase containment of errors RA,PD,DD,CT,IT,FR

- 27% savings in cost of rework

Testing activities consumed 17-30% of project resources versus 32-47%

- more testing
- higher quality code based on FR

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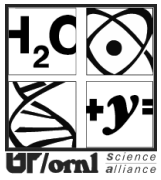
Getting Started

Training: University of Tennessee

Tools

Demonstration project

References available upon request



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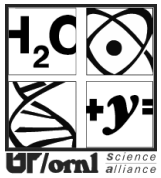
Model Based Testing: Combinatorial Design Method



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Combinatorial Explosion:

- Example: Parameters

F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
in	**in**	**in**	**in**	**in**	**in**	**in**	**in**	**in**	**in**	**in**
out	**out**	**out**	**out**	**out**	**out**	**out**	**out**	**out**	**out**	

  - –2^11 possible combinations- allowed
  - –Some constraints by system requirements- here 2^10

Number of possible tests are very large
e.g., 10 fields, 2 inputs/field, possible test cases = 1024
13 fields, 3 inputs/field, possible test cases = 1,594,323
Real 75 fields, 2 inputs/field, possible test cases = 3.5*10^22

Combinatorial Explosion: What should be the strategy?

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Plane Rolling Characteristics: Requirements

Configuration	Altitude	AirSpeed	Mach No.	Aileron Deflection
		140	0.26	1/4, 1/2, 3/4, Full
	10000	200	0.36	1/4, 1/2, 3/4, Full
		250	0.45	1/4, 1/2, 3/4, Full
		300	0.54	1/4, 1/2, 3/4, Full
		200	0.26	1/4, 1/2, 3/4, Full
CLEAN				4, Full
				4, Full
		350	0.65	1/4, 1/2, 3/4, Full
		200	0.54	1/4, 1/2, 3/4, Full
	30000	250	0.67	1/4, 1/2, 3/4, Full
		300	0.79	1/4, 1/2, 3/4, Full
		350	0.9	1/4, 1/2, 3/4, Full
		120	0.2	1/4, 1/2, 3/4, Full
GEAR, FLAPS	5000	140	0.23	1/4, 1/2, 3/4, Full
		180	0.3	1/4, 1/2, 3/4, Full

> 2000 combinations

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Plane Rolling Char

Configuration	Altitude		
	100		
			3/4, Full
		0.26	1/4, 1/2, 3/4, Full
CLEAN			4, Full
			4, Full
	350	0.65	1/4, 1/2, 3/4, Full
	00		
			4, Full

Additional Constraints: Outside Temperature, Rudder Position, etc.
How to model these ?

> 2000 combinations

Gear and Flap Conf. should be deployed only at 5000 fts. or less.

For altitudes less than 5000 fts,

Air Speed should be less than 180

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AETG SYSTEM: TEST CASES- UI, MESSAGE INTEROPERABILITY TESTING

Find A Good Subset: A new idea try all pairwise (triple, 4 way) interactions

13 Fields, 3 Inputs (1,2,3) per field

TEST	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Field 7	Field 8	Field 9	Field 10	Field 11	Field 12	Field 13
Case 1	1	1	1	1	1	1	1	1	1	1	1	1	1
Case 2	1	2	2	2	2	2	2	2	2	2	1	1	1
Case 3	1	3	3	3	3	3	3	3	3	3	1	1	1
Case 4	2	1	1	2	2	2	3	3	3	1	2	2	1
Case 5	2	2	2	3	3	3	1	1	1	2	2	2	1
Case 6	2	3	3	1	1	1	2	2	2	3	2	2	1
Case 7	3	1	1	3	3	3	2	2	2	1	3	3	1
Case 8	3	2	2	1	1	1	3	3	3	2	3	3	1
Case 9	3	3	3	2	2	2	1	1	1	3	3	3	1
Case 10	1	2	3	1	2	3	1	2	3	1	2	3	2
Case 11	2	3	1	2	3	1	2	3	1	2	3	1	2
Case 12	3	1	2	3	1	2	3	1	2	3	1	2	2
Case 13	1	3	2	1	3	2	1	3	2	1	3	2	3
Case 14	2	1	3	2	1	3	2	1	3	2	1	3	3
Case 15	3	2	1	3	2	1	3	2	1	3	2	1	3

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Model Based Testing: AETG System

–Creates near optimal test cases for any n

–**Example: Complex Messages- 126 fields, 2 values - 10 Tests**

–Allows for constraints, grammar for specifying constraints

–Creates scripts which can be connected to automation harness

–Creates invalid and valid test cases

http://aetgweb.argreenhouse.com

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Combinatorial Design Uses: AETGWeb

Many uses:

Software Industry

Defense Industry

Telecommunications Industry

Chip making company

Railroad

Financial Interbank Company

Cost savings of 67% & schedule savings of 68% are shown for an example.

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Reducing Time to Market with Combinatorial Design Method Testing

Raytheon Company

Abstract. Testers face the challenge of doing as much testing as possible within the available, and usually constrained, schedule. In the hyper-competitive commercial marketplace, it is not practical to exhaustively test all combinations of system test cases. This paper discusses the author's experience with a method that generates a small subset of test cases which provides good coverage of the test domain—the Combinatorial Design Method. It has proven to be flexible for system level testing of small, commercial satellite ground systems. Cost savings of 67% and schedule savings of 68% are shown for an example.

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SOME RESULTS

- Faults: 9 system tested ui-
  - 49 faults found
- Effort: 2.75 hours/screen
- Coverage:Unix Commands-Sort- 92%
  OSS system- 93%

References: IEEE TSE, IEEE Software, ICSE, ISSRE, Technometrics

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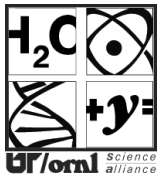
When to Stop Testing?

- **Cost Based Model:**
  - ***K(t) = # of faults found until time t***
  - ***N= Total # of faults in the simulated system***
  - ***Challenge: K(t) changes over time, and N is unknown***



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When to Stop Testing? Two formulations

- **Cost Based Model**
  - **Cost at time *t* = *f t* + *a K(t)* + *b (N- K(t))***
  - ***Minimize Cost***
- **Probabilistic Guarantee on # of faults remaining**
  - **Want stopping time T such that Pr{N-K(T)<=m}= 1-a**

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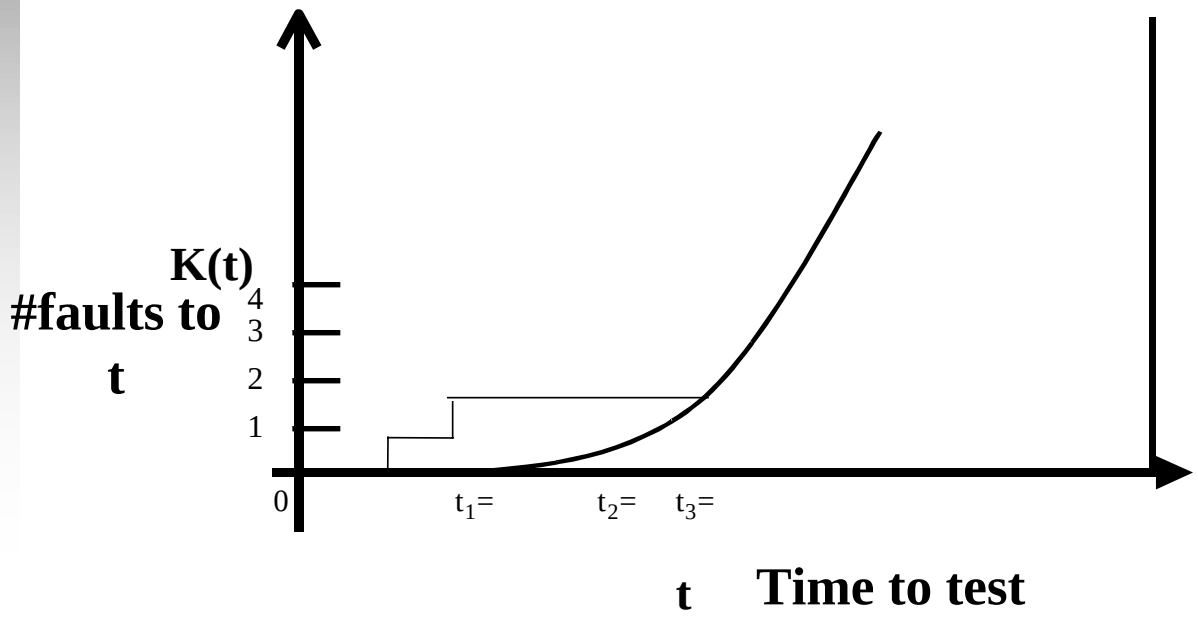
Method 1: When to stop testing?



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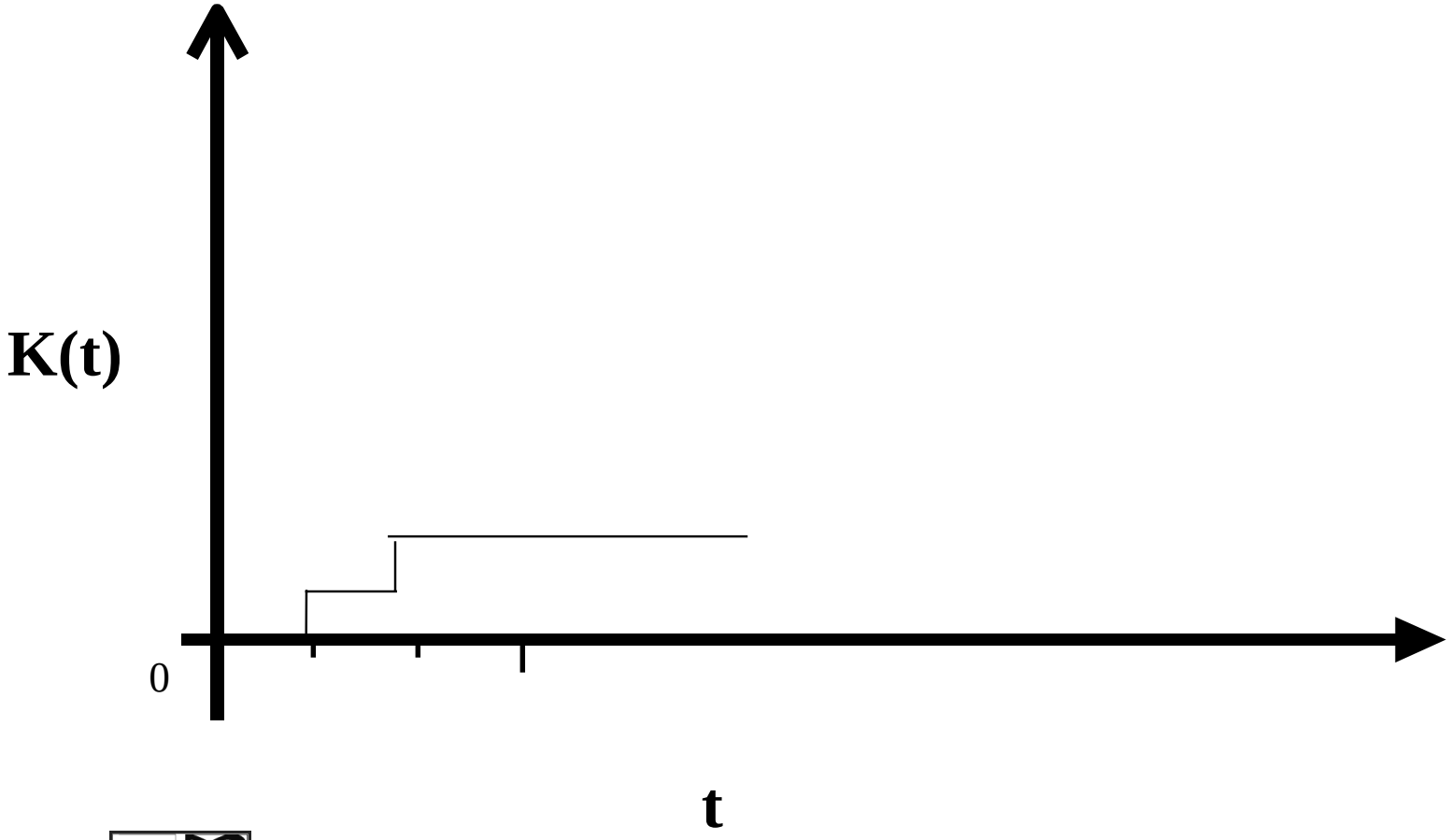
Method 2: When to stop testing?

Time between faults is large



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When to Stop Testing?

- **Challenges**:
  - Fixes during testing, New Source Lines, New Features
  - Assume that software doesn't change
  - Look at the components and how to allocate resources

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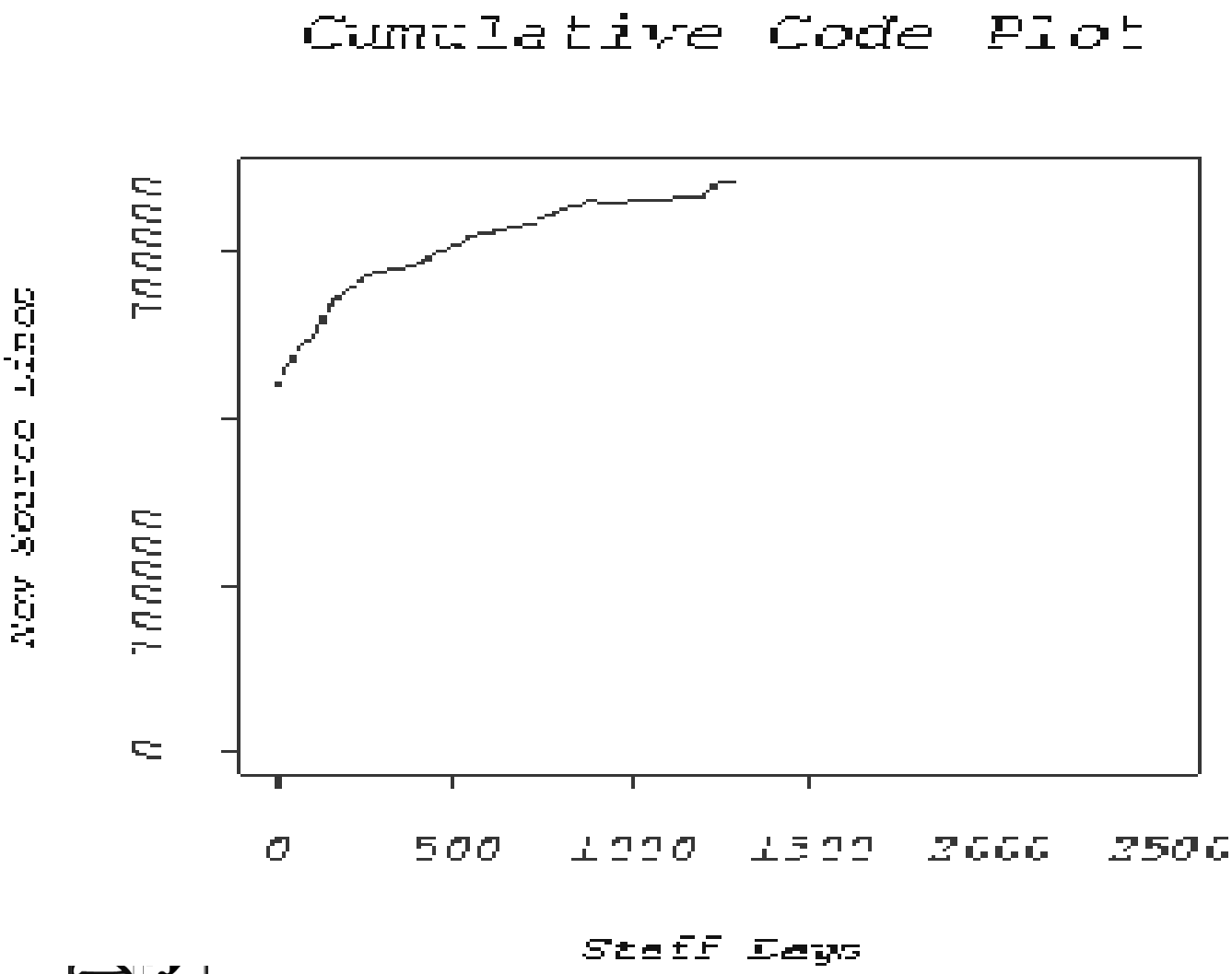
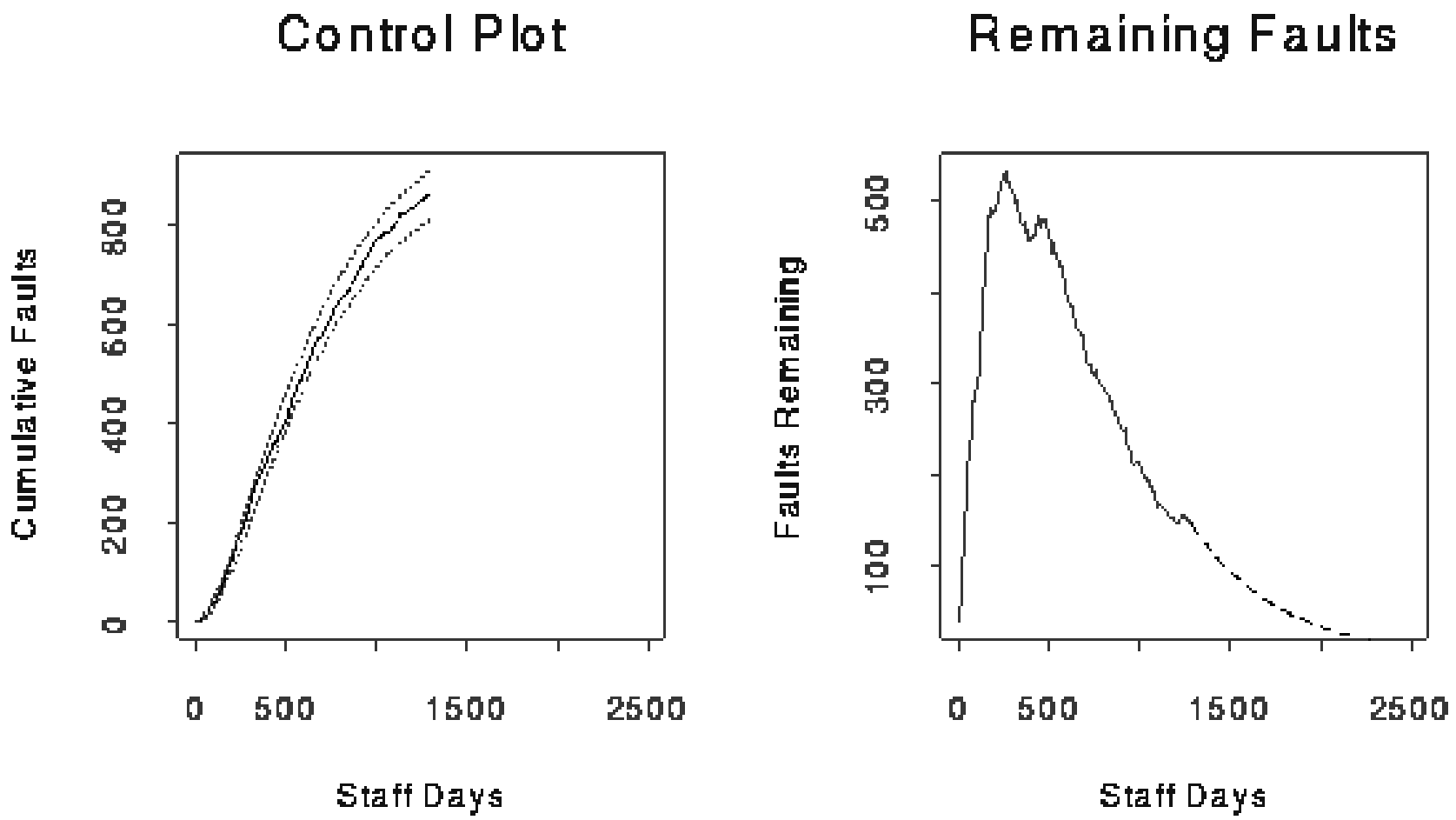
ANALYSIS: NEW SOURCE LINES



ANALYSIS: QUALITY INDEXES



IASA, IEEETSE, IEEEJSAC, Annals Appl. Prob.

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Conclusion

- Markov Chain Models allow for scientific way of testing across paths of a tree
- Combinatorial Designs allow for reduction in test cases for a given path
- When to stop testing Method helps manage Testing Effort

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