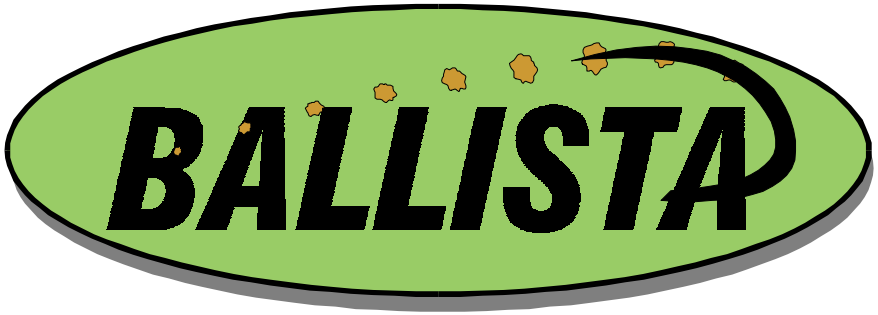
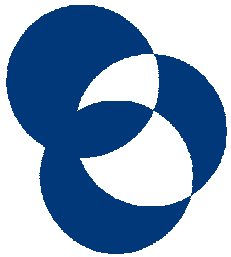
Software Robustness Testing Service



http://www.ices.cmu.edu/ballista

John P. DeVale

devale@cmu.edu - (412) 268-4264 - http://www.ece.cmu.edu/~jdevale

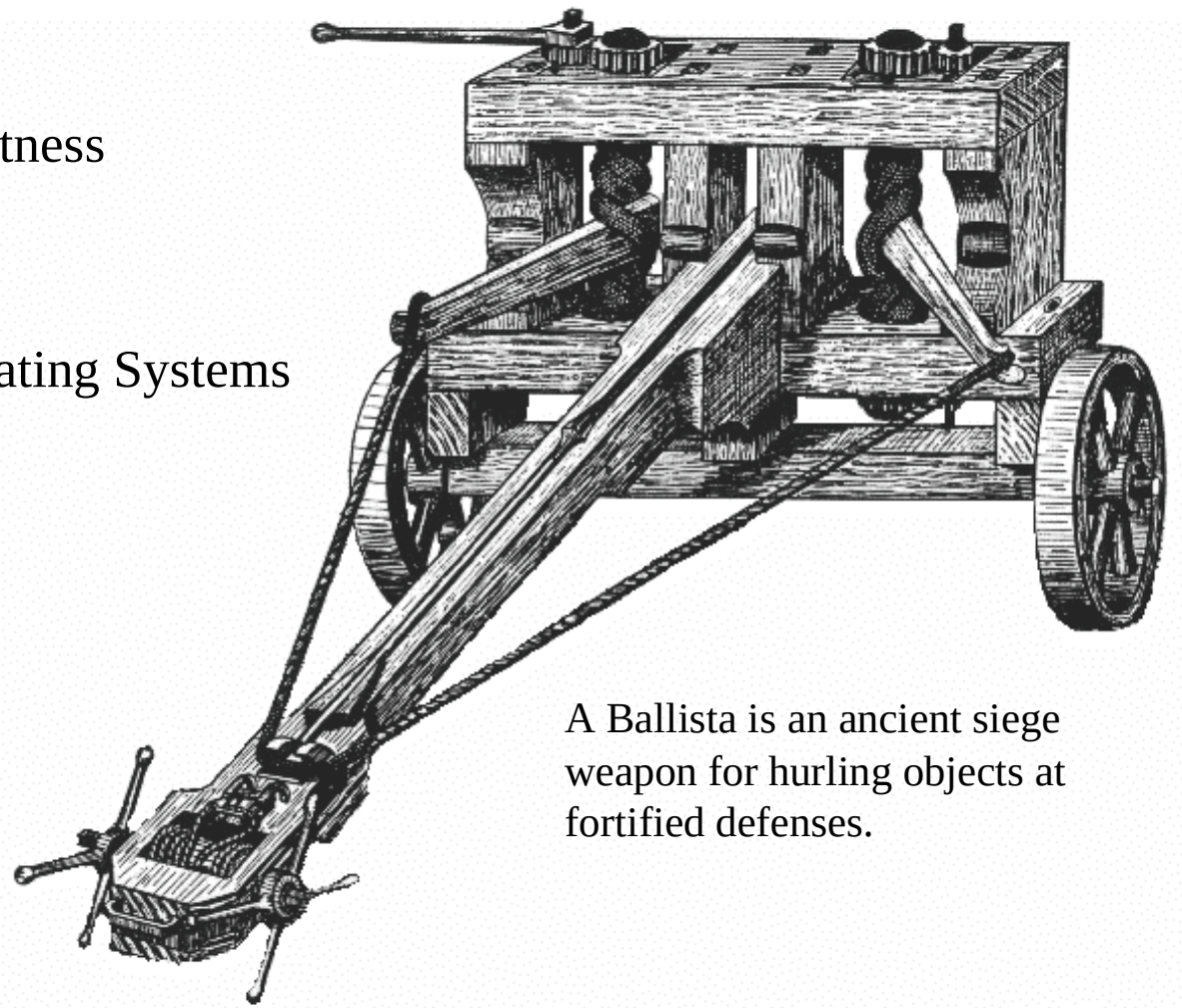


Institute for Complex Engineered Systems

Carnegie Mellon

Overview: Ballista Automated Robustness Testing

- **System Robustness**
  - Motivation
  - Ballista automatic robustness testing tool
- **OS Robustness Testing**
  - Raw results for 15 Operating Systems
- **Testing Service**
- **Conclusions**



A Ballista is an ancient siege weapon for hurling objects at fortified defenses.

BALLISTA

System Robustness

Ariane 5 Flight 501 Robustness Failure

- **June, 1996 loss of inaugural flight**
  - Lost $400 million scientific payload (the rocket was extra)
- **Efforts to reduce system costs led to the failure**
  - Re-use of Inertial Reference System software from Ariane 4
  - Improperly handled exception caused by variable overflow during new flight profile (that wasn't simulated because of cost/schedule)
    - 64-bit float converted to 16-bit int *assumed* not to overflow
    - Exception caused dual hardware shutdown (because it was assumed software doesn't fail)
- **What really happened here?**
  - **The narrow view:** it was a software bug -- fix it
    - Things like this have been happening for decades -- Apollo 11 LEM computer crashed during lunar descent
  - **The broad view:** the loss was caused by a lack of system robustness in an exceptional (unanticipated) situation
- **Our research goal: *improved system robustness***

System Robustness -- Improves Dependability

- **Graceful behavior in the presence of exceptional conditions**
  - Unexpected operating conditions
  - Activation of latent design defects

- **Robustness definition also includes operation in overloads**
  - Not in current research, but is set as an eventual goal
  - We conjecture overload robustness also hinges on exception handling

- **Current test case -- Operating Systems (POSIX API)**
  - Goal: *metric for comparative evaluation of OS robustness*
  - If a mature OS isn't "bullet-proof", what hope is there for application software?

Ballista Software Testing Heritage

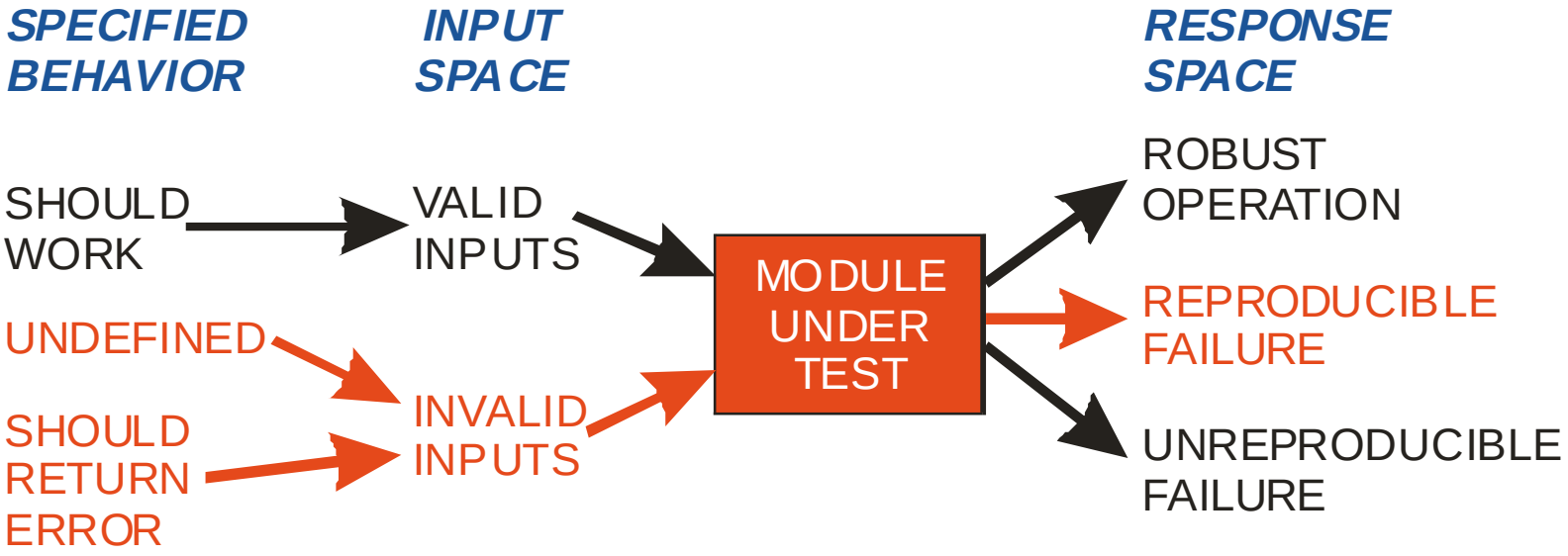
- **SW Testing requires:**
  - Test case
  - Module under test
  - *Oracle* (a "specification")

Ballista uses:

"Bad" value combinations

Module under Test

Watchdog timer/core dumps



- **Ballista combines:**
  - Domain testing ideas / Syntax testing ideas
  - In general, "dirty" testing

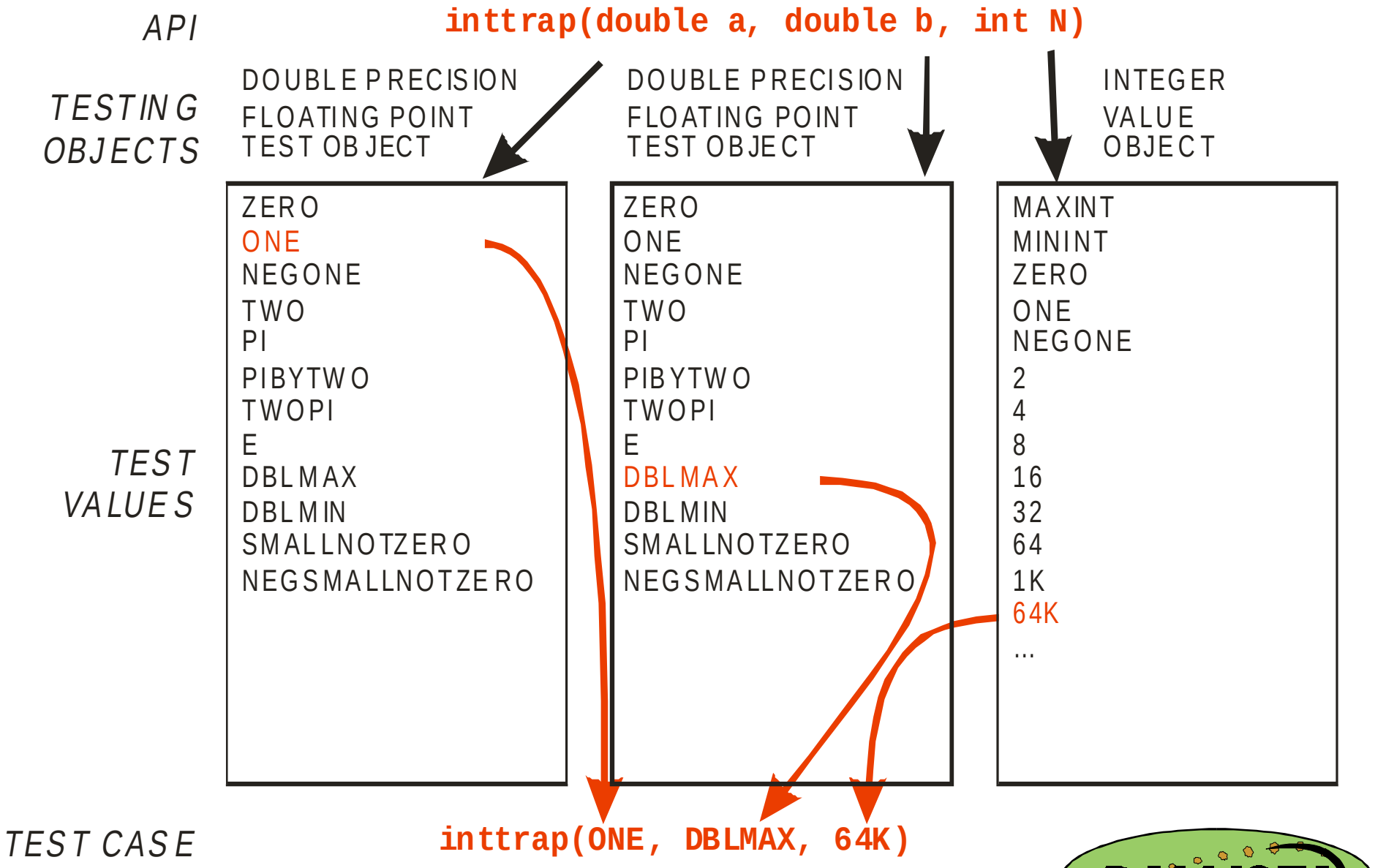
Ballista Fault Injection Heritage

Name	Method	Level	Repeatability
FIAT	Binary Image Changes	Low	High
FERRARI	Software Traps	Low	High
Crashme	Jump to Random Data	Low	Low
FTAPE	Memory/Register Alteration	Low	Medium
FAUST	Source Code Alteration	Middle	High
CMU-Crashme	Random Calls and Random Parameters	High	Low
Fuzz	Middleware/Drivers	High	Medium
Ballista	Specific Calls with Specific Parameters	High	High

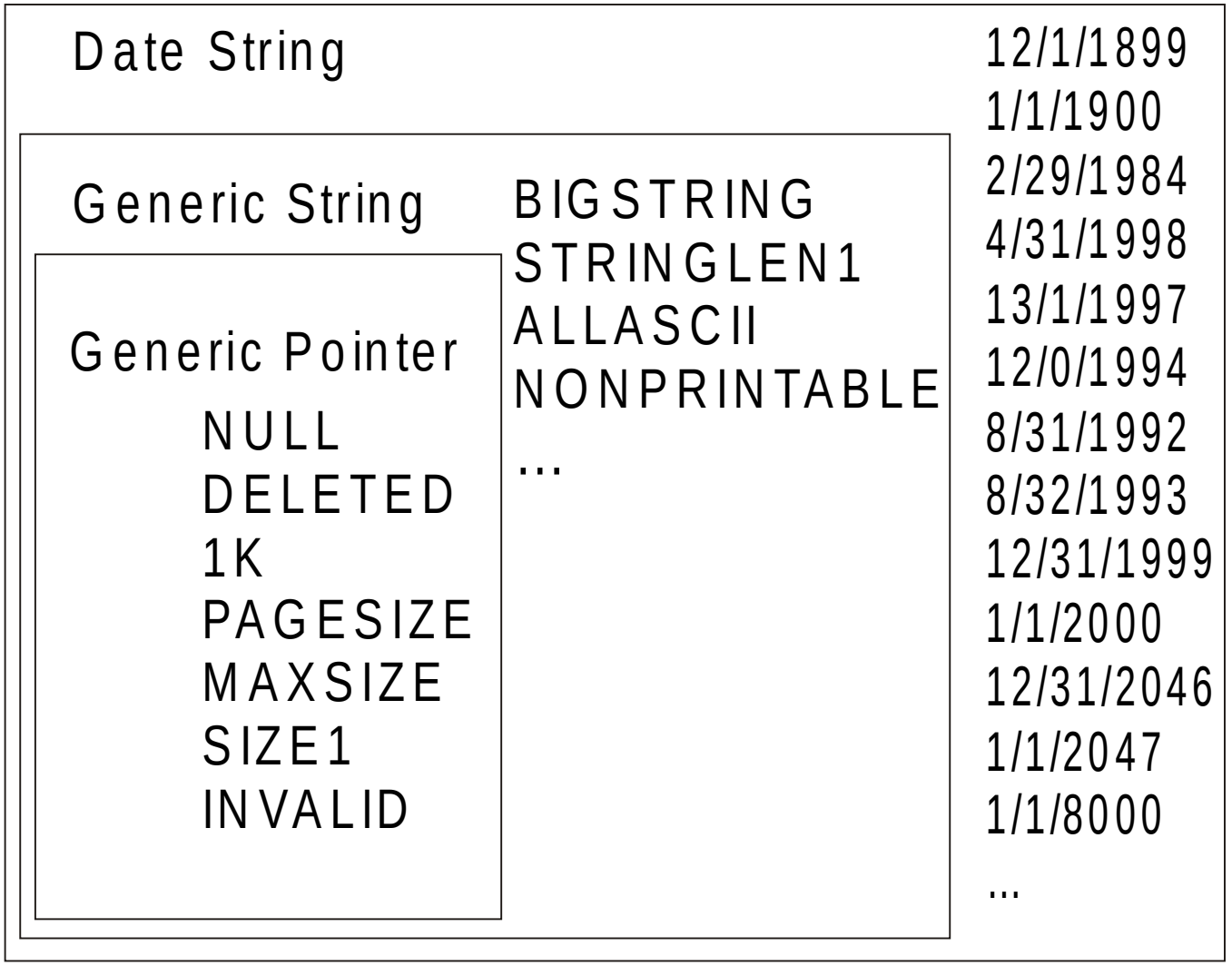
CRASH Severity Scale

- **Catastrophic**
  - Test computer crashes (both Benchmark and Starter abort or hang)
  - Irix 6.2: `munmap( malloc((1<<30)+1), ((1<<31)-1)) );`
- **Restart**
  - Benchmark process hangs, requiring restart
- **Abort**
  - Benchmark process aborts (*e.g.*, “core dump”)
- **Silent**
  - No error code generated, when one should have been (*e.g.*, de-referencing null pointer produces no error)
- **Hindering**
  - Incorrect error code generated

Ballista: Scalable Test Generation



Test Value Inheritance



Date string inherits test cases from all parents

Ballista: “High Level” + “Repeatable”

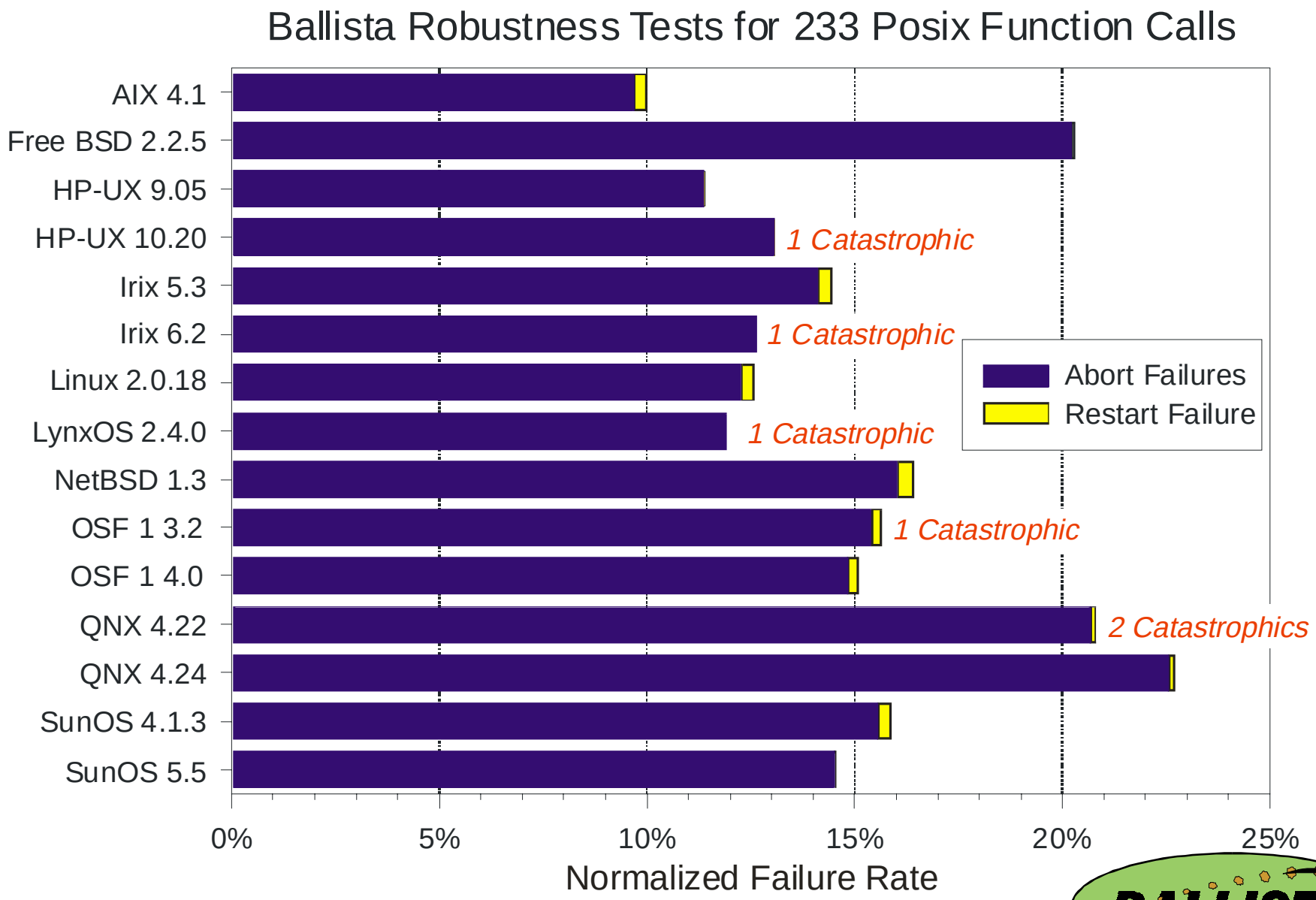
- **High level testing is done using API to perform fault injection**
  - Send exceptional values into a system through the API
    - Requires no modification to code -- only linkable object files needed
    - Can be used with any function that takes a parameter list
  - Direct testing instead of middleware injection simplifies usage

- **Each test is a specific function call with a specific set of parameters**
  - System state initialized & cleaned up for each single-call test
  - Combinations of valid and invalid parameters tried in turn
  - A “simplistic” model, but it does in fact work...

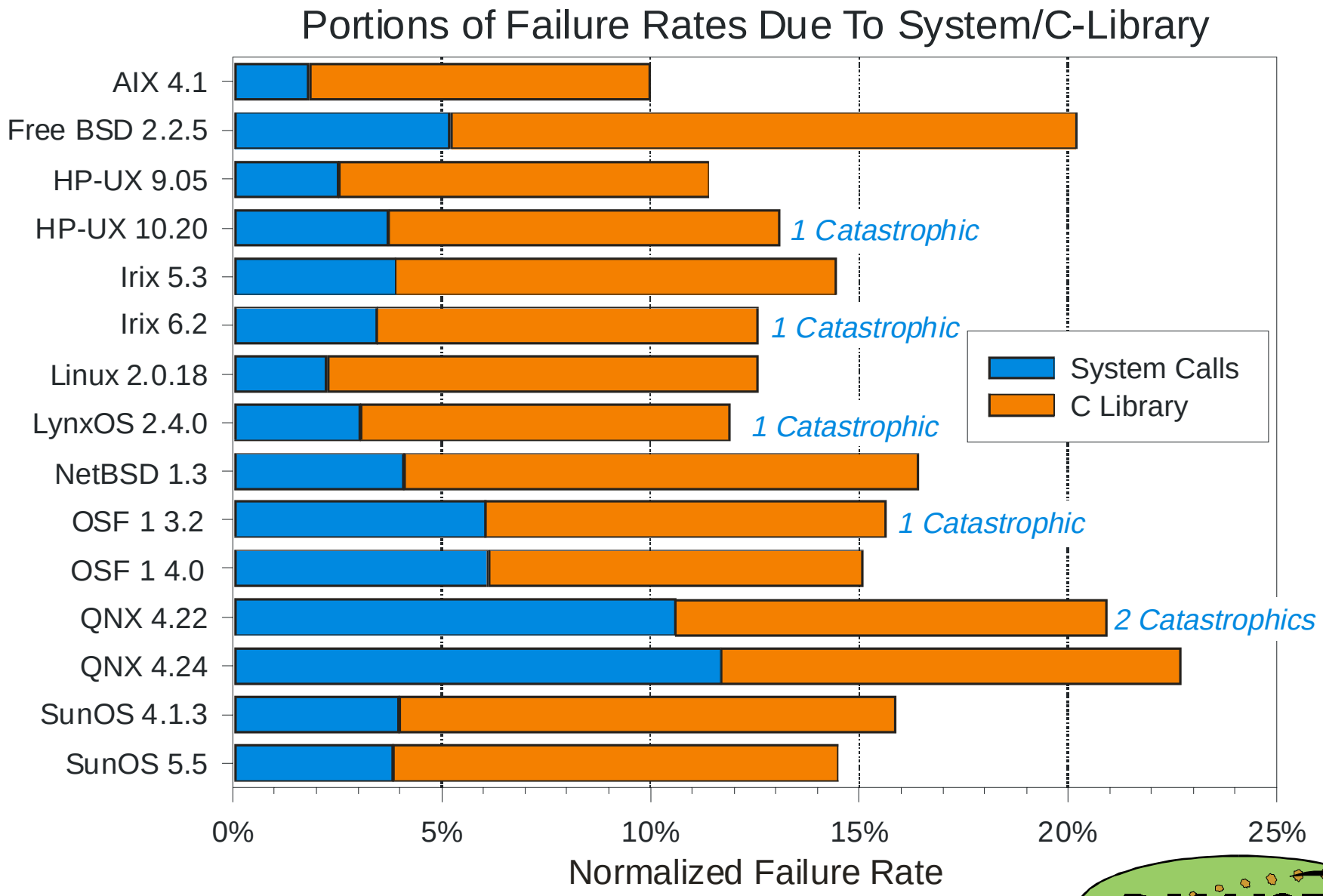
- **Early results were encouraging:**
  - Found a significant percentage of functions with robustness failures
  - Crashed systems from user mode

OS Robustness Testing

Comparing Fifteen Operating Systems



C Library Is A Potential Robustness Bottleneck



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Common Failure Sources

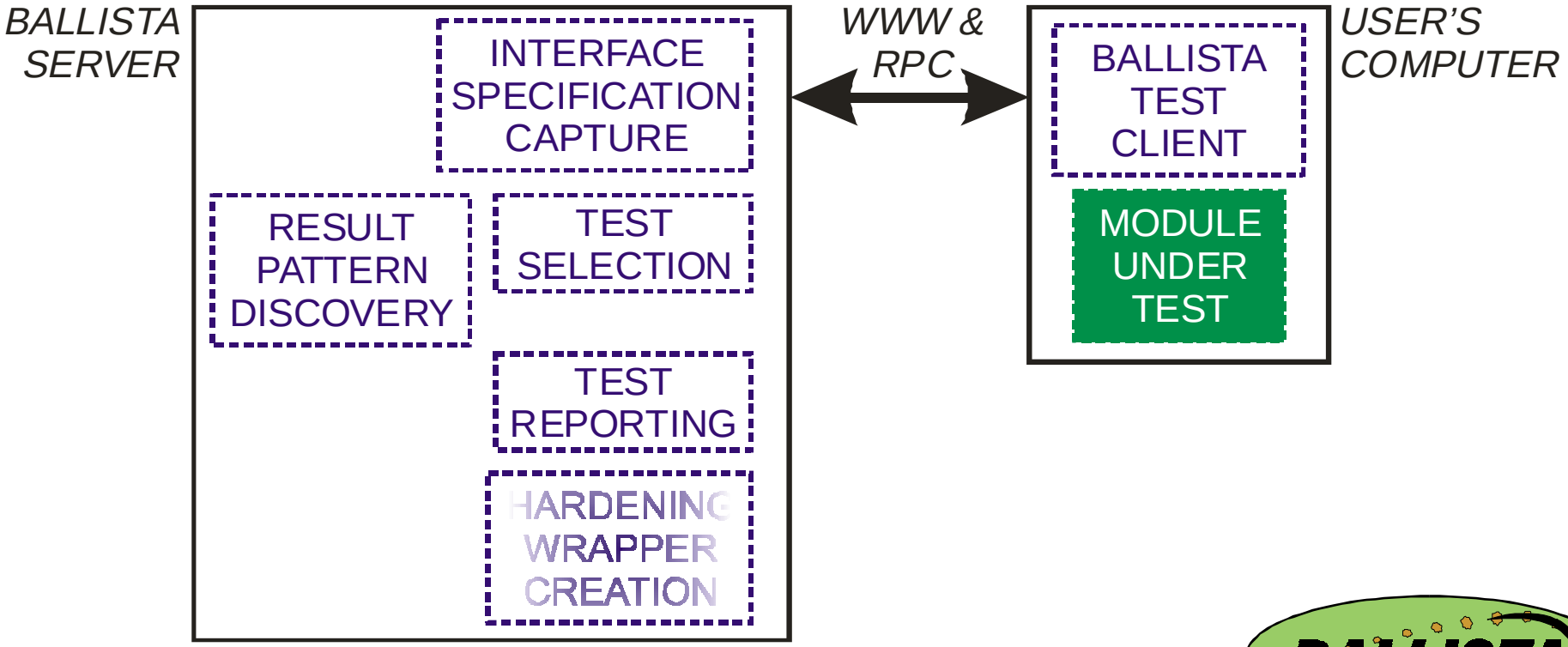
- **Based on correlation of failures to data values, not traced to causality in code**

- **Associated with a robustness failure were:**
  - 94.0% of invalid file pointers (excluding NULL)
  - 82.5% of NULL file pointers
  - 49.8% of invalid buffer pointers (excluding NULL)
  - 46.0% of NULL buffer pointers
  - 44.3% of MININT integer values
  - 36.3% of MAXINT integer values

Testing Service

Robustness Testing Service

- **Ballista Server**
  - Selects tests
  - Performs pattern Analysis
  - Generates “bug reports”
  - Never sees user’s code
- **Ballista Client**
  - Links to user’s SW under test
  - Can “teach” new data types to server (defn. language)

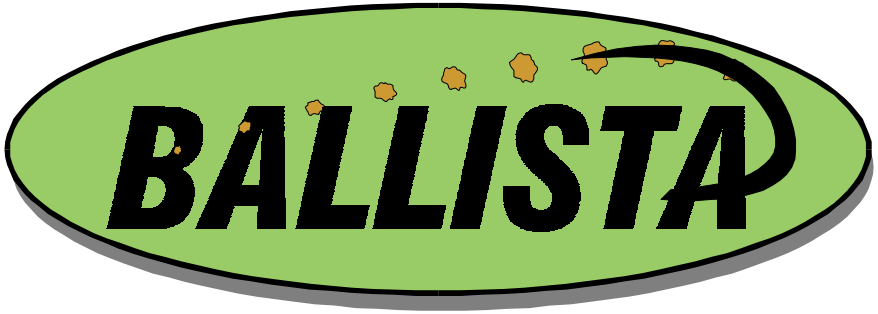


Ballista Capability Summary

- **Automated testing of software components**
  - Generically applicable to modules having parameter lists
- **Minimal knowledge of component**
  - Interface specification is typically available (data types)
  - No source code, no reverse compilation, no functional specification
- **Highly scalable**
  - Effort to create tests sub-linear with number of functions tested
  - No per-function test scaffolding
- **Repeatable results**
  - Robustness failures that are identified are repeatable on demand
  - Single-function-call failure generation
    - Creation of very simple “bug report” code
    - Makes it possible to create reasonably simple wrappers
    - Only addresses a subset of problems (but, a big subset?)

Conclusions

- **Ballista robustness testing approach**
  - Scalable, portable, reproducible
  - Can include considerable state information (although that's not obvious)
- **Also applied to DoD HLA/RTI simulation backplane**
  - C++, call-backs, client/server, throws signals for exception handling
  - Specifically written for robustness; has lower failure rates than OS code
- **Internet-based testing service available**



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