

System Testing & Performance

- System Testing
 - system testing vs. unit testing
 - planning for system testing
- Bug Finding
 - bug detection rates
 - release phases & ship criteria
- Performance Management
 - basic principles
 - performance design and repair
 - basic tools and practices

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Unit vs. System Testing

- Goals
 - is this component ready to integrate? ●
 - is this system ready to ship? ●
- Context
 - testing components in relative isolation ●
 - testing the entire assemblage ●
- Focus
 - component functionality and specifications ●
 - system functionality and specifications ●
 - “whole system” behavior ●

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In-System Unit Testing

- test new component in a whole system
 - other components with which to interact
 - we are able to exercise more functionality
 - we can identify component interface issues
- add new component to existing system
 - where other components are known good
- test builds of experimental components
 - tracking down problems can be difficult
- this is still unit, and not system testing ●

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Testing Responsibilities

- There are multiple players
 - developers ●
 - testers working with the developers ●
 - independent Test Group ●
- There are many types of testing
 - component functional validation ●
 - system functional validation ●
 - usability, security, performance, robustness ●
- Many theories about who should do which
 - organizational, philosophical, process, moral

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Typical System Test Activities

- System functionality and error handling
 - does the system do the things it is supposed to do
 - including the correct handling of all specified error conditions
- Installation testing
 - do all of the parts install and configure correctly
 - different combinations of platforms, install, configuration options
- Usability testing
 - can customers use it
- Security testing
 - authentication, authorization, privacy, attacks
- Interoperability testing
 - platforms, devices, different clients & servers
- Performance testing
 - capacity, throughput, response time
- Stress testing
 - overload, resource exhaustion, error recovery

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Planning System Testing

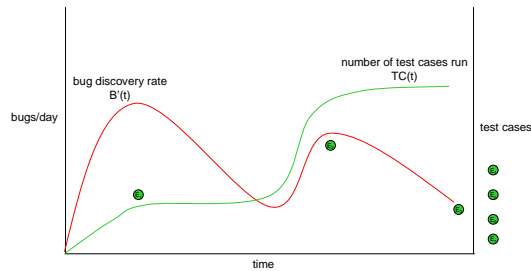
- Some system testing is fairly obvious
 - does the whole system meet specified requirements
 - derive test cases from the requirements
 - fully exercise independent component interactions
 - derive test cases from architecture and specifications
- But what other tests do we need to include?
 - standard types of testing:
 - installation, usability, security, interoperability, performance
 - other types of product or domain specific testing?
- System Testing is about confidence
 - what will the product be expected to do? ●
 - what are we already confident that it can do? ●
 - what are we not yet sure of? ●

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Testing and Bug Discovery



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Pre-FCS Exposure

- give key customers an early sniff
 - so they can better prepare for new release
 - so they can start work on related products
- get additional feedback prior to FCS
 - real customers will use it in different ways
 - they will find different bugs
 - they will find usability issues
 - they will find compatibility issues
- obscure the fact we are behind schedule
 - we shipped something!

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Alpha Testing

- alpha products are usually incomplete
 - missing functionality and documentation
 - very buggy
 - non-standard installation and management
- alpha sites are carefully selected
 - they are prepared to deal with problems
 - they can be trusted to exercise the product
- goals of alpha testing
 - gather feed-back on key features and content
 - early access for partners, key customers

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Beta Testing

- a beta product is very near final form
 - all functionality and documentation complete
 - few significant known problems
- beta sites are real customers
 - they will put the product to real use
 - they have agreed to give us feedback
- goals of beta testing
 - confirm the product is ready to ship
 - gather last-minute feed-back
 - early access for key customers

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determining ship-ability

- many types of metrics are commonly used
 - list of tests that must be passed
 - hours of load/stress tests passed
 - performance criteria
 - beta report results
 - open bug counts
 - new bug arrival rates
- concurrence (engineering, Q/A, support)
- fiat (product executive says “ship it”)
- criteria must be set at start of project

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Basic Principles of Performance

- The Pareto Principle
 - 80% of cycles are spent in 20% of the code
 - in my experience it is more like 90% and 2%
- Performance requires real measurement
 - our intuition usually turns out to be wrong
- Performance demands eternal vigilance
 - if we aren't getting faster, we're getting slower
- Performance is mostly about design
 - code optimization is only occasionally useful

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Design for Performance

- Establish performance requirements
- Anticipate bottlenecks
 - frequent operations (interrupts, copies, updates)
 - limiting resources (network/disk bandwidth)
 - traffic concentration points (resource locks)
- Design to minimize problems
 - eliminate, reduce use, add resources
 - and, sometimes, optimize implementation
- Include performance in design reviews

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Fixing Performance Problems

- is a lot like finding and fixing a bug
 - formulate a hypothesis
 - gather data to verify your hypothesis
 - be sure you understand underlying problem
 - review proposed solutions
 - for effectiveness
 - for potential side effects
 - make simple changes, one at a time
 - re-measure to confirm effectiveness of each
- only harder

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For Next Lecture

- McConnell chapter 27, 28.3
 - good chapter on implications of program size
 - brief advice on project estimation
- Kampe: S/W Estimation Principles
 - 3 pages of basic principles
- Wikipedia: COConstructive COst MOdel
 - introduction to constructive estimation
- Peters: S/W Project Estimation
 - general discussion of project estimation
- Wiegers: Risk Assessment
 - good overview of risk assessment and management

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Supplementary Slides

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Functionality Testing

- does system function as specified?
 - test all specified functional requirements
 - these are part of the acceptance criteria
- may involve a large number of test cases
 - many may be existing unit test cases
 - may include standards conformance suites
 - may include whole-system exercises
 - may include sample scenarios
- this testing should be automated

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Robustness Testing

- introduce each specified error
 - invalid options, requests, and data
 - communications errors, resource failures, ...
- verify correct system response
 - check that system properly detects it
 - check that system properly reports it
 - check that system properly responds to it
 - check that system continues working
- this testing should be automated

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Installation Testing

- installation is functionality too
 - component install may be checked w/unit test
- whole system install also needs testing
 - follow directions and use the defaults
 - try all of the options and combinations
 - is feedback correct
 - is correct software installed correctly
 - does upgrade work (preserving old data)
- some automated testing, some manual

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Usability Testing

- most testing should be automated
 - so that it can be run frequently
 - so that it is run consistently
- this should be complemented with usage
 - users sit down and try to use the software
 - they try do do normal things
 - they try to make obvious mistakes
 - such testing turns up many problems
 - but at some point, the pay-off falls off

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Security Testing

- much of this is specified functionality
 - authentication/authorization mechanisms
 - data protection mechanisms
 - response to unauthorized requests
 - covered by automated functionality test cases
- it is also necessary to look for holes
 - design review by domain security experts
 - penetration tests by experienced hackers

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Interoperability Testing

- consider everything system depends on
 - hardware, operating system, other services
 - there are probably multiple versions of each
- consider everything system talks to
 - browsers, servers, routers, etc.
 - there are probably multiple versions of each
- we should test on all combinations
 - or one from each equivalence partition
 - defining these requires insight an experience

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Stress Testing

- bugs are often found in special cases
 - resource exhaustion, error handling
 - unlikely combinations of events
- stress tests create these continuously
 - traffic generators running at full capacity
 - with changing random mixes of requests
 - continuous error generation
 - with random error selection
- stress tests can run for days or longer
 - they shake out many hard-to-cause problems

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Load Generation

- system specifications include capacity
 - support up to 3000 transactions/second
- performance should be measured at load
 - response time a 1500 transactions/second
- many bugs involve concurrent operations
 - locking, allocate/free, protection, etc.
- these require automatic load generation
 - generate traffic of specified types
 - generate traffic at calibrated rates

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Performance Testing

- identify key performance metrics
 - throughputs, response times, capacities
 - some may be external competitive numbers
 - some may be internal assessment numbers
- define ways to measure each
 - test transactions and measurement points
- write suites to exercise and measure
 - there are often performance benchmarks
- this testing should be automated

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Performance: what to measure

- competitive performance metrics
 - used to compare competing products
 - nominal response time for simple query
 - standard transactions per second
- engineering performance metrics
 - used to spec components
 - used to analyze performance problems
 - time to perform a particular sub-operation
 - channel utilization, idle time, cycles per operation
- must be meaningful and well defined

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Perf: meaningful measurements

- measure under controlled conditions
 - on a specified platform
 - under a controlled and calibrated load
 - without other conflicting activities
- ensure validity of results
 - measuring very brief operations
 - ultra-high resolution timers
 - perform a large number of operations
 - repeatability of results
 - collect many samples, explain variations

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Execution Profiling

- automated measurement tools
 - compiler options for routine call counting
 - one counter per routine, incremented on entry
 - statistical execution sampling
 - timer interrupts execution at regular intervals
 - increment a counter in table based on PC value
 - may have configurable time/space granularity
 - tools to extract data and prepare reports
 - number of calls, time per call, percentage of time
- very useful in identifying the bottlenecks

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Execution Profiling

Simple execution profiling

%time	seconds	cum %	cum sec	procedure (file)
42.9	0.0029	42.9	0.00	printit (profsample.c)
42.9	0.0029	85.7	0.01	add_vector (profsample.c)
14.3	0.0010	100.0	0.01	mult_by_scalar (profsample.c)

Profiling with call counting

% cumulative	self	self	total			
time	seconds	seconds	calls	ms/call	ms/call	name
42.9	0.0029	0.0029	2200	0.0013	0.0013	printit
42.9	0.0058	0.0029	20	0.1450	0.1450	add_vecto
0	0.0058	0.0000	1			main
14.3	0.0068	0.0010	2	0.5000	1.2225	mult_by_scalar

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Time Stamping

- application instrumentation technique
- create a log buffer and routine
 - call log routine for all interesting events
 - routine stores time and event in a buffer
 - requires a cheap, very high resolution timer
- extract buffer, archive, mine the data
 - time required for particular operations
 - frequency of operations
 - combinations of operations
 - also useful for post-mortem analysis

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Time Stamping

Dump of simple trace log

date	time	event	sub-type
05/11/06	09:02:31.207408	packet_rcv	0x20749329
05/11/06	09:02:31.209301	packet_route	0x20749329
05/11/06	09:02:31.305208	wakeup	0x4D8C2042
05/11/06	09:02:31.401106	read_packet	0x033C2DA0
05/11/06	09:02:31.401223	read_packet	0x033C2DA0
05/11/06	09:02:31.402110	sleep	0x4D8C2042
05/11/06	09:02:31.614209	interrupt	0x00000003
05/11/06	09:02:31.614209	dispatch	0x1B0324C0
05/11/06	09:02:31.614210	intr_return	0x00000003
05/11/06	09:02:31.652303	check_queue	0x2D3F2040
05/11/06	09:02:31.652306	packet_rcv	0x20749329