Robustness Testing of the Microsoft Win32 API

http://ballista.org

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Overview: Applying Ballista to Windows Systems

- **Introduction**
  - Motivation for measuring robustness of Windows Operating Systems
  - Ballista Testing Service

- **Running Ballista on Windows**
  - Test Development
  - Systems Tested
- **Results**
  - Catastrophic Failures (system crashes)
  - Comparing Windows and Linux
  - Restart and Abort Failures (task hangs and crashes)
  - Silent Failures
- **Conclusions and Future Work**

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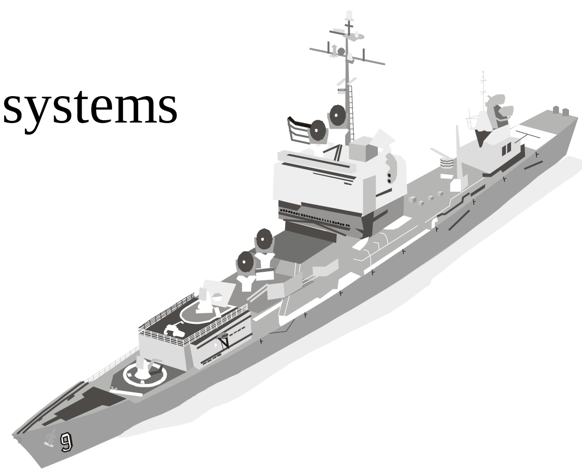
Robustness and Microsoft Windows

- **Little Quantitative data on Windows system robustness**
  - Only anecdotal evidence comparing Windows systems to POSIX systems
  - Measuring how well Windows systems handle exceptions will give us insight into its robustness
  - Specifically target Win32 API calls similar to POSIX system calls

- **Windows NT and Windows CE deployed in critical systems**
  - US Navy is moving to Windows NT as standard OS for all ship computer systems
  - Windows CE is a contender for many embedded systems
    - Emerson Electric sponsored this work

      (use Windows CE in industrial equipment?)



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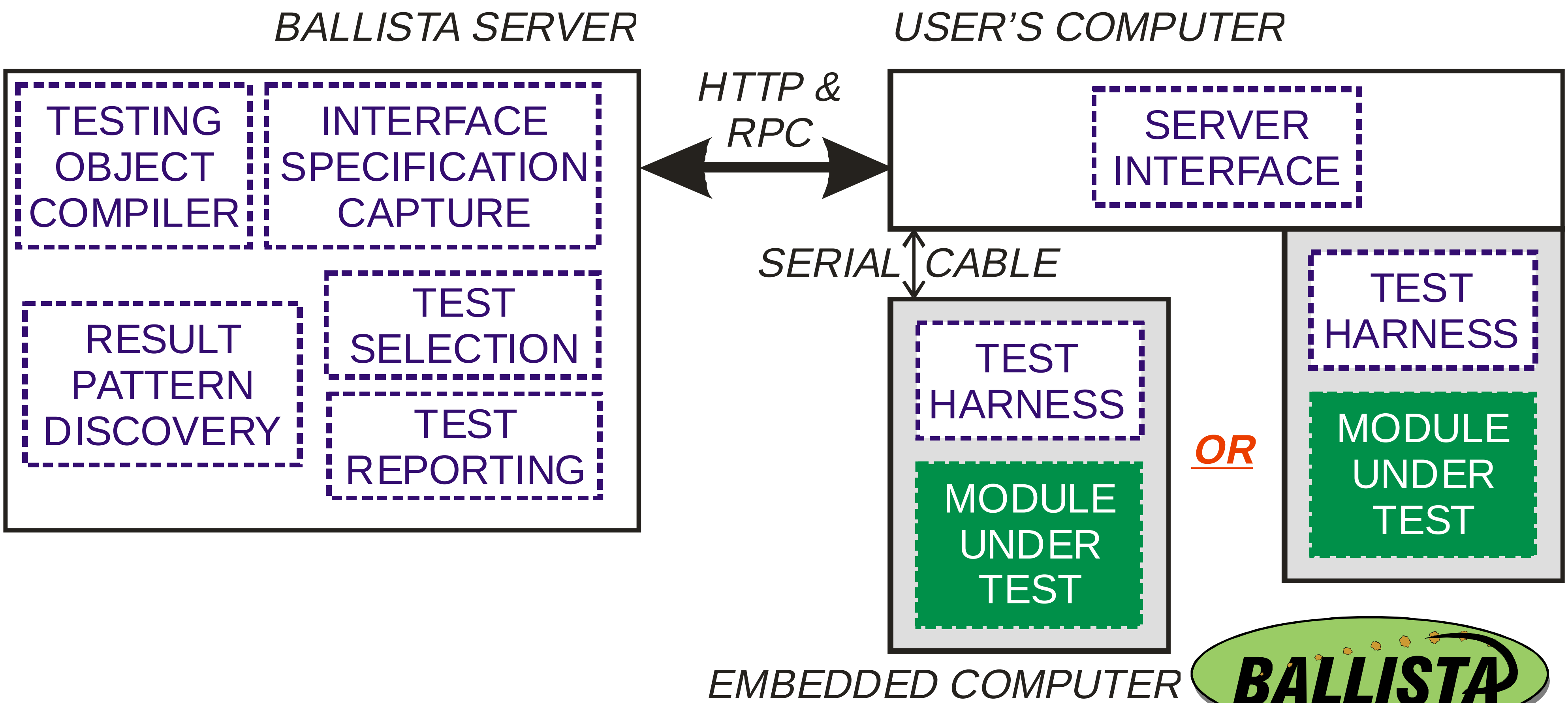
Ballista Robustness Testing Service

- **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 (definition language)



Windows Test Development

- **Start with test suite of standard UNIX datatypes**
- **The Win32 API uses many non-standard datatypes**
  - However, most of these are pointers to structures that can inherit test cases from generic pointer datatypes
  - The HANDLE datatype in Windows required the most development of new test cases
    - Win32 API uses HANDLEs for everything from file pointers to process identifiers
    - Test cases were generated to specifically exercise different uses of the HANDLE datatype
- **Test cases**
  - 1,073 distinct test values in 43 datatypes available for testing in Win32
  - 3,430 distinct test values in 37 datatypes available for testing in POSIX (2,908 of these values in two datatypes that had no analog in Windows)
  - Limit of 5,000 test cases per function
  - Over 500,000 generated test cases for each Windows variant
  - Over 350,000 generated test cases for Linux

Systems Tested

- **Desktop Windows versions on Pentium PC**
  - Windows 95 revision B
  - Windows 98 with Service Pack 1 installed
  - Windows 98 Second Edition (SE) with Service Pack 1 installed
  - Windows NT 4.0 with Service Pack 5 installed
  - Windows 2000 Beta 3 Pre-release (Build 2031)
  - 143 Win32 API calls + 94 C library functions tested

- **Windows CE**
  - Windows CE 2.11 running on a Hewlett Packard Jornada 820 Handheld PC
  - 69 Win32 API calls + 82 C library functions tested

- **POSIX System for Comparison**
  - RedHat Linux 6.0 (Kernel version 2.2.5)
  - 91 POSIX kernel calls + 94 C library functions tested

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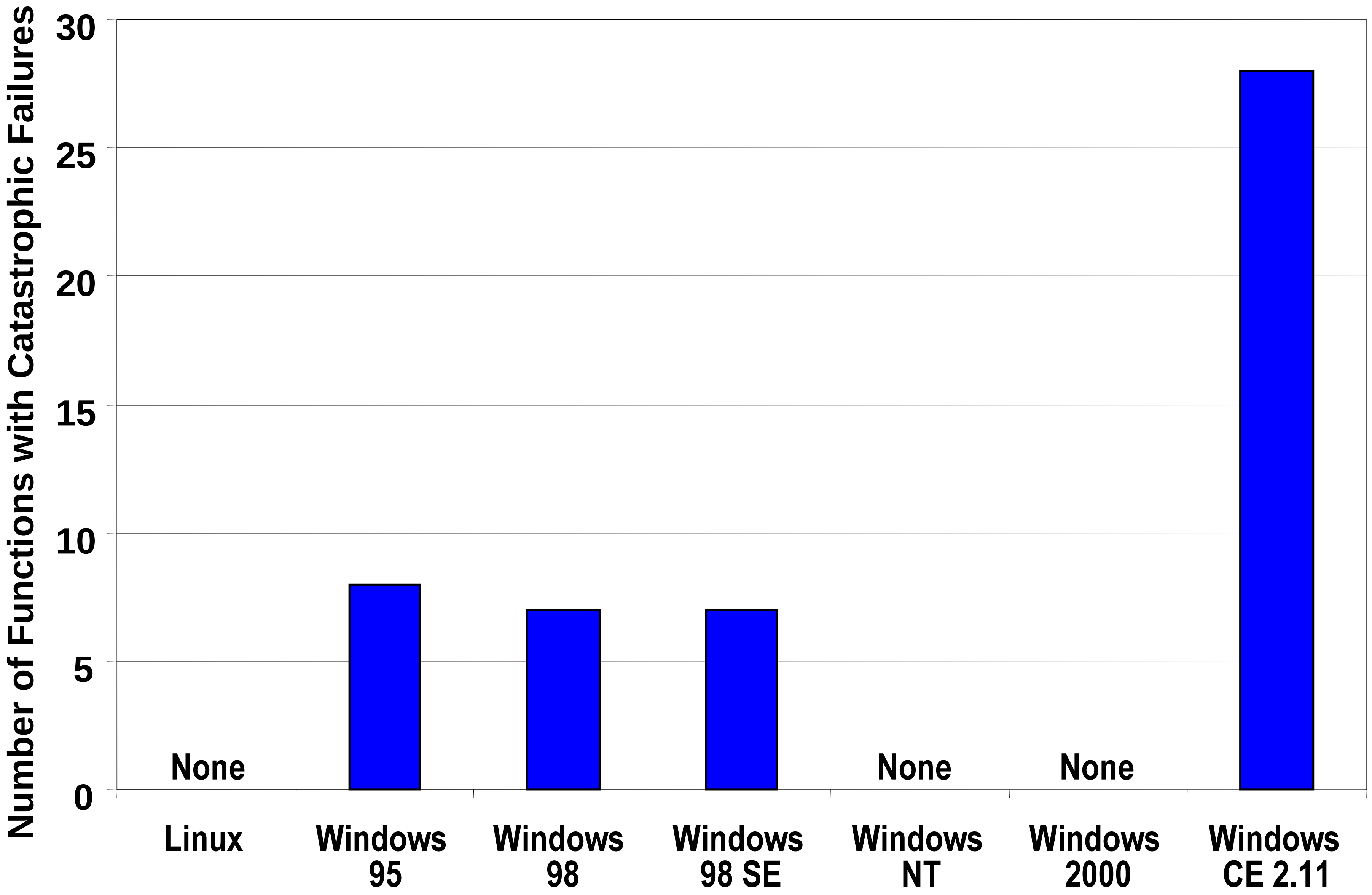
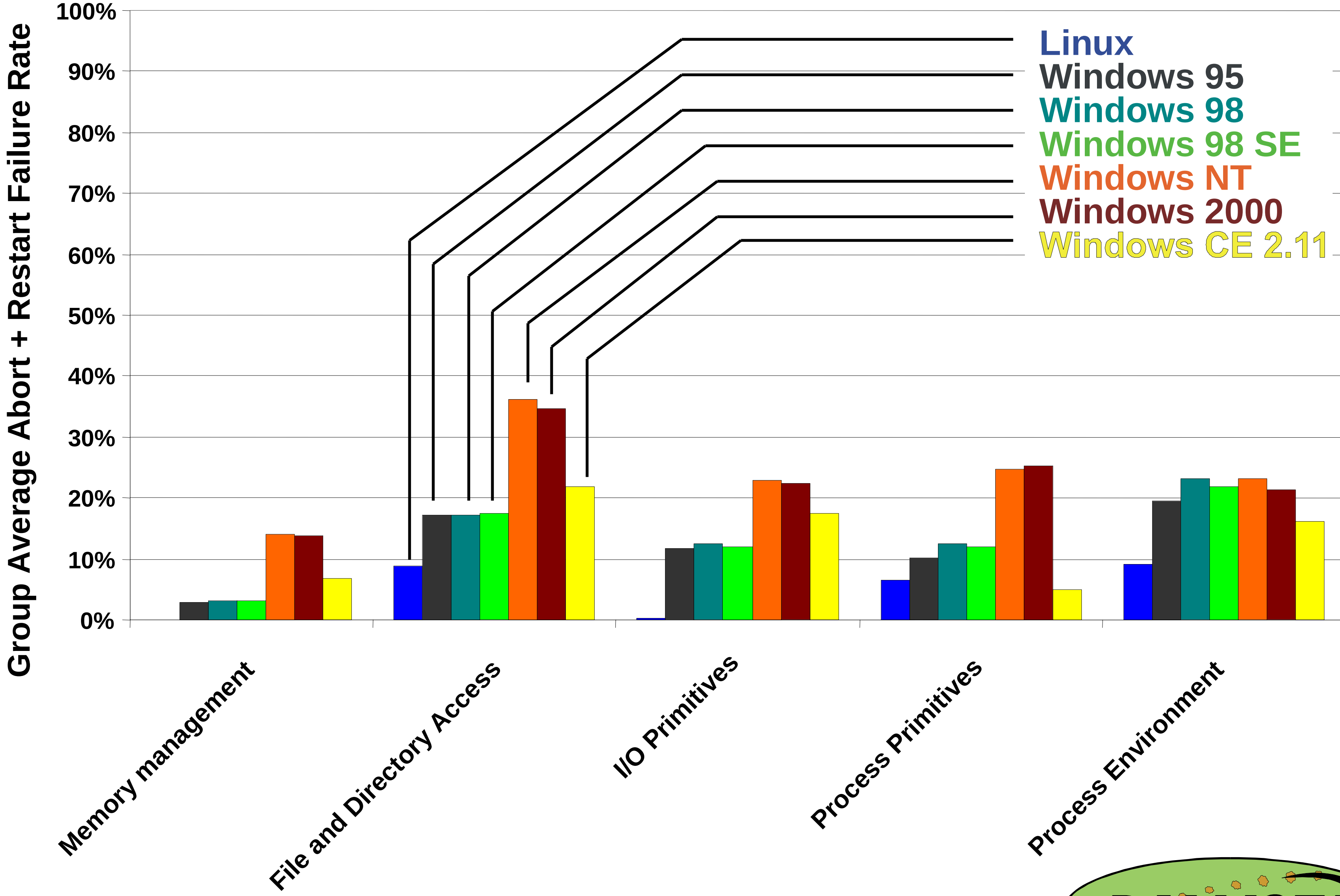
Robustness Problems Found – System Crashes



Data Analysis and Comparison

- **How do we compare robustness results of non-identical API's?**
  - Win32 API is vastly different from POSIX API
  - Windows CE only supports a fraction of entire Win32 API
- **Group functions according to services provided**
  - Groups of C library functions
  - Groups of system calls
  - Calculate percent failure rate for each function in group
  - Take average of all functions in the group to determine overall group percent failure rate
  - Windows CE notes
    - Functions in C File I/O and C Stream I/O groups have too many crashes to report failure rates in percent
    - Windows CE does not support functions in the C Time group: asctime(), ctime(), gmtime(), localtime(), mktime(), etc.

Failure Rates by Function Group – System Calls



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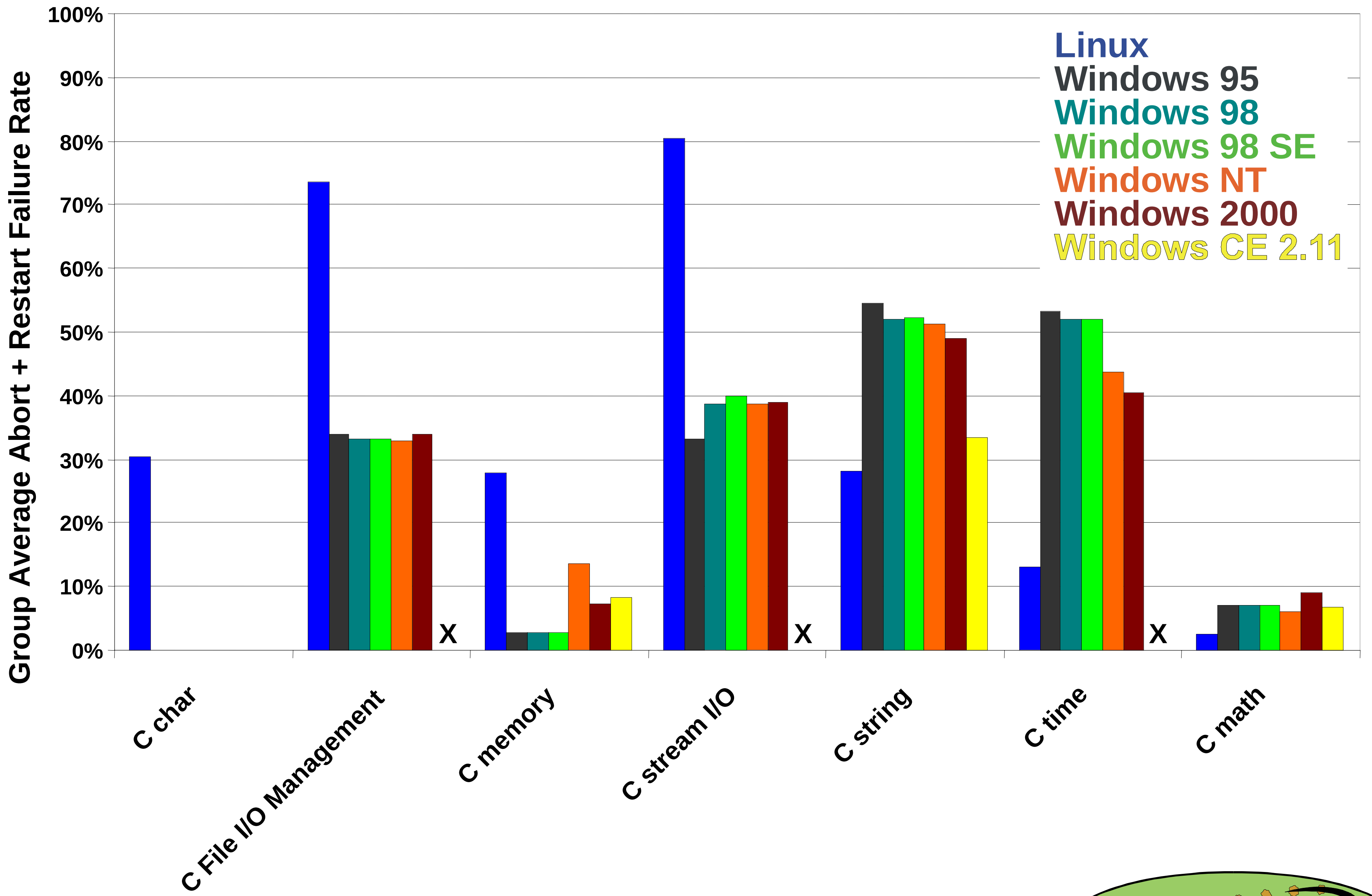
Failure Rates by Function Group – C Library



Silent Failures

- **False negative failure detection**
  - Function called with invalid parameter values but no error reported
- **Silent failures cannot be directly measured**
  - How do you declare silent failures without annotating every test case?
  - Requires an oracle for correctness testing
  - Doesn't scale
- **But they can be estimated**
  - We have several different implementations of the same API with identical test cases
    - Excludes Linux and Windows CE
  - Every test case with a "Pass" result with no error reported is a possible silent failure
  - Vote across identical test cases in different systems
    - Assumes the number of false Abort/Restart failures is not significant
    - Does not catch silent failure cases where all systems do not report an error

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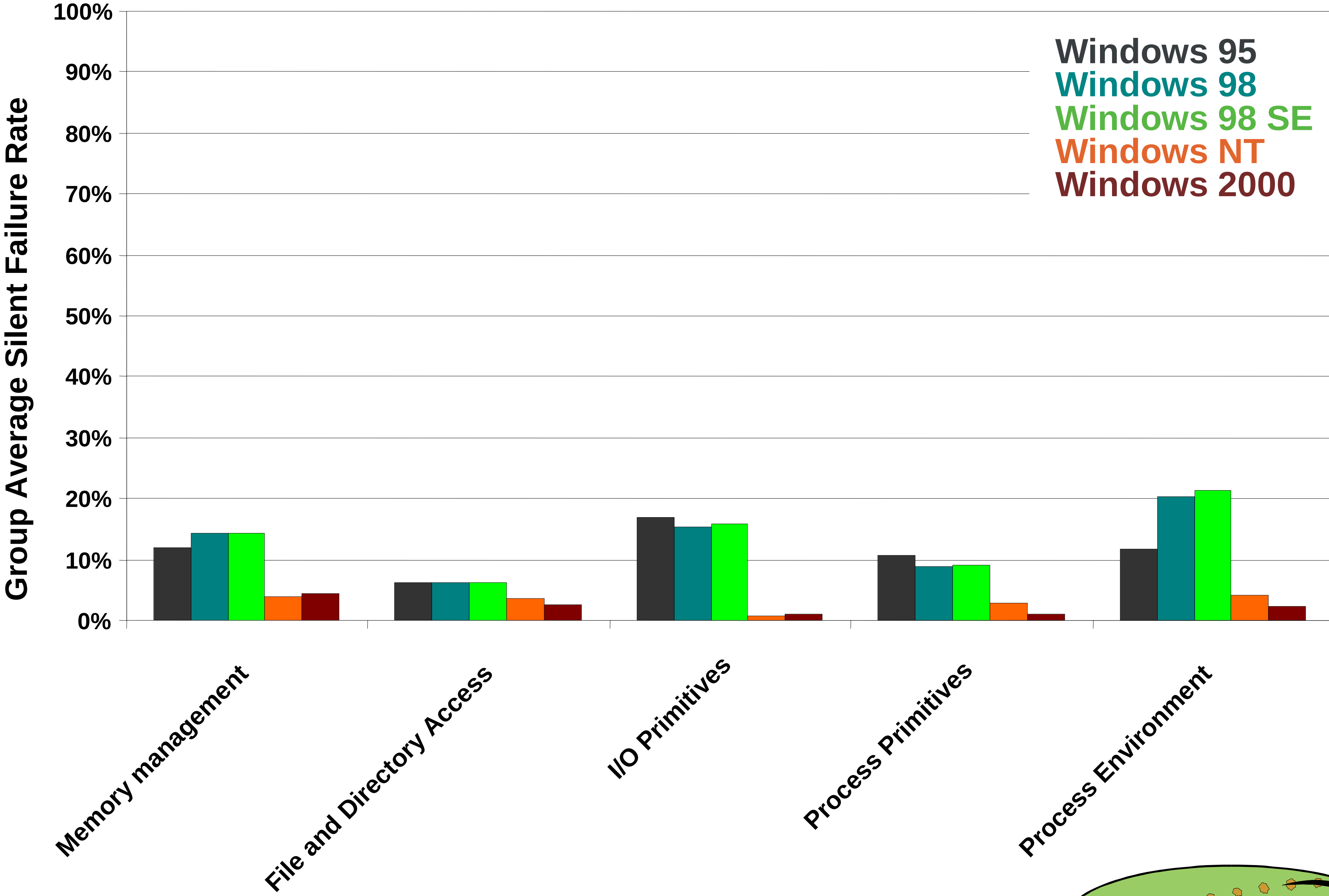
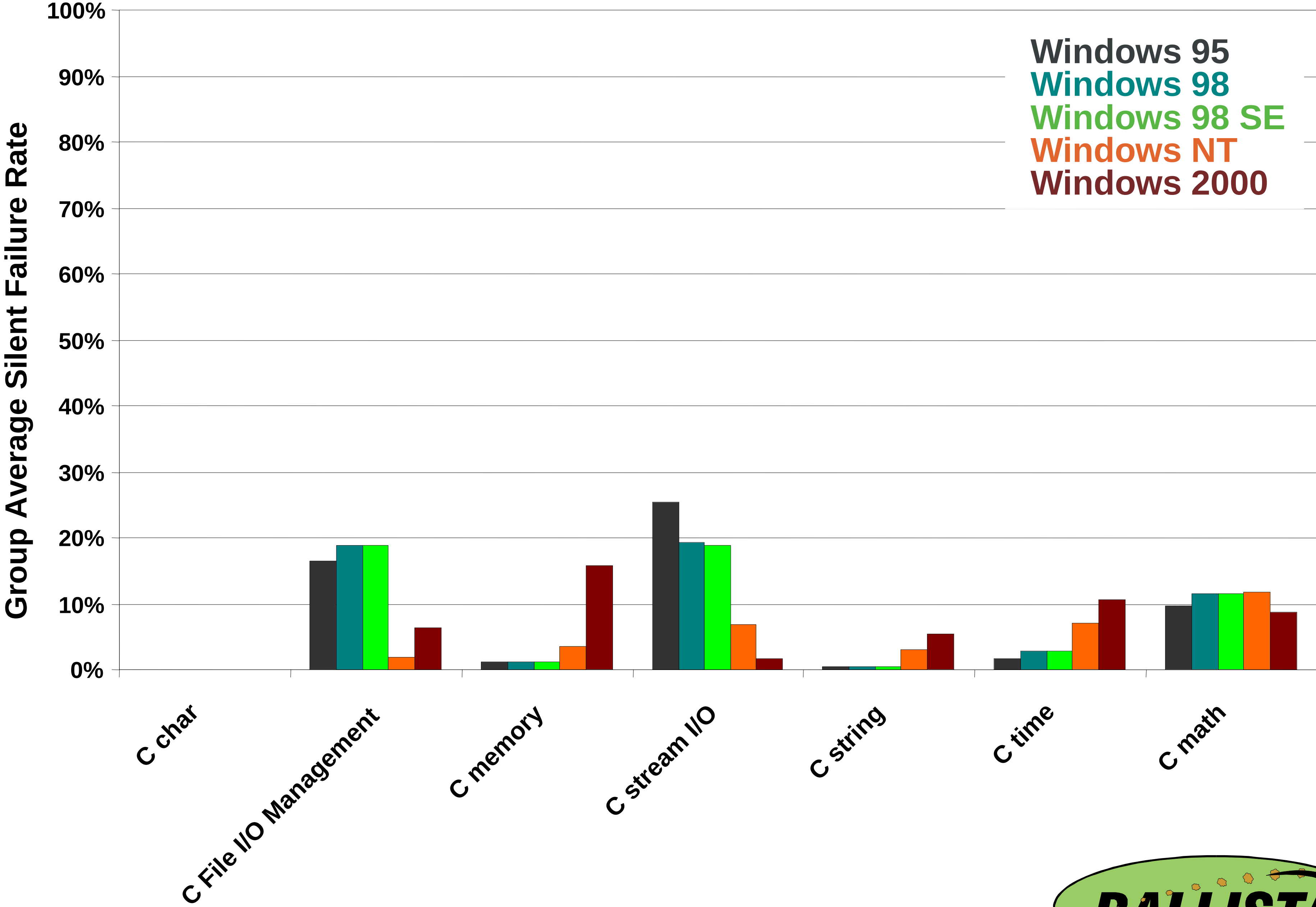
Estimated Silent Failure Rates – System Calls



Estimated Silent Failure Rates – C Library



Windows Testing Conclusions

- **Compare different API's by Functional Grouping**
  - Approximate an "apples-to-apples" comparison
  - Functional groupings identify relative problem areas

- **Linux and Windows NT/2000 seem more robust than Windows 95/98/98 SE and Windows CE**
  - Complete system crashes observed on Windows 95/98/98 SE and Windows CE; none observed on Windows NT/2000 or Linux
  - Low Abort failure rate on Win 95/98/98 SE system calls … … because of a high Silent failure rate
  - Windows CE is markedly more vulnerable to crashes

- **Comparison of Windows NT/2000 and Linux inconclusive**
  - Linux POSIX system calls generally better than Windows Win32 calls
  - Windows C library generally better than Linux / GNU C libraries

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Future Work - Microsoft Support

- **Submitted bug reports for Catastrophic failures for Windows 95/98/98 SE**
- **Will Windows ME (Millennium) fix the problems we found?**
- **Arranging to report Windows CE Catastrophic failures**
- **Heavy load testing**