Software Reliability Engineering

Objectives

- Look at some details on Software Reliability Engineering (SRE)
  - Steps in the SRE process
  - Setting reliability objectives
  - Using operational profiles to guide effort
  - Interpreting reliability trend graphs

Reliability Focus

- "Testing can only prove the presence of errors, not their absence."

  Dijkstra
- So, focus on reliability, not defects
  - Correctness

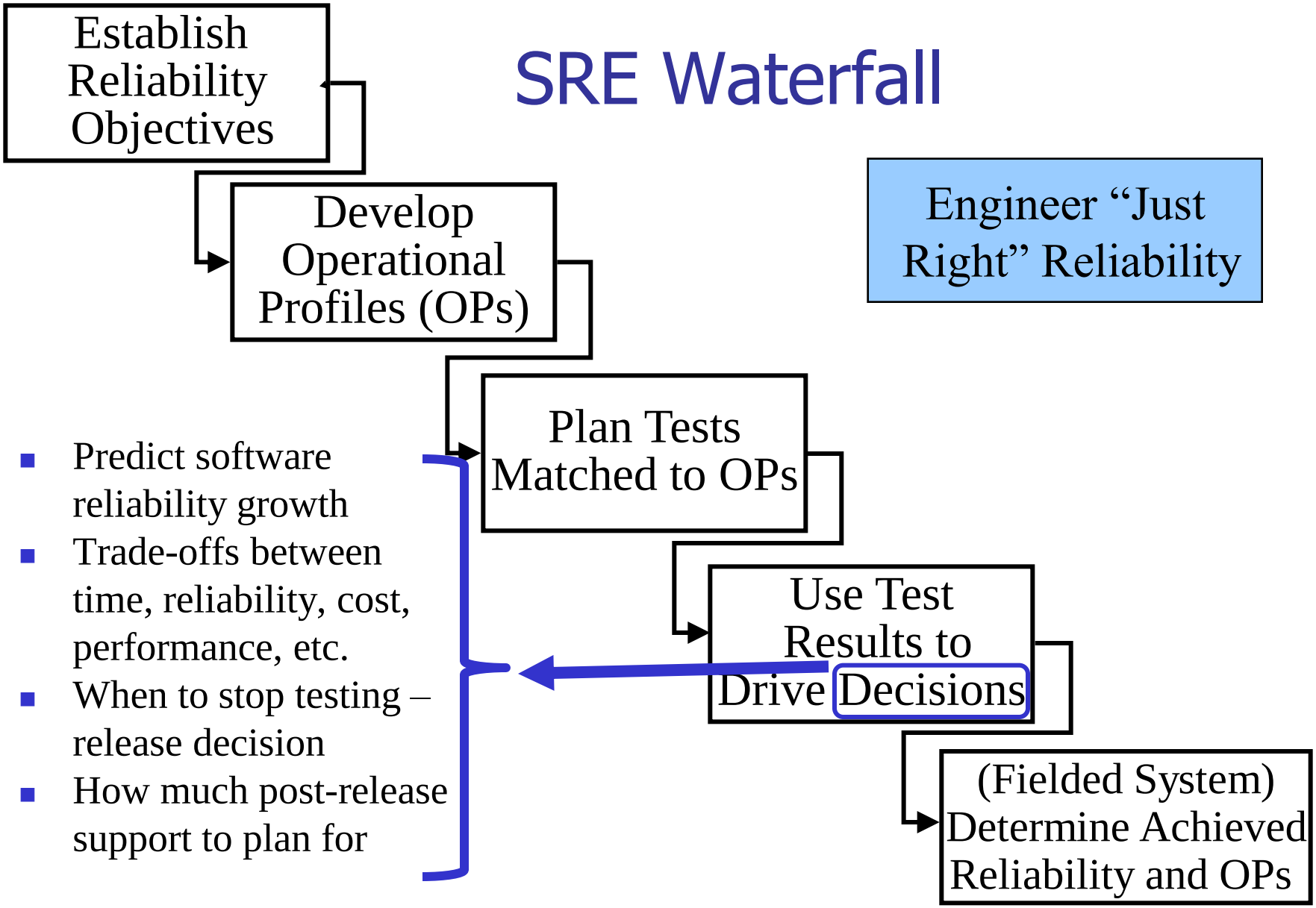
Software Reliability Engineering

- Software Reliability Engineering (SRE) addresses the measurement, modeling, and improvement of software reliability
- Use quantitative information to choose the most cost-effective software reliability strategies for your situation

Reliability Engineering Practices

- Define reliability objectives
- Use operational profiles to guide test execution
- Track failures during system tests
- Use reliability growth curves to track quality of product
- Release when quality of product meets reliability objectives

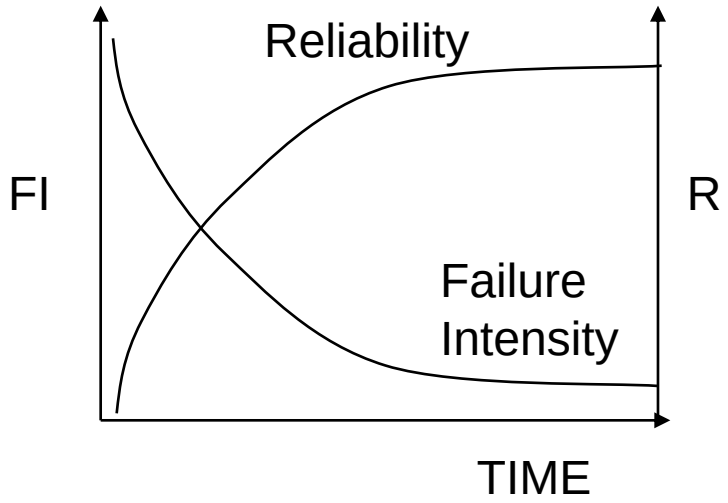
SRE Waterfall



- Predict software reliability growth
- Trade-offs between time, reliability, cost, performance, etc.
- When to stop testing – release decision
- How much post-release support to plan for

Reliability and Failure Intensity

- Failure intensity: Number of failures per hour of operation
- Reliability is the inverse of failure intensity (FI)



Defining Reliability Objectives

- Set quantitative targets for level of reliability that make business sense

Impact of a failure	FI Objective	MTBF
100's deaths, >10^9 cost	10^{-9}	114,000yrs
1-2 deaths, around 10^6 cost	10^{-6}	114 yrs
$1,000 cost	10^{-3}	6 weeks
$100 cost	10^{-2}	100 h
$10 cost	10^{-1}	10 h
$1 cost	1	1 h

From John D. Musa

Operational Profiles Guide Effort

- Guide software development priorities and quality effort by what the user will use the most often
  - Pareto principle: 20% of the software's functionality or "size" may satisfy 80% of the user's needs
  - Operational profiles expose most frequently used product features

Operational Profile

- Sample application: Word Processor

Operation	**Frequency**	**Approx. Relative Freq.**
Open file	1/session (5 session/day)	0.001
Close file	1/session	0.001
Save file	25/session	0.04
Insert text	1000/session	1.0
Cut-and-paste	6/session	0.006
Check spelling	1000/session	1.0
Repaginate	100/session	0.1
Upgrade software	1/ 6 months	0.000001

Testing Based on Operational Profiles

- Done during black-box system testing
- Mix of test cases that match operational profile
- If possible, create automated test harness to execute test cases
  - Need to run large numbers of test cases with randomized parameters for statistical validity
- Execute test cases in randomized order, with selection patterns matching frequencies in operational profile
  - Simulating actual pattern of usage

Studying Patterns in the Trends of Reliability Growth

Reliability Metric

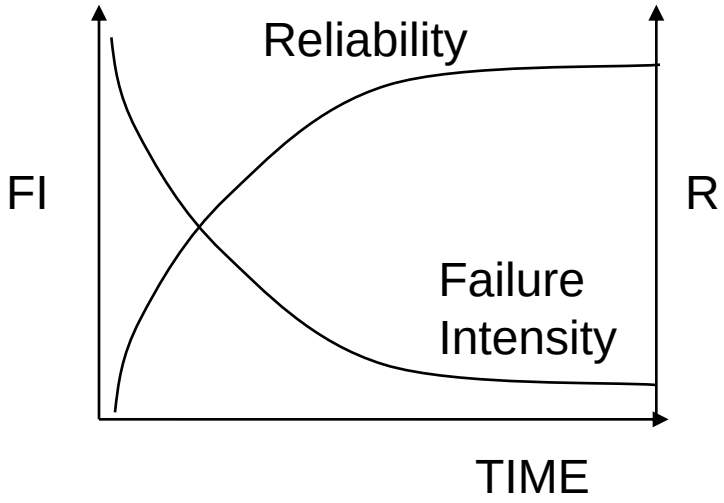
- Estimated failure intensity
  - (Reliability = 1 / failure intensity)
  - Use reliability tracking and analysis tools to show actual (to date) and predicted (future) estimates of how failure intensity varies over time
- The curve is referred to as the “reliability growth curve”
  - Note that the product being tested varies over time, with fixes and new code
  - In-process feedback on how quality is changing over time

Code Integration/Build Patterns

- Most large projects have periodic builds
  - Development team integrates a new chunk of code into the product and delivers to test team
- Test team does black box system testing
  - Identifies defects (failures) and reports them to development team
- Track pattern of defects found during system testing to see how reliability varies as development progresses
  - Defects found should decrease over time as defects are removed, but each new chunk of code adds more defects
- Pattern of reliability growth curve tells us about the code being added, and whether the product code is becoming more stable
- Pattern can also be used to statistically predict how much more testing will be needed before desired reliability target reached
  - Useful predictions only after most of the code is integrated and failure rates trend downward

Tracking Failures During Testing

- Enter data about when failures occurred during system testing into reliability tool such as CASRE (Computer-Aided Software Reliability Engineering tool) or Statistical Modeling and Estimation of Reliability Functions for Software (SMERFS)
  - Plots graph of failure intensity vs. development/test time

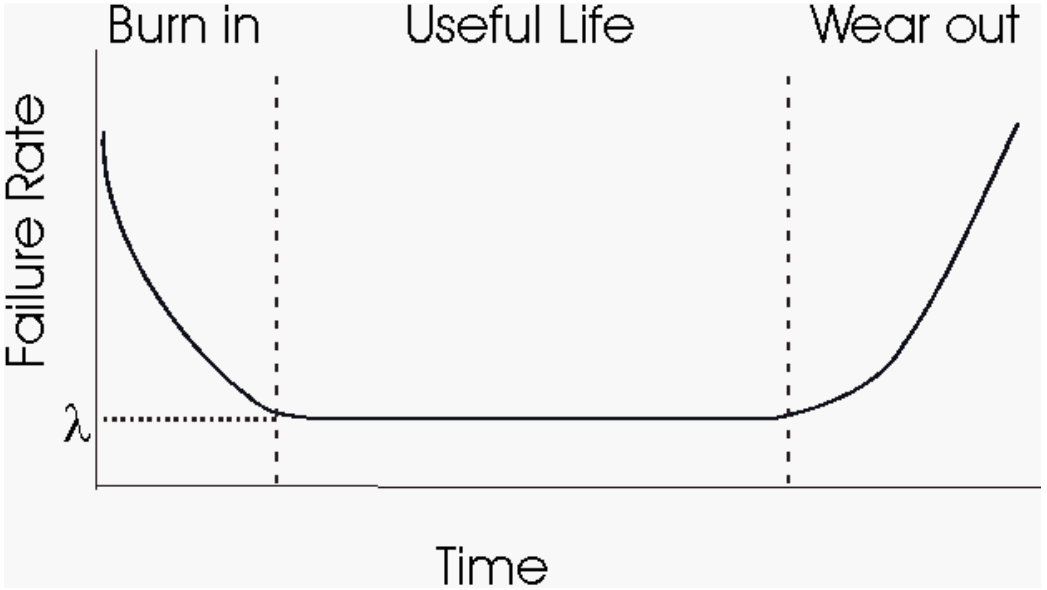


In concept, a nice smooth curve of reliability growth

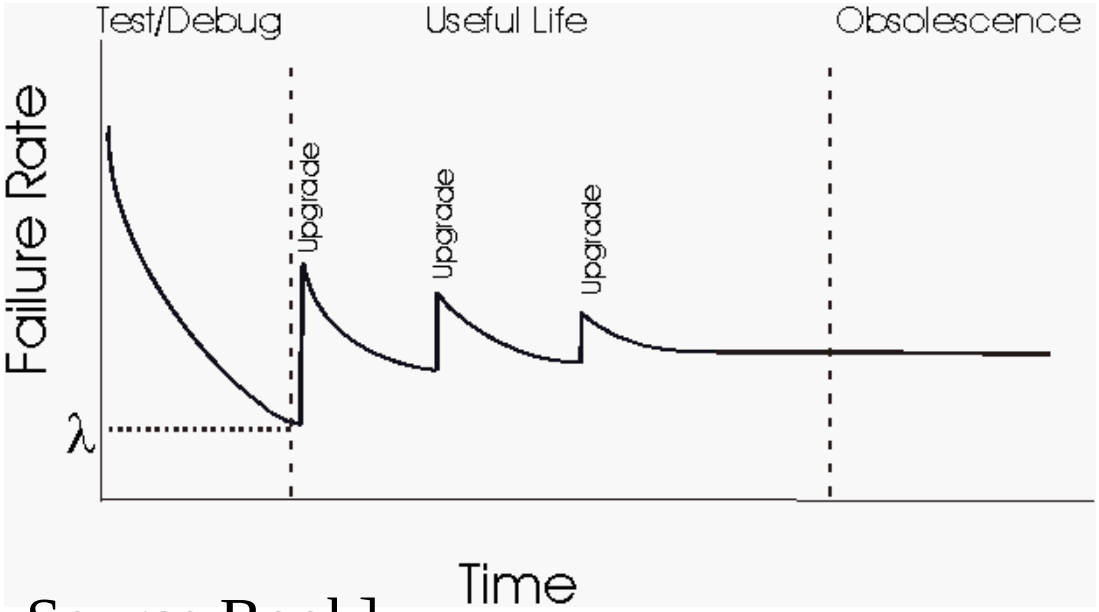
From netserver.cerc.wvu.edu/numsse/Fall2003/691D/lec3.ppt

Reliability Over Time

Hardware "Bathtub" Model

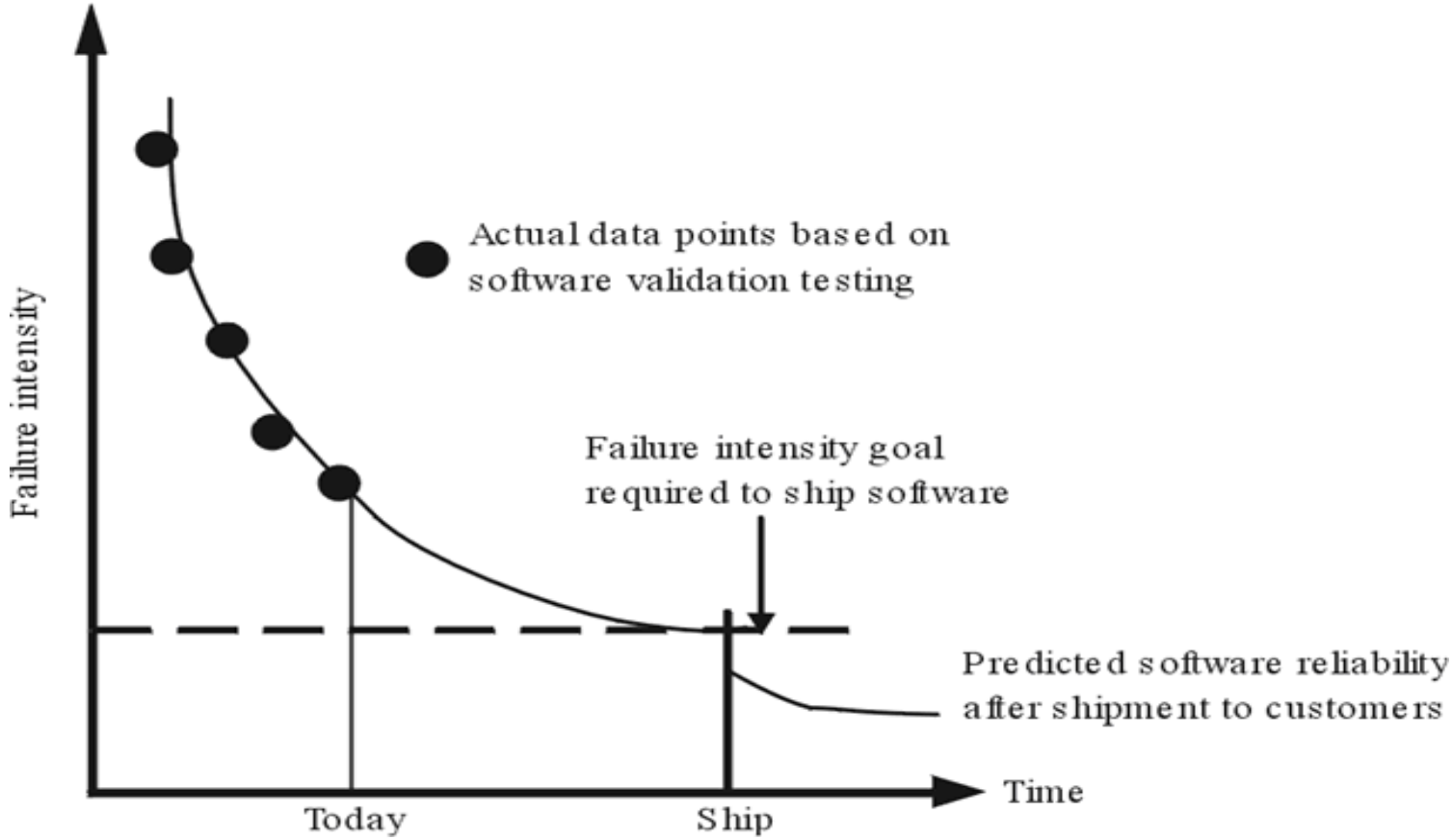


Software Model



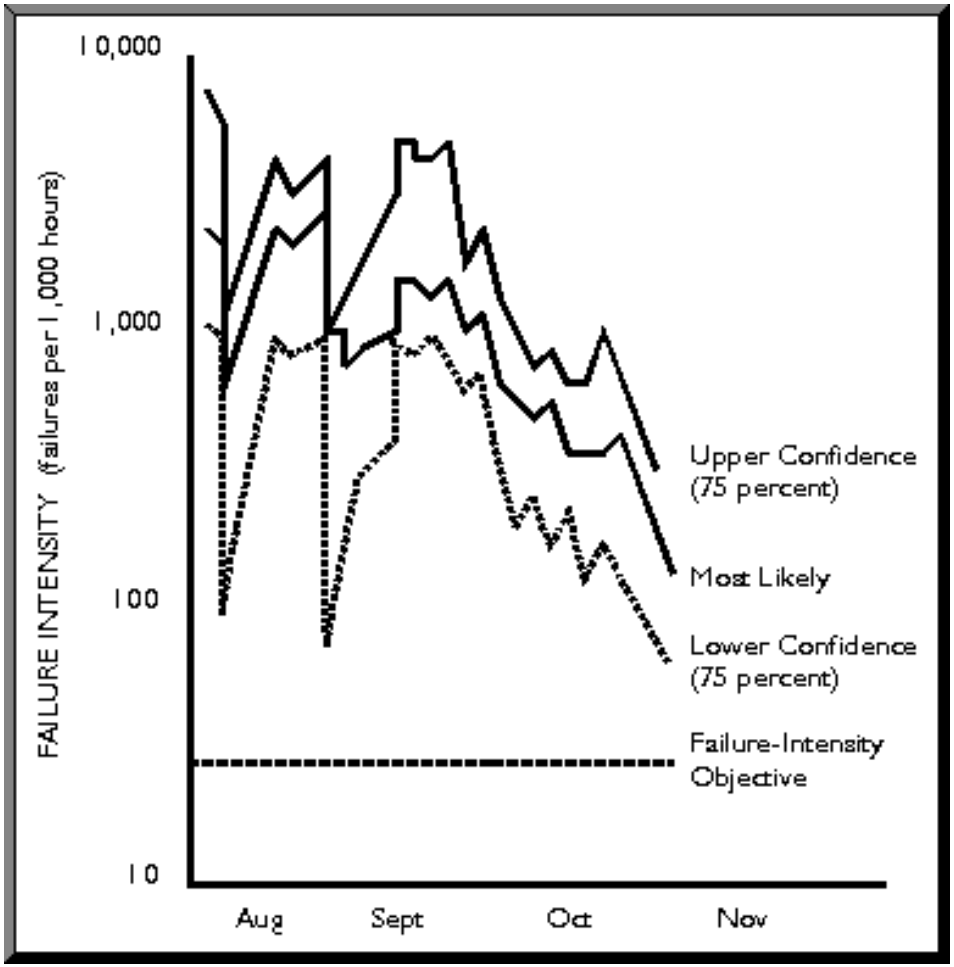
[DACS Software Reliability Source Book]

Predicting with a Software Reliability Growth Model



[Rakitin]

A More Realistic Curve During Development

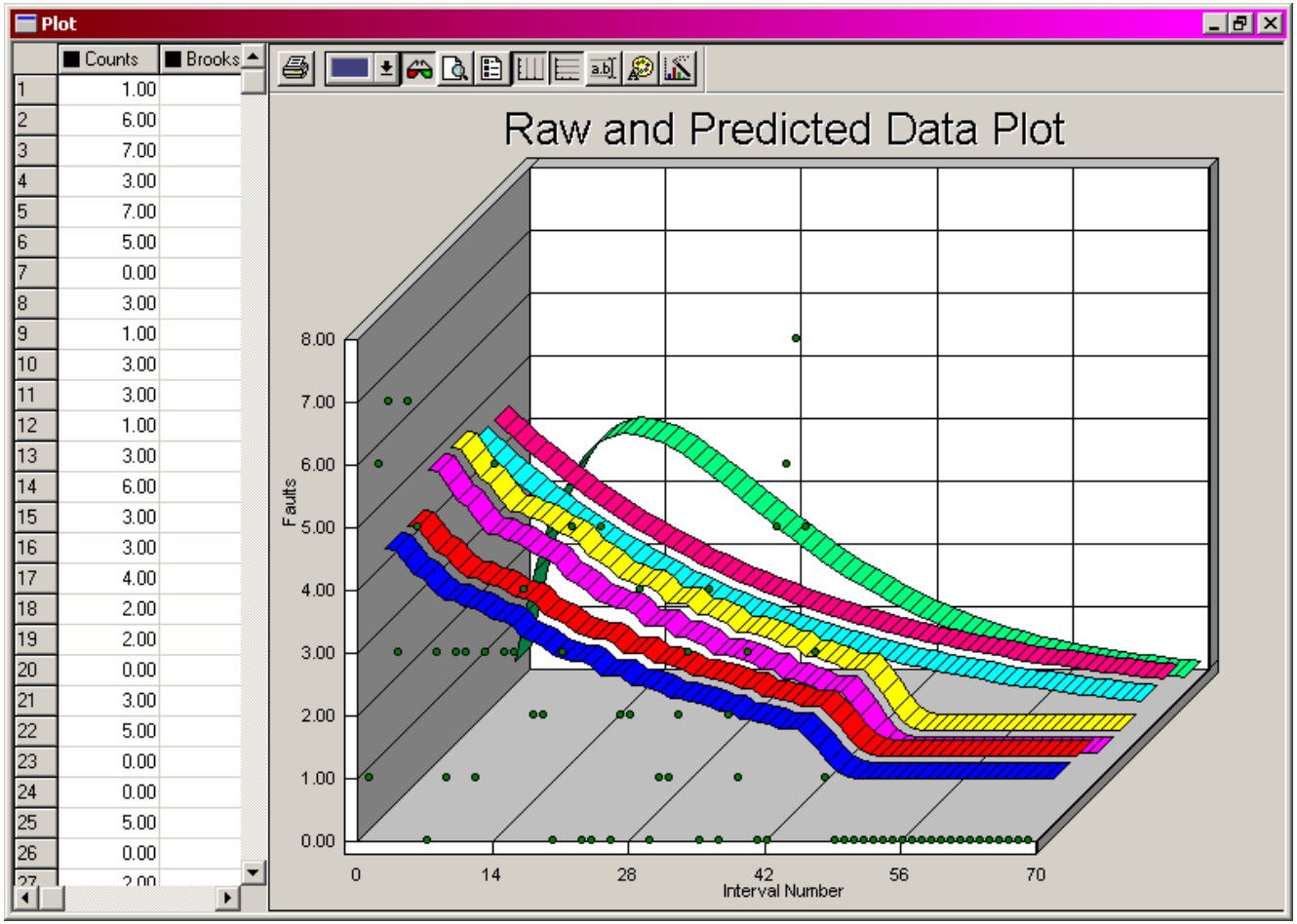


From http://www.stsc.hill.af.mil/crosstalk/1996/06/Reliabil.asp

Many Statistical Models of Reliability Growth

- The Statistical Modeling and Estimation of Reliability Functions for Software (SMERFS) contains a collection of several reliability models, including:
  - The Littlewood-Veral Bayesian model
  - The Musa execution time model
  - The geometric model
  - The nonhomogeneous Poisson model for execution time data
  - The Musa logarithmic Poisson execution time model
  - The generalized Poisson model for interval data
  - The nonhomogeneous Poisson model for interval data
  - The Brooks-Motley discrete software reliability model
  - The Schneidewind maximum likelihood model
  - The Yamada S-shaped reliability growth model
- Get SMERFS at http://www.slingcode.com/smerfs/

Model Comparison Using SMERFS^3



[Dolores R. Wallace Practical Software Reliability Modeling]

Interpreting Reliability Growth Curves

- Spikes are normally associated with new code being added
- Larger volumes of code or more unreliable code causes bigger spikes
  - The curve itself tells us about the stability of the code base over time
- If small code changes/additions cause a big spike, the code is really poor quality or impacts many other modules heavily
- The code base is stabilizing when curve trends significantly downward
  - Release (ideally) only when curve drops below target failure intensity objective … indicates right time to stop testing
  - Can statistically predict how much more test effort needed before target failure intensity objective needed

Limitations of Reliability Curves

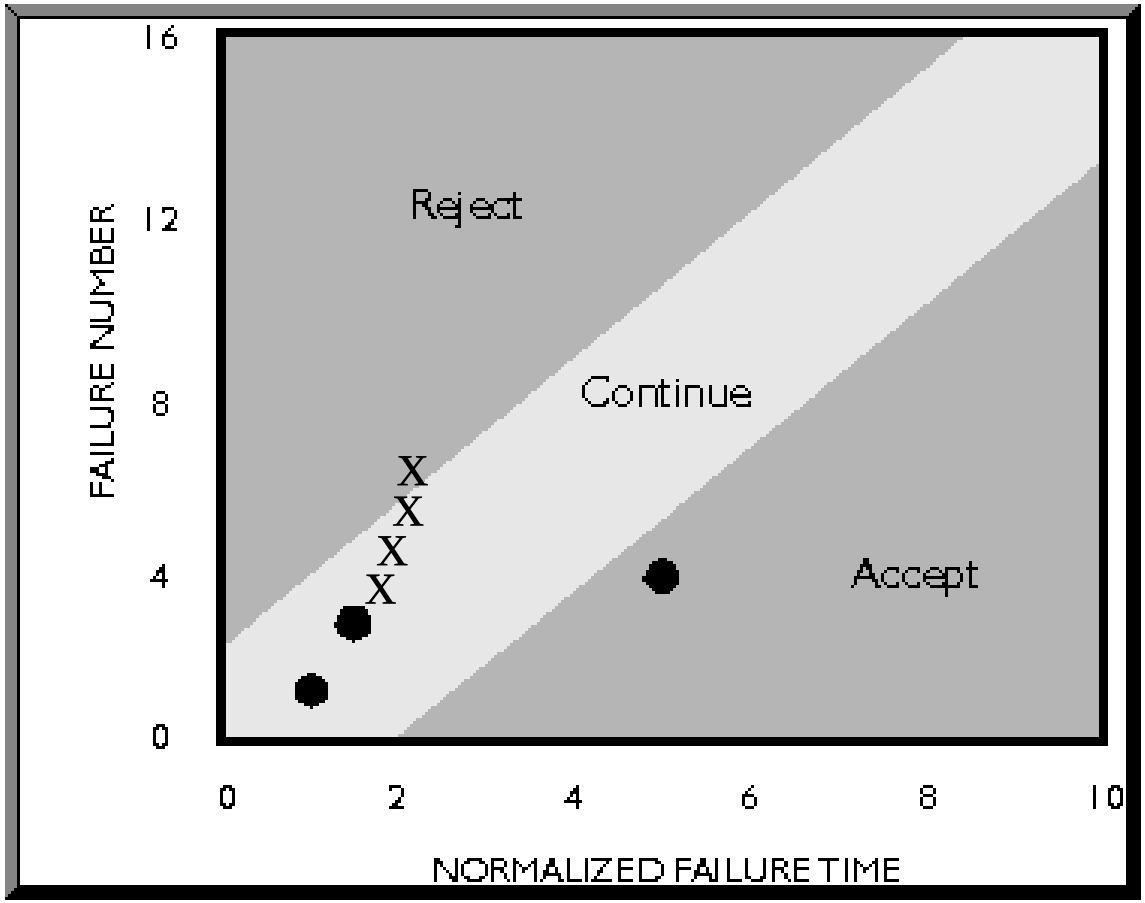
- Operational profiles are often "best guesses," especially for new software products
- The reliability models are empirical and only approximations
- Failure intensity objectives should really be different for different criticality levels of different kinds of failures
  - Results in loss of statistical validity!
- Automating test execution is challenging (particularly building verifiers) and costly
  - But it does save a lot over the long run
  - More worthwhile when reliability needs are high
- Hard to read much from the growth curves till later stages of system testing … very late in the development cycle

Reliability Certification

- Another use for reliability engineering is to determine the reliability of a received or acquired software product: Certification of Acceptability
  - For example, you are evaluating web servers for your company website – reliability is a major criterion
- Build a test suite representative of your likely usage
  - Put up some pages, maybe including forms
  - Create test suite that generates traffic
  - Log failures such as not loading, wrong data received, server time out
  - Track failure patterns over time
- Evaluate multiple products or new releases using test suite, to determine reliability
  - Avoids major problems and delays with poor vendor software
- Note that this applies the analysis to a fixed code base
  - Fewer problems with statistical validity

Example Certification Curve

Run the product and track the time of occurrence of each failure



- Failure #1 Decision: Don't know enough yet, so continue running
- Failure #2 Decision: Don't know enough yet, so continue running
- Failure #3 Decision: Came far enough later (in MTBF sense) that the product is certified acceptable
- Had failures #3-7 happened as shown by the x's, then the failures are occurring too frequently -- Reject

Based on http://www.stsc.hill.af.mil/crosstalk/1996/06/Reliabil.asp

Summary

- Software Reliability Engineering is a scientific (statistical) approach to reliability
- Vast improvement over common current practice
  - "Keep testing until all our test cases run and we feel reasonably confident"
- Avoids under-engineering as well as over-engineering ("zero defects")
- When done well, Software Reliability Engineering adds ~1% to project cost
  - Musa's numbers: ~10% for medium-sized projects if you include cost of automated testing
  - Note that as the number of builds and releases increases, automated testing more than pays for itself