CUTTING THRU THE HYPE:

An Analysis of Application Testing Methodologies, Their Effectiveness & The Corporate Illusion of Security

David Bonvillain
Neel Mehta
Jon Miller
Alex Wheeler

AGENDA

- Introduction
- Application Vulnerability Classes
- Testing Methodologies & Solutions Analysis
  - Examples
  - Strengths
  - Challenges
  - Use Cases
- Solutions
- Conclusions

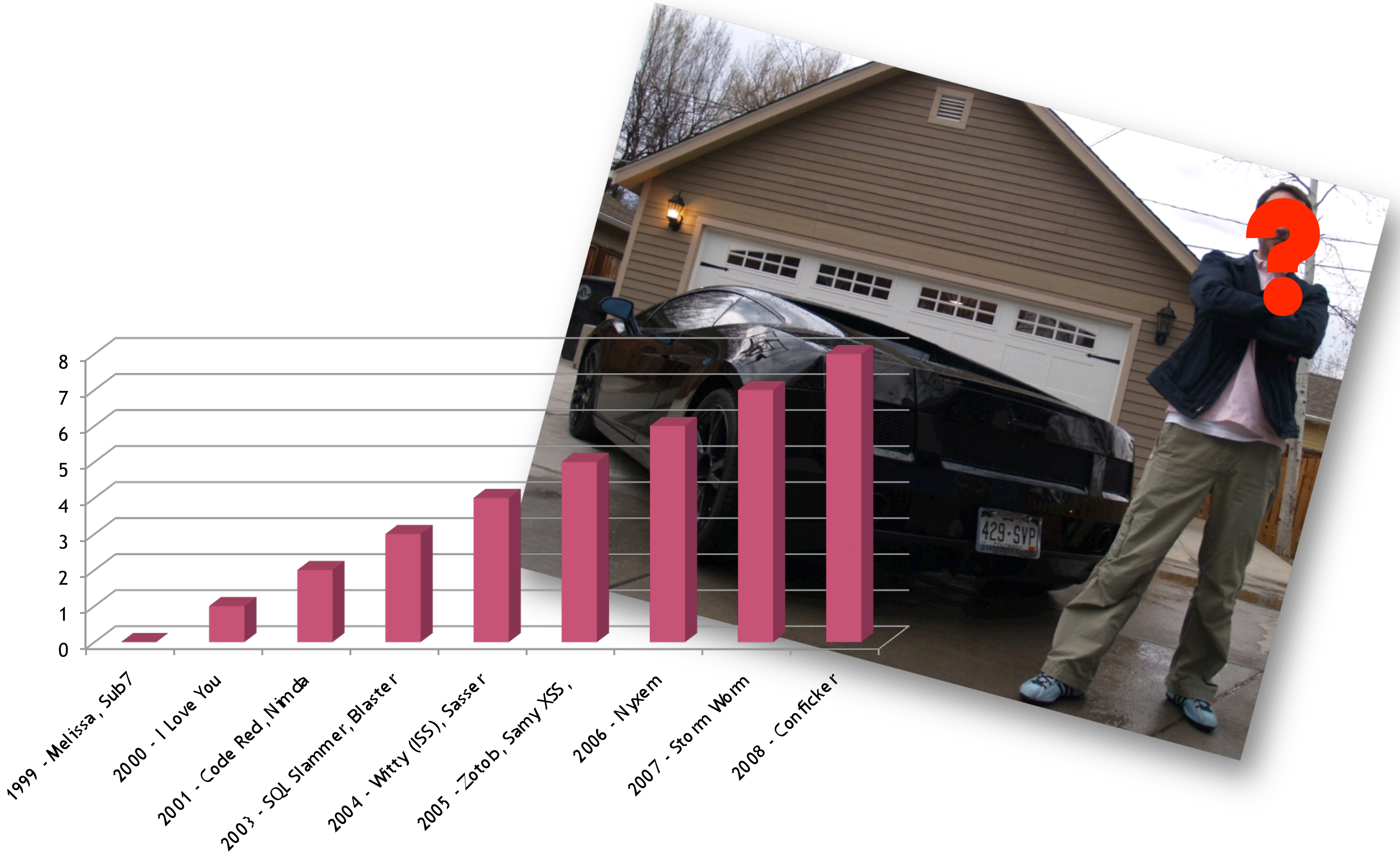
OVERVIEW

- Most organizations are implementing application security initiatives
- Wide variety of solutions and methodologies available – Many claim to 'find all the problems'
  - Application vulnerability scanning
  - Static code analysis
  - 3rd party penetration testing & app assessments
  - Binary Analysis
  - Fuzzing
  - etc.
- Which solutions find which issues? What are their strengths & weaknesses? What is the best methodology for different applications?
- General lack of knowledge & understanding…

OVERVIEW

- Reason for faults/vulnerabilities = the reason any testing solution isn't perfect
  - (some are nowhere close)
- Organizations have chosen a blind approach of "I'll fix it if it's a known issue or something in the LHF category of vulnerabilities"
- From a software builders perspective…no company has ever gone out of business due to a security issue in their product
  - Issues can cause less sales – ISS Witty Worm
  - Issues can also increase niche business space

TRENDS IN EXOTIC CARS PURCHASED BY SECURITY EXECUTIVES



THE FIGHT CLUB FORMULA

On a long enough timeline the survival rate of anything drops to zero…

Can we develop software without bugs?

-> Is it worth it to develop secure software?

-> Is it profitable to develop securely?

-> Does secure code affect the bottom line?

-> No company has gone out of business by writing insecure code

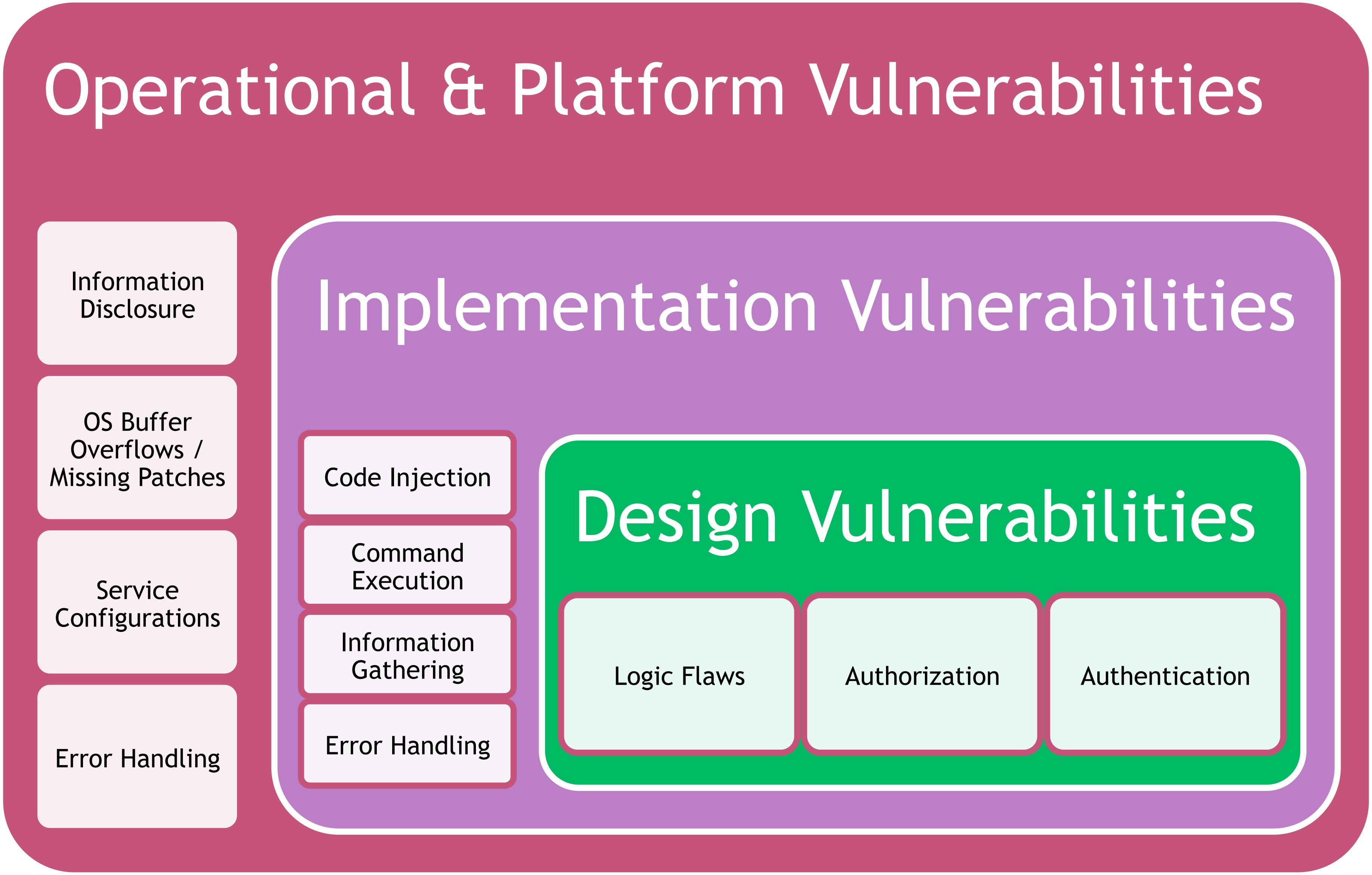
Let's examine using our version of the Fight Club formula for applications

The number of applications in the field = A
The probable rate of failure (active exploits) = B
The average cost of business loss & developing and deploying a patch = C

[A*B*C=X]

If X is less than the cost of the additional Q&A, coder training and 3rd party security audits, it financially makes more sense to distribute insecure code.

VULNERABILITY CLASSES

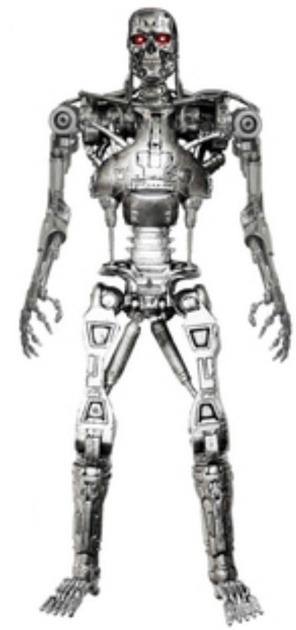


SECURITY ANALYSIS METHODOLOGY

LEVEL OF AUTOMATION

Manual

vs.

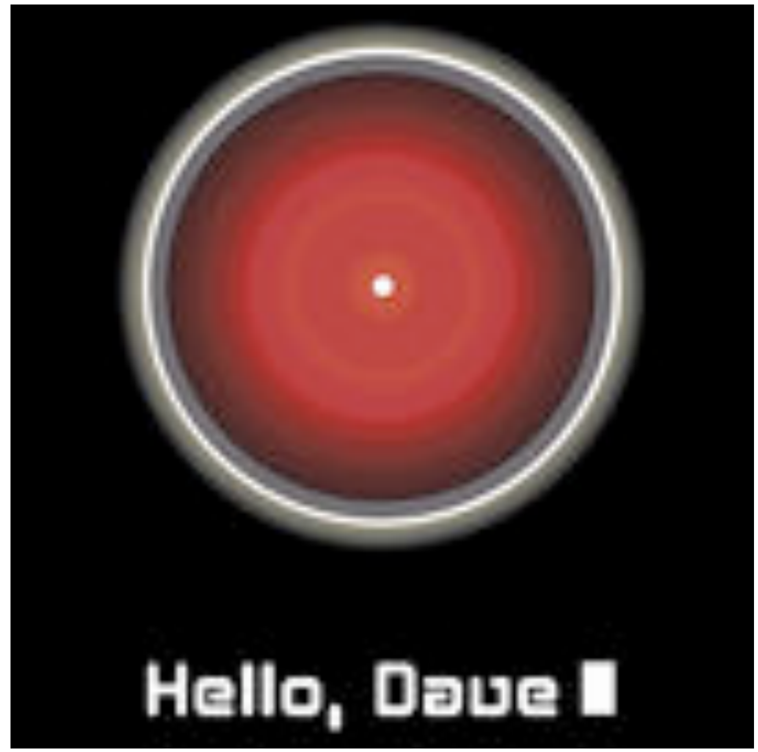


Automated

FICTION MIRRORS REALITY?

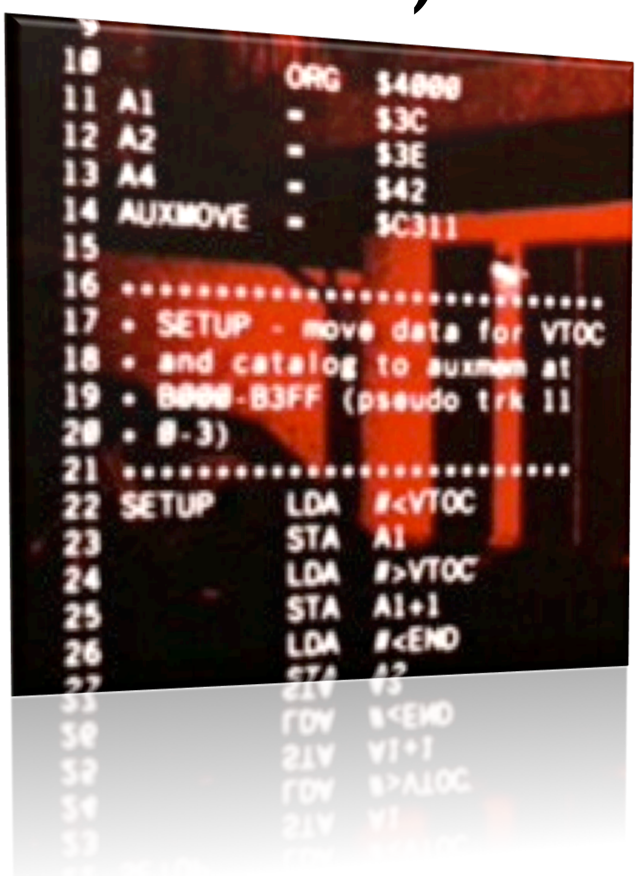
HAL: "Let me put it this way, Mr. Amor. The 9000 series is the most reliable computer ever made. No 9000 computer has ever made a mistake or distorted information. We are all, by any practical definition of the words, foolproof and incapable of error."

2001: A Space Odyssey



SECURITY ANALYSIS METHODOLOGY TARGET TESTING STATE

Static (Off-Line)



vs

Dynamic (Runtime)

CLASSIFYING SECURITY ANALYSIS METHODS
FOUR MAIN CATEGORIES

Automated Dynamic

- e.g., Fuzz Testing, Vulnerability Scanning

Automated Static

- e.g., Source/Binary Code Scanning

Manual Dynamic

- e.g., Parameter Tampering and Social Engineering

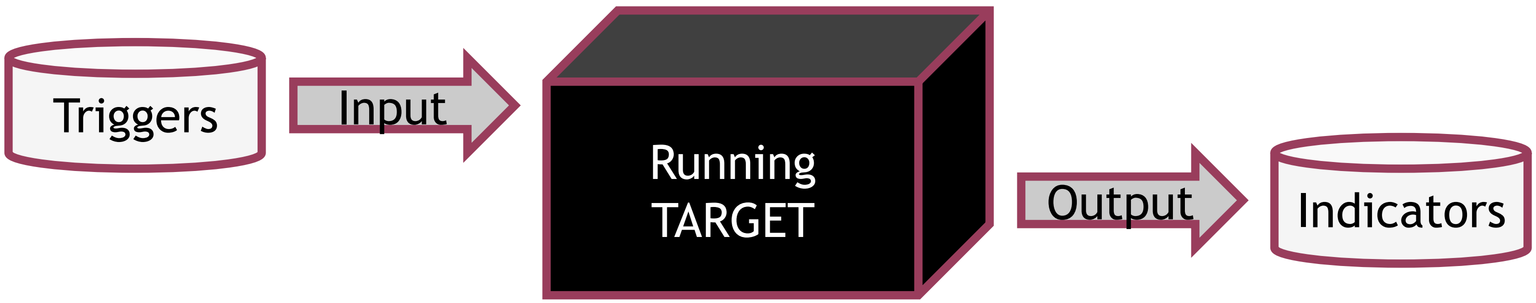
Manual Static

- e.g., Source/Binary Code Auditing

AUTOMATED DYNAMIC TESTING

AUTOMATED DYNAMIC SECURITY TESTING

Programmatic Analysis of a Runtime Target for Security Issues



Common Components:

- Trigger: inputs to invoke security issue conditions
- Indicator: anomaly evidencing security issue
- Runtime Engine: controls the firing of triggers and observing of indicators

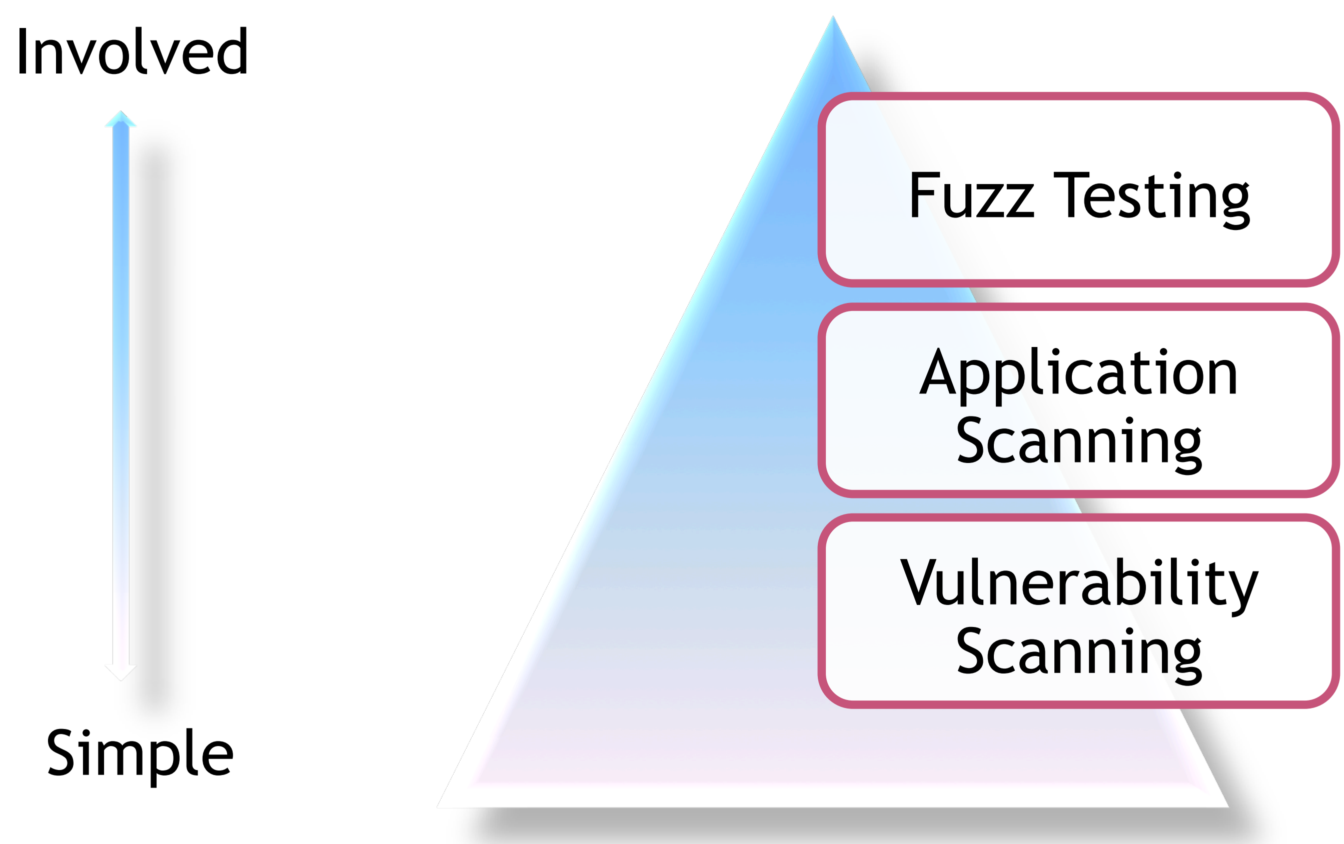
AUTOMATED DYNAMIC SECURITY TESTING EXAMPLE FORMS

- **Fuzz Testing** – Noting defects by observing failures generated by programmatically submitting arbitrary data to program inputs.

- **Vulnerability Scanning** – programmatically submitting transactions from a data set of inputs and outputs mapped to known issues.

- **Application Scanning** – A combination of both approaches, where inputs are fuzzed with data for known classes of issues.

AUTOMATED DYNAMIC SECURITY TESTING
SCALE OF COMPLEXITY FOR EXAMPLES



AUTOMATED DYNAMIC SECURITY TESTING GENERAL STRENGTHS

False Positives

- Runtime provides inherent benefits
  - Interpretation can still be an issue

Reliability & Consistency

- Programmatic approach ensures reliable and consistent application of tests (including mistakes), useful in developing baselines

Resource Requirements

- Scanning vs. Fuzz Testing

AUTOMATED DYNAMIC SECURITY TESTING GENERAL CHALLENGES

Weak Assurance (Positive & Negative)

- No Fault != No Flaw
- Unknown level of unexercised code data permutations

Unknown Level Coverage

- Only code audit can provide a baseline for measurement

Low Flexibility

- Unexpected circumstances cannot be addressed without additional programming

AUTOMATED DYNAMIC SECURITY TESTING STRONG USE CASES

Fuzz Testing

- Pre-production
- Sparsely audited code base
- Complex application input processing
- Weak, immature, or informal SDLC
- Large amount of observable indicators
- Prior runs yield numerous significant results

AUTOMATED DYNAMIC SECURITY TESTING STRONG USE CASES

Application Scanning

- Strongly typed flaw classes
- Deterministic & observable behavior
- Generally known input types
- Prior runs yield numerous significant results

Vulnerability Scanning

- Deterministic & observable behavior
- Known transaction sequences
- Strong trigger to indicator mappings

AUTOMATED DYNAMIC SECURITY TESTING WEAK USE CASES

Fuzz Testing

- Mature & widely deployed code base
- Low fault observation accuracy or ability
- Thoroughly audited code base
- Prior runs yield no significant results
- Largely unknown program inputs

AUTOMATED DYNAMIC SECURITY TESTING EXAMPLE 1

MS07-010

- Default Enabled in Vista
- Integer Overflow in Protection Engine Library PDF Parser affecting multiple products
- Simple Issue with complex data flow
- Discovered in Static Binary Analysis
  - Fuzz Testing would have needed multiple encoding support
  - Source Testing would have needed

AUTOMATED DYNAMIC SECURITY TESTING WEAK USE CASES

Application Scanning

- Substantial variability around program inputs
- Low visibility into issue indicators
- Built with non-standard/custom technology

Vulnerability Scanning

- Highly customized services environment
- Low confidence in response accuracy

AUTOMATED STATIC TESTING

AUTOMATIC STATIC ANALYSIS

- An automatic static analysis tool discovers security issues in code (src/binary), when run with minimal or no user interaction.
- Numerous commercial tools, open source tools, academic papers and work in the field of automated static analysis.
- Administrations run a quick static analysis of their application at an appropriate point in the development lifecycle, and then respond to the results.

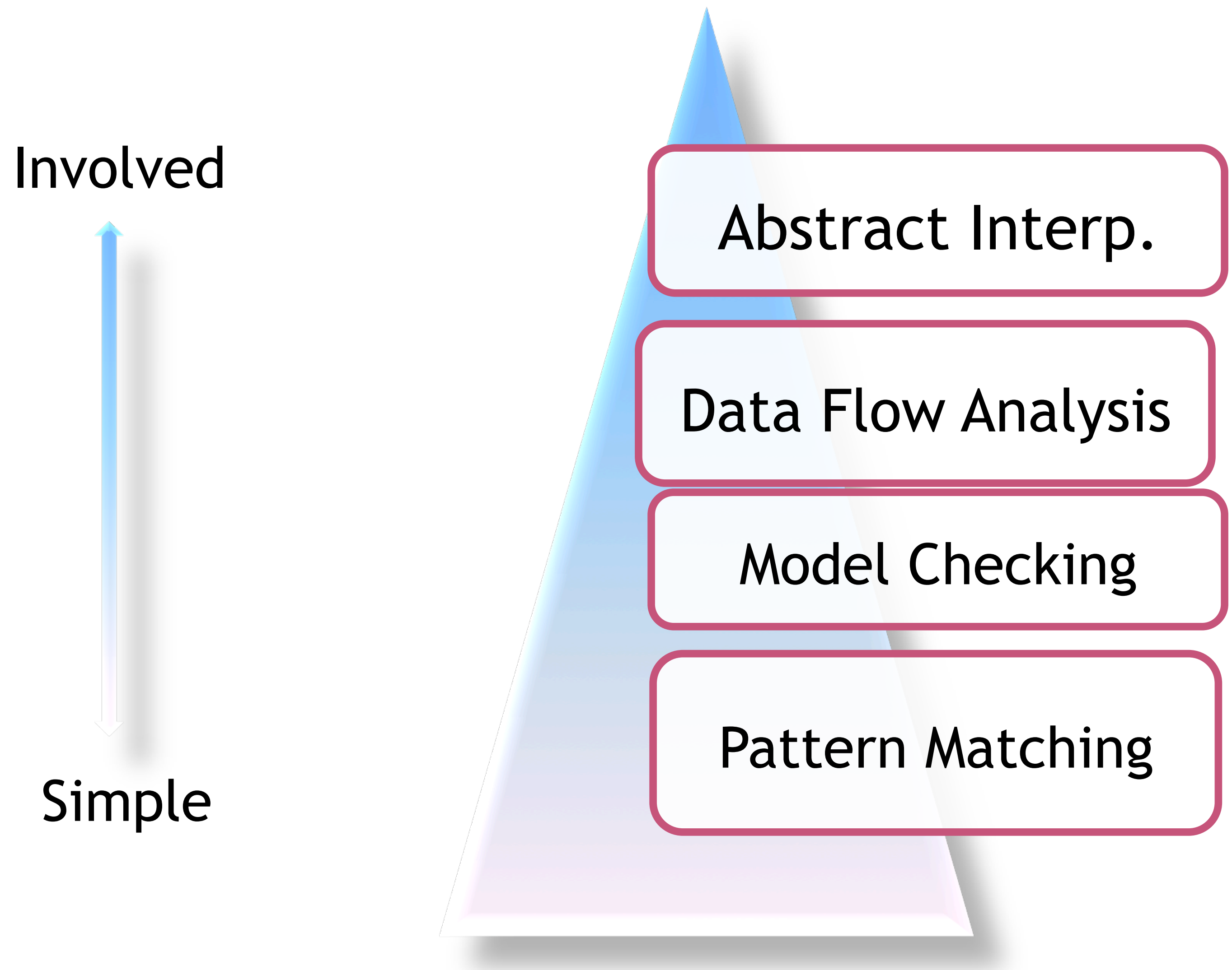
HOW TO EVALUATE AN AUTOMATED STATIC ANALYSIS TOOL

- Evaluation procedure:
  - Select a legacy version of an application (closed-src), containing known but private vulnerabilities.
  - Evaluate the coverage of the tool over known issues.
- Less fair evaluation procedure:
  - Select a current version of a widely-deployed and scrutinized application with privately known 0day issues (Apache, Firefox 3.08, etc.)
  - Evaluate their competence, relative to the state of the art attacks these applications constantly face.

EXAMPLE FORMS:

- Informal flaw identification:
  - Antiquated pattern-matching solutions (context-away or grep).
- Formal verification methods:
  - Model-checking solutions.
  - Data-flow analysis solutions.
  - Abstract interpretation-derived solutions.

AUTOMATED DYNAMIC SECURITY TESTING
SCALE OF COMPLEXITY FOR EXAMPLES



GENERAL STRENGTHS

- Locating low-context flaws:

  $my_table = $req->getParameter("unfiltered");

  $db->query("SELECT * FROM ",$my_table,"WHERE intent = "EXPOSE ALL MY DATA");

  - Quite useful if you left assessing enormous volumes of terrible code.
- Speed, human interaction:
  - Fast, little to no human interaction during scans
- Integrates well with most development life-cycles.

GENERAL CHALLENGES

- Tool-specific challenges:
  - -applications without source code, binaries without information to return to source
  - -no application support for your language
  - -SAT that are not tightly integrated with the build processes are at a disadvantage
  - -SAT applications that perform 'pseudo-compilation' are dangerously deficient and vulnerable to asymmetries
- High noise ratios :
  - Balancing false positives and negatives
  - An application that discovers 1 single serious security issue, and 10,000 non-issues is useful?
  - Tuning may help, we wish you luck.

FORMAL VERIFICATION CHALLENGES

- Two extremely high level problems, neither simple for automated SAT:

  1) Developing and correctly expressing a set of security-critical invariants, which if disproven are issues.

  - It's challenging to express high-level criteria or requirements as program invariants.
  - It is rarely easy to define all critical invariants for any sufficiently large application manually, let alone via automatic SAT.
  - Invariants are typically a large relatively static vendor-provided list, woefully limited to issues they can confidently detect.

FORMAL VERIFICATION CHALLENGES

2) Developing an interpretation of the application that lends itself to proving or disproving invariants.

- Abstract interpretation is largely a purpose-driven approach, tailored to the invariants you're looking to prove/disprove.
- Abstract interpretation to prove a single invariant might be simple, but is quickly complicated by inter-procedural analysis, undecidable data structures or storage mechanisms.
- Model checking is limited to a crippling subset of operations in any modern application.

STRONG USE CASES

- Timely, and sometimes resource-efficient detection of blatantly-simple flaws in enormous code bases.
- As part of a dev lifecycle, quickly detecting regression or re-introduction of blatantly-simple flaws.
- For applications where the risk profile is limited to none, that do not warrant alternate forms of testing.

WEAK USE CASES

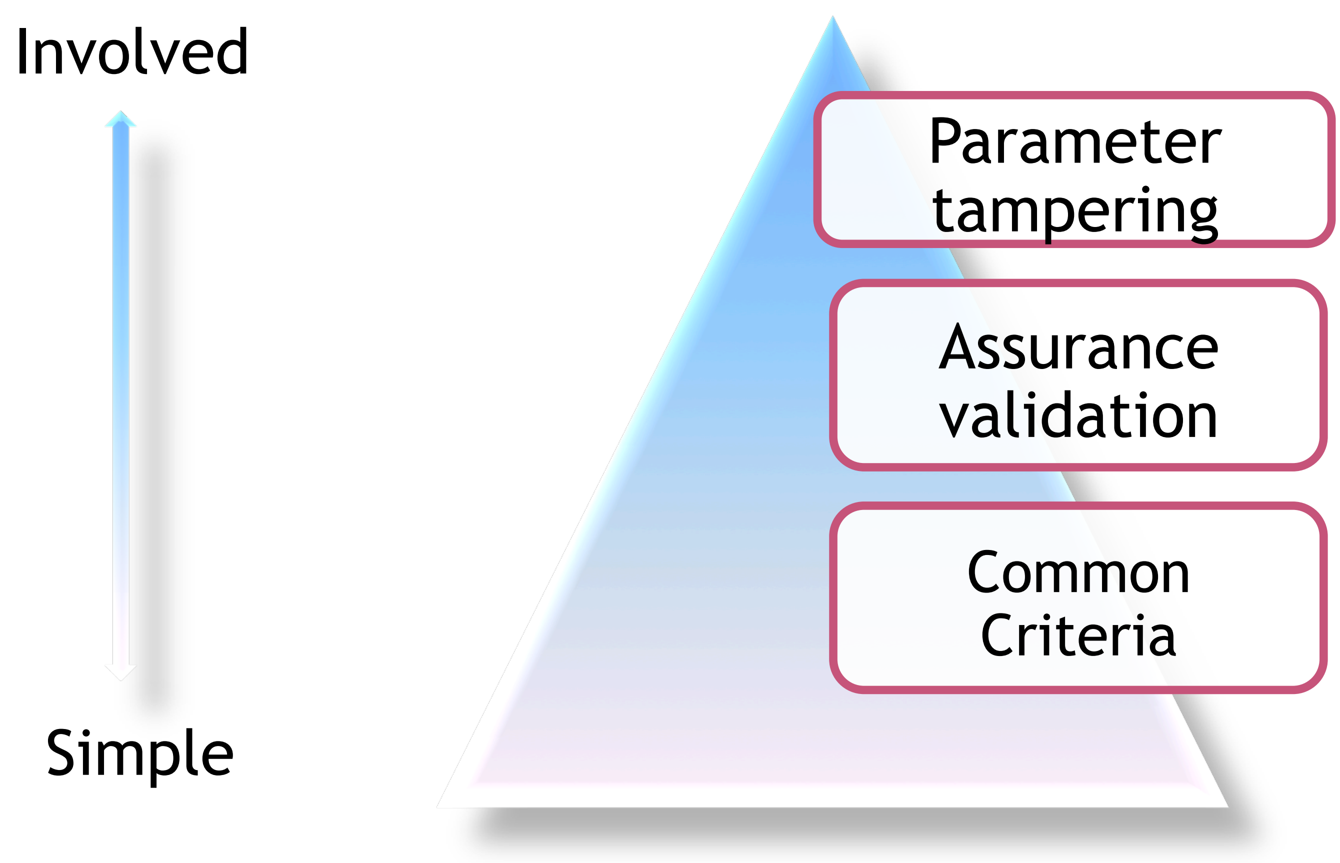
- Obtaining strong assurance about the security of a critical application in the face of a skilled and motivated attacker.
- Against a code base that has undergone any degree of more sophisticated review.
- In the hands of a developer who cannot interpret or filter reports correctly.
  - Such as when deciding to remove code with memory leaks from PRNG’s.

MANUAL DYNAMIC TESTING

MANUAL DYNAMIC TESTING

- Human-navigated application usage.
- Generally focused on one of the following:
  - Manual fuzz-testing – discovering unanticipated implementation flaws.
  - Assurance validation.
  - Verifying implementation against specification.
- Almost always aided by test tools.
- Test cases come almost exclusively from the tester.
- Critical background information provided by developers.

MANUAL DYNAMIC SECURITY TESTING SCALE OF COMPLEXITY FOR EXAMPLES



GENERAL STRENGTHS

- Draws on the intuition of the tester (capacity for parallelism in thought).
- Much of manual security testing is pattern recognition, an inherently subconscious process.
  - Innocuous, seemingly irrelevant inconsistencies often reveal large and severe underlying flaws.
- Tests live implementations, so false positives are reduced.
- Directly emulates the process of a malicious attack performed without source.

GENERAL CHALLENGES

- Can be time consuming for large and complex applications.
  - Application risk profile, relative to size of critical attack surface and complexity, must be favorable to justify in-depth testing.
- Might include a steep learning curve.
- Heavily dependent on the tester:
  - How orthogonal their security testing skillset and methodology is to the application's vulnerability set.
- Testing environment may not mirror production.

STRONG USE CASES

- A highly experienced security researcher or consultant, properly scoped:
  - High risk applications, or high-risk portions of the attack surface for larger applications.
- Especially critical to use manual dynamic testing in cases where:
  - Attackers are expected to be blindly attacking a high-risk application.
  - Results of test cases that fail cannot be easily identified through automated testing.
  - An application that is inherently risky will almost always require this form of testing (especially new and untested technologies).

WEAK USE CASES

- Applications with limited or no feedback, or asynchronous feedback
- The wrong tester, or the wrong application for the tester
- Cases where the requirements of an assessment doesn’t match the expected risk profile for an application

EXAMPLE 1 - MANUAL DYNAMIC

- SSH CRC32 Compensation Attack (CVE-2001-1044) – Discovered by Michal Zalewski:
- From Bugtraq post Feb. 2001:

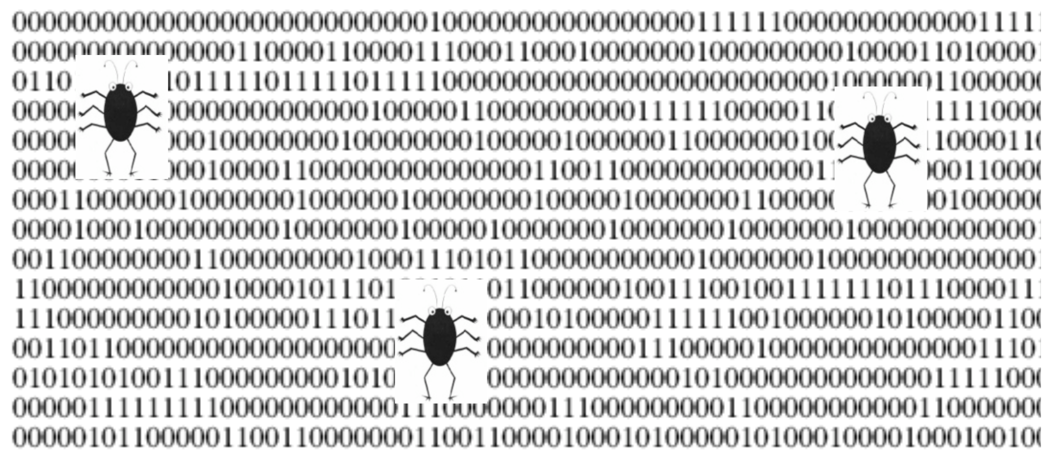
$ ssh -v -l `perl -e '{print "A"x88000}'` localhost

- Remote, pre-authentication, default remote vulnerability in SSH.COM and OpenSSH daemons, at the peak of their usage.
- Actual issue:
  - 16-bit integer truncation deep in code designed to correct a less serious protocol weakness.
  - Extremely subtle for the time, and unlikely to be found by other methods.

MANUAL STATIC TESTING

MANUAL STATIC SECURITY TESTING

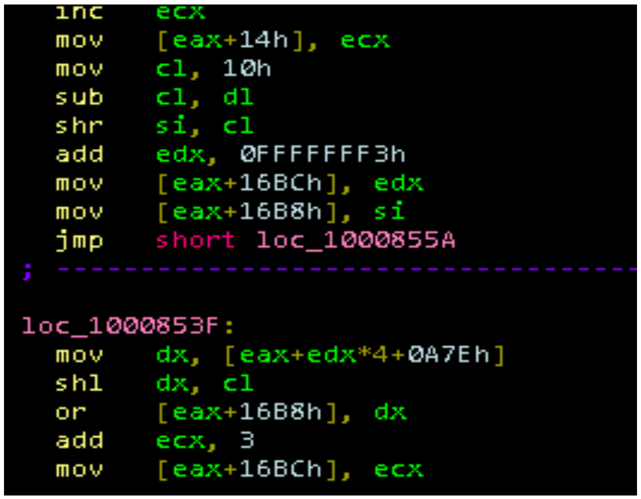
Human Review of a Non-Running Target for Security Issues



Common Components:

- Target documentation (architecture, implementation, configuration)
- Offline toolset (code browser, disassembler, graphing tools)

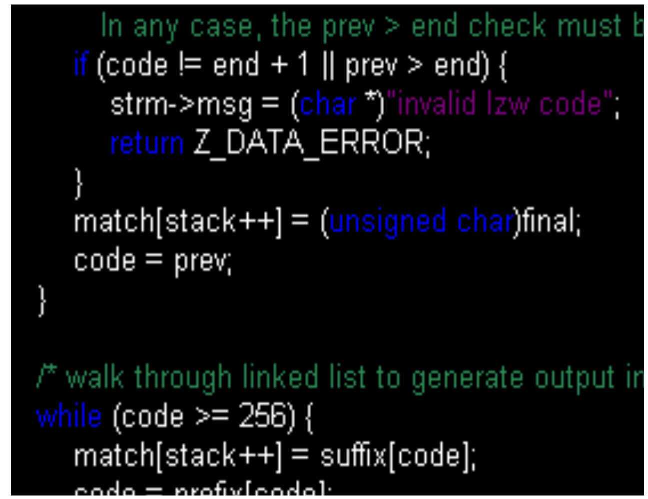
MANUAL STATIC SECURITY ANALYSIS EXAMPLE FORMS



```
  inc    ecx
  mov    [eax+14h], ecx
  mov    cl, 10h
  sub    cl, dl
  shr    si, cl
  add    edx, 0FFFFFFF3h
  mov    [eax+16BCh], edx
  mov    [eax+16B8h], si
  jmp    short loc_1000855A
; ---------------------------------

loc_1000853F:
  mov    dx, [eax+edx*4+0A7Eh]
  shl    dx, cl
  or     [eax+16B8h], dx
  add    ecx, 3
  mov    [eax+16BCh], ecx
```

Binary Code Audit



```
      In any case, the prev > end check must b
    if (code != end + 1 || prev > end) {
        strm->msg = (char *)"invalid lzw code";
        return Z_DATA_ERROR;
    }
    match[stack++] = (unsigned char)final;
    code = prev;
}

/* walk through linked list to generate output in
while (code >= 256) {
    match[stack++] = suffix[code];
```

Source Code Audit

```
lp:*:4:7:lp:/var/spool/lpd:
sync:*:5:0:sync:/sbin:/bin/sync
shutdown:*:6:0:shutdown:/sbin:/sbin/shutdown
halt:*:7:0:halt:/sbin:/sbin/halt
mail:*:8:12:mail:/var/spool/mail:
news:*:9:13:news:/var/spool/news:
```

Configuration Audit

MANUAL STATIC SECURITY ANALYSIS GENERAL STRENGTHS

Strong Assurance Potential

- Known data and code points allow baseline

High Coverage Potential

- Without resource considerations

Flexibility

- Adaptable skill & tool set

MANUAL STATIC SECURITY ANALYSIS GENERAL CHALLENGES

Accuracy Issues

- False positives: without verification step, many issues cannot be triggered
- Missing: humans make mistakes

High Resource Requirements

- Skill-based methodology, with high demand

High Error Factor

- Same factors introducing flaws are also at work here

Inconsistency

- Same auditor may miss or hit the same flaw on different days.

MANUAL STATIC SECURITY ANALYSIS STRONG USE CASES

Manual Code Audit

- Access to overlapping skilled resources for repeat engagements
- Prior automated tests returned only minor findings
- Largely non-standard/custom program inputs

MANUAL STATIC SECURITY ANALYSIS STRONG USE CASES

Configuration Review

- Low risk of setting values changing in runtime (e.g., malware or backdoor)
- Largely known data sources and formatings
- Availability of job aids for reduction of effort (e.g., grep, work plans, or checklists)

MANUAL STATIC SECURITY ANALYSIS EXAMPLE 1: MS08-001

```
struct igmp_report
{
   __u8 type;
   __u8 resv1;
   __be16 csum;
   __be16 resv2;
   __be16 ngrec;
   struct igmpv3_grec grec[0];
};
```

MANUAL STATIC SECURITY ANALYSIS EXAMPLE 1: MS08-001 CONTINUED

```
Generate_Report ( … )
   igmp_report *report = arg_0;
   SLIST  *addrlist = arg_4;
   unsigned short cnt;


   for(addrlist = addrlist->nxt, cnt=0; report->nxt; cnt++);

   report = malloc(cnt*sizeof(report->ngrec)
   +sizeof(*report));

   for(addrlist = addrlist->nxt, cnt=0; report->nxt; cnt++)
         memcpy(report->ngrec+cnt, addrlist, 4)
```

STATISTICAL ANALYSIS OF METHODOLOGIES

WASC Statistics Project: Consolidated analysis of common vulnerabilities across a variety of web applications

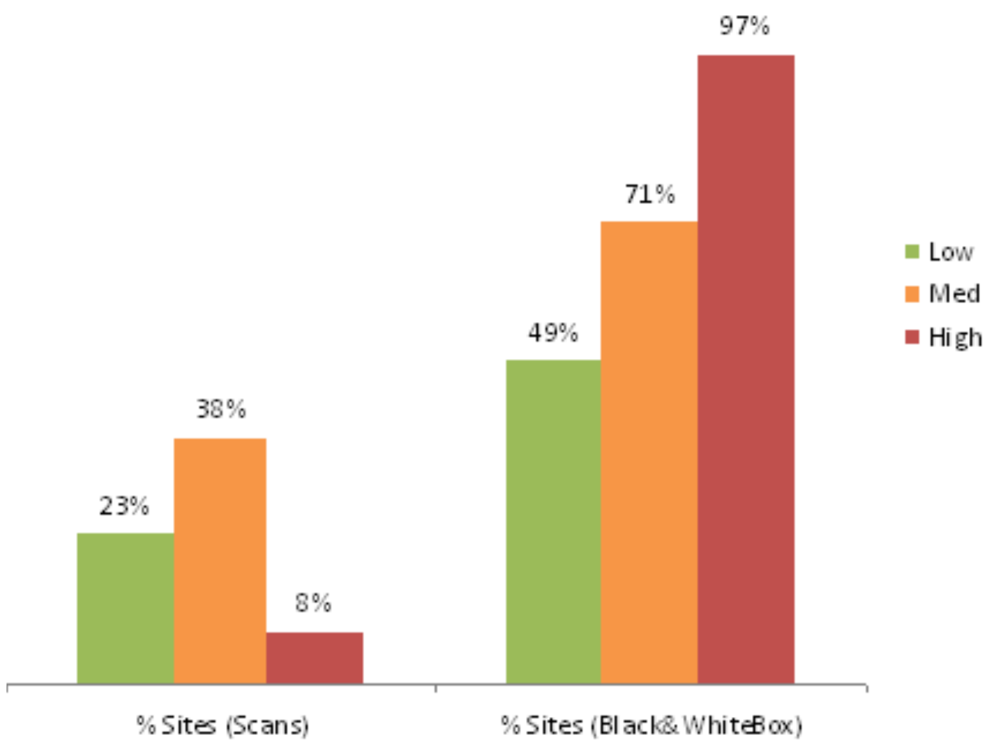
- Statistics based on over 32,000 sites and 70,000 vulnerabilities of different degrees of severity
- 2 different data sources:
  - Automated vulnerability scanning testing results
  - Combination / Grey-Box Testing methodology:
    - Application vulnerability scanning coupled with manual analysis, manual search for vulnerabilities which cannot be detected by automated scanner, and source code analysis.
- 3 data sets were obtained:
  - Overall statistics
  - Automated scanning statistics
  - Black and White-Box methods security assessment statistics
    - Grey-Box testing was limited to interactive web applications

(http://www.webappsec.org/projects/statistics/)

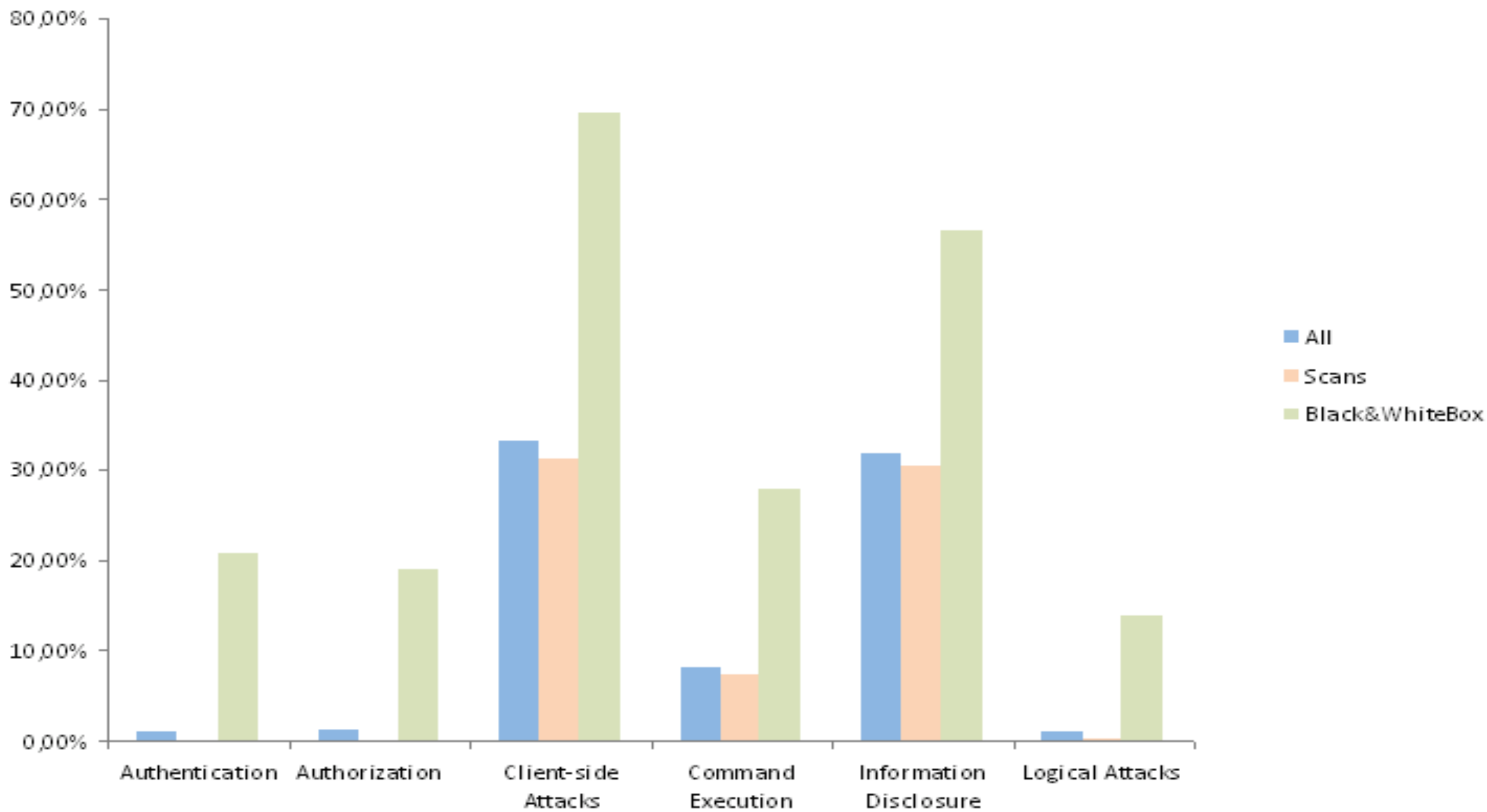
STATISTICAL ANALYSIS OF METHODOLOGIES

Results:

- Probability to detect high risk vulnerabilities using combined testing methodologies is 12.5 times higher than using automated scanning.
- Over 7% of analyzed sites can be compromised automatically.
- Using combined/grey-box methodologies high severity probability reaches 96.85%.



STATISTICAL ANALYSIS OF METHODOLOGIES

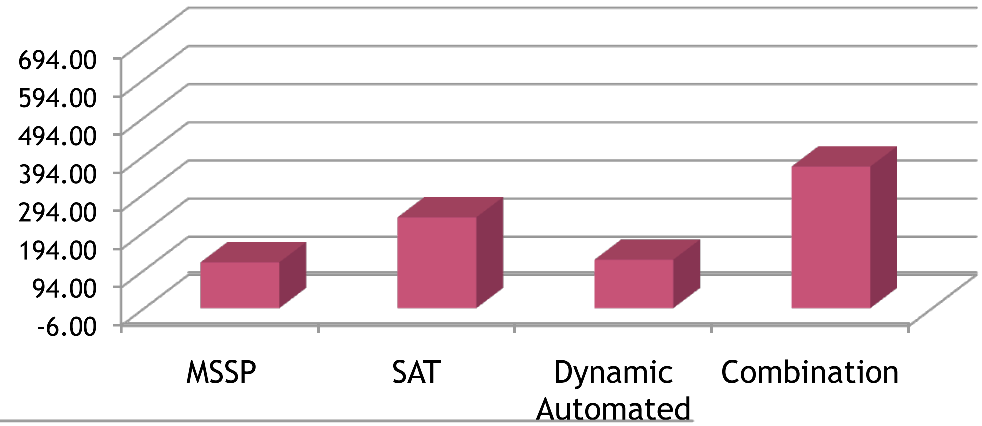


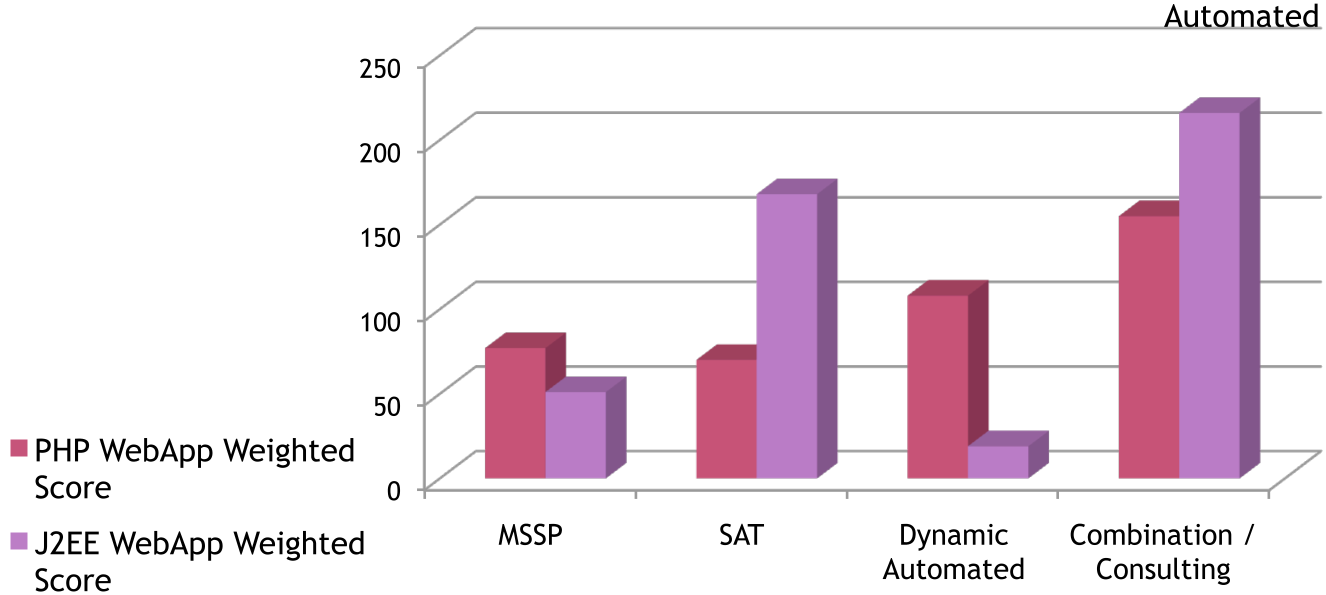
STATISTICAL ANALYSIS

- Recent Consulting Project Dataset
  - 2 Representative Applications used – PHP and J2EE
- Application testing methodologies analyzed across multiple vendor types
  - MSSP
  - Static Code Analysis Tools
  - Automated Dynamic Scanning
  - Consulting Vendors
- Present vulnerabilities analyzed and then additional implanted across all vulnerability classes and ranges of severity

STATISTICAL ANALYSIS

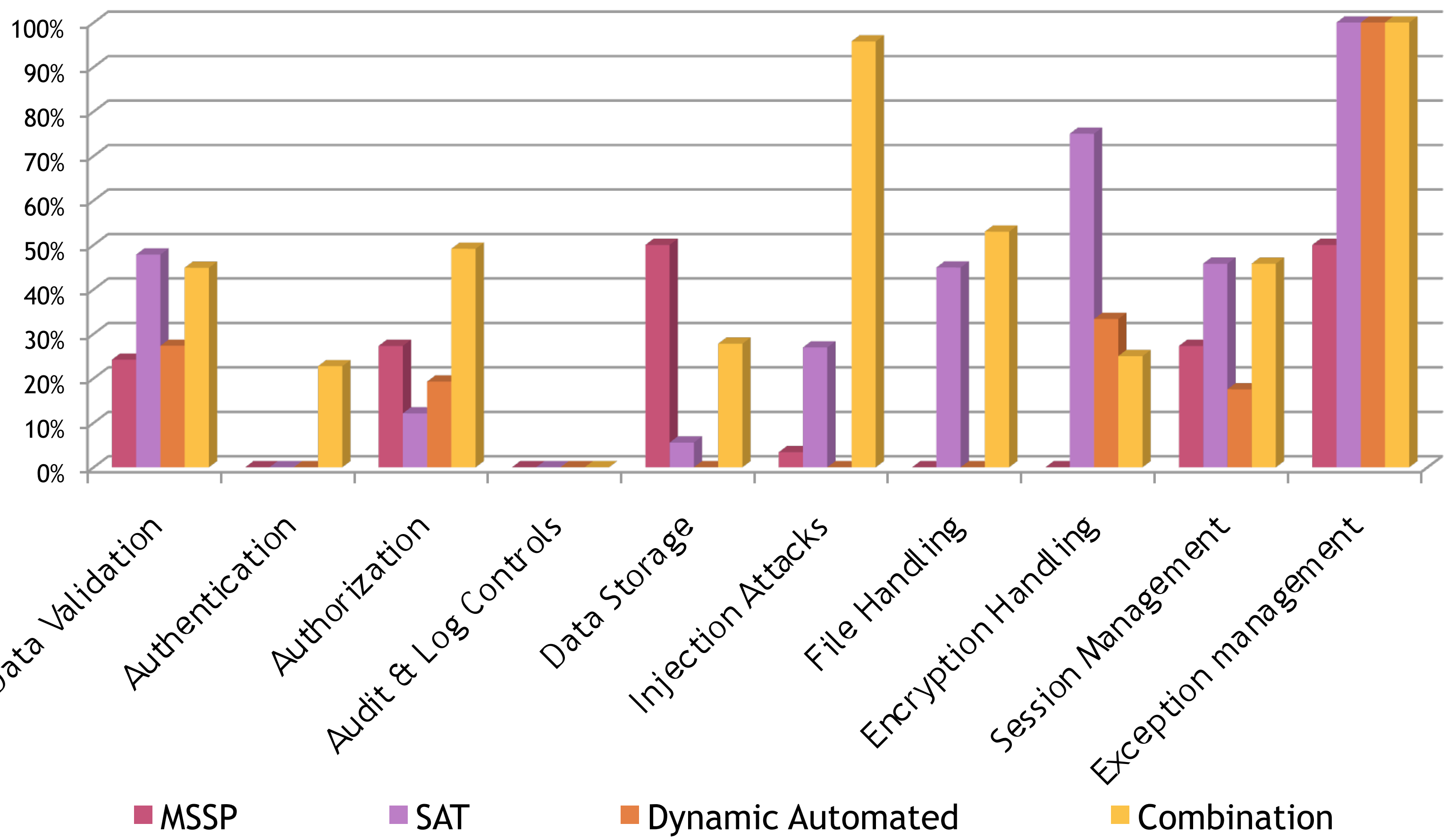
Chart of solutions overall ability to identify vulnerabilities when compared as a whole



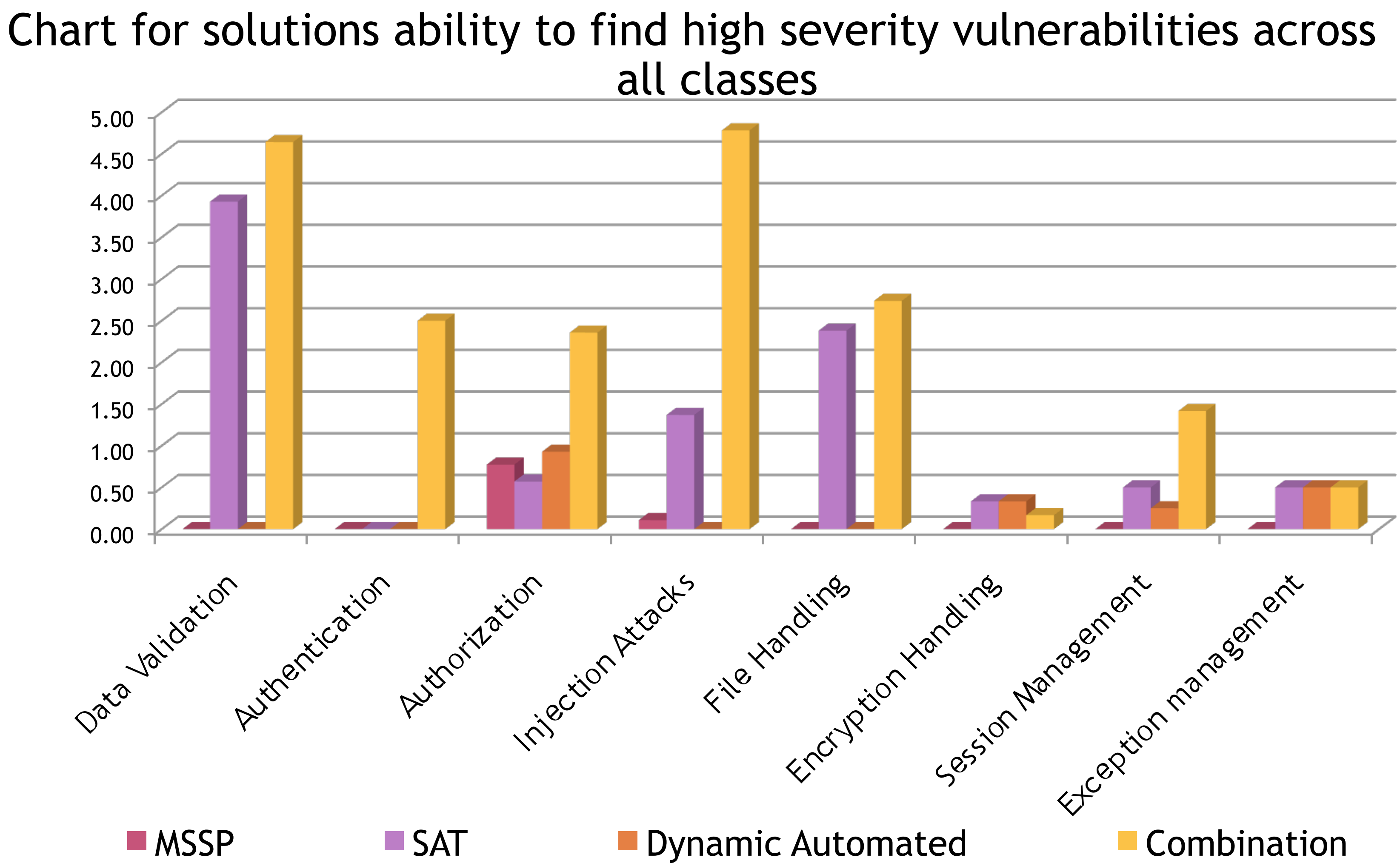


STATISTICAL ANALYSIS

Solutions overall ability to find vulnerabilities within particular vulnerability class



STATISTICAL ANALYSIS



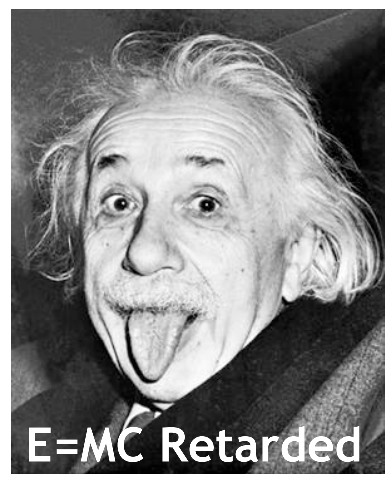
DETERMINE RISK

- You must determine risk to establish testing methodology.
- Spending more on security than the overall liability is a waste of time, resources and money.

PUBLIC RISK FORMULAS

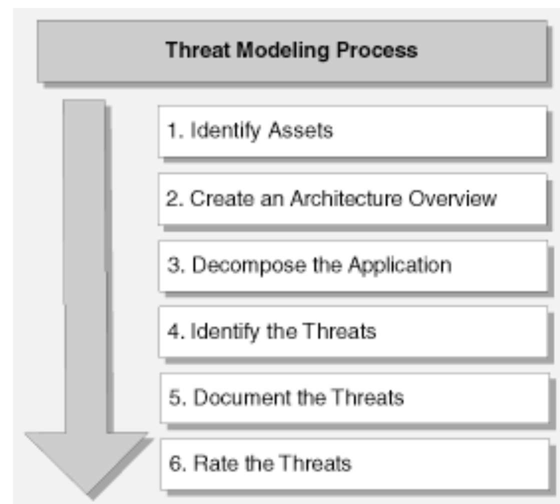
- Risk =
  - Threat x Vulnerability x Impact
  - Asset Value x Threat
  - Confidentiality x Integrity x Availability x (Threat x Vulnerability)
  - Probability x Damage Potential (Microsoft)

- Seriously?
- How are these ideas defined?
- How do I rank CIA?
- Great idea, stupid implementation



THREAT MODELING… IS DETERMINING RISK

- Intro…
  - Microsoft
  - Understand (Asset / Threat / Vulnerability / Attack / Countermeasure)
  - DREAD Ranking
    - Damage Potential
    - Reproducibility (only needs to happen once)
    - Exploitability
    - Affected Users
    - Discoverability

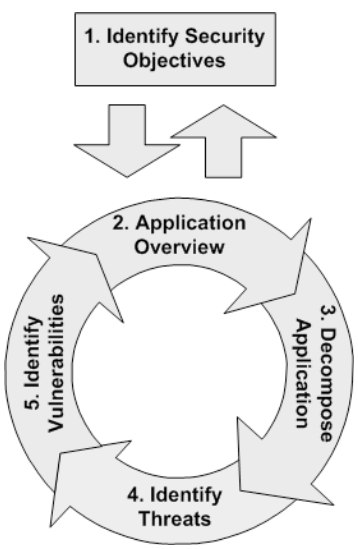


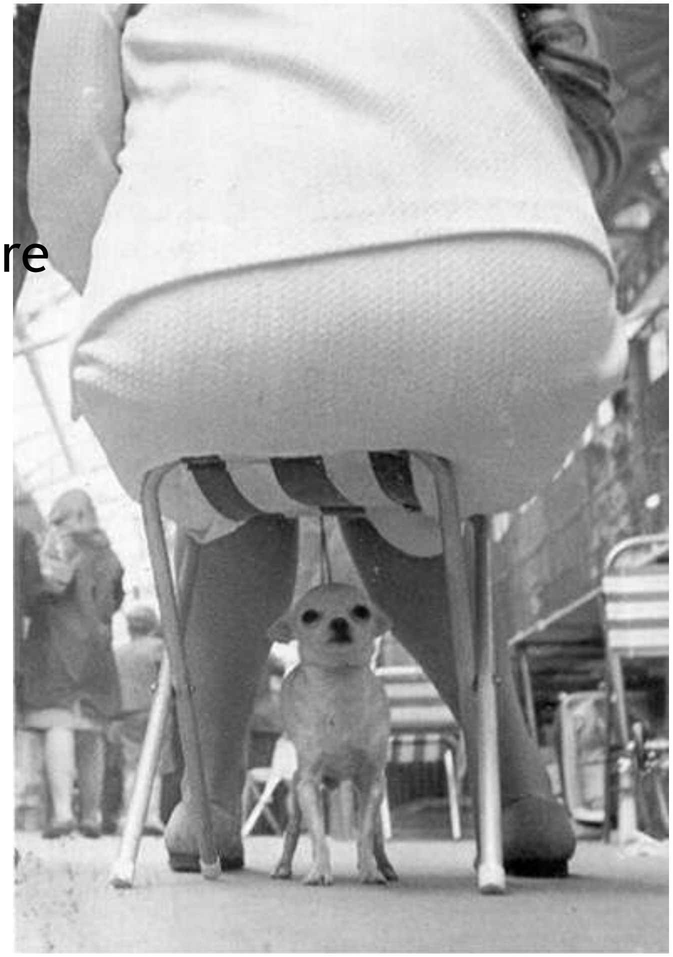
  - What about money??
    - That's all I care about…

The only risk that matters is financial…

THREAT MODELING… IS DETERMINING RISK

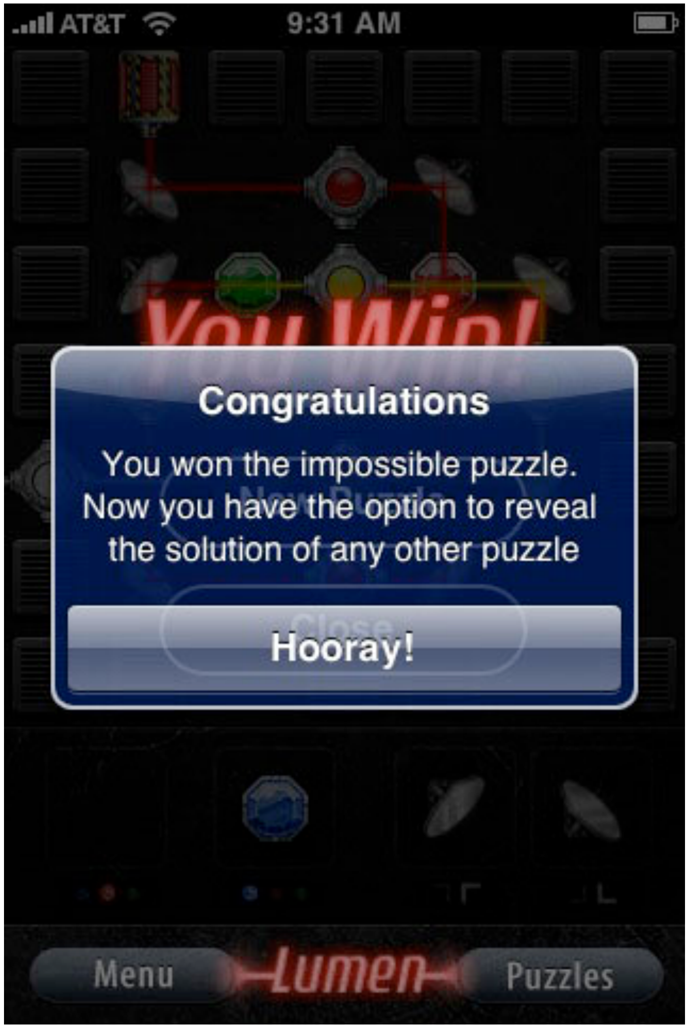
- Business criticality / risk modeling
  - Exposure to attack
  - Business criticality
    - Effect to business
    - Effect to customers / reputation
    - Effect to personal information/exposure
    - Financial loss impact





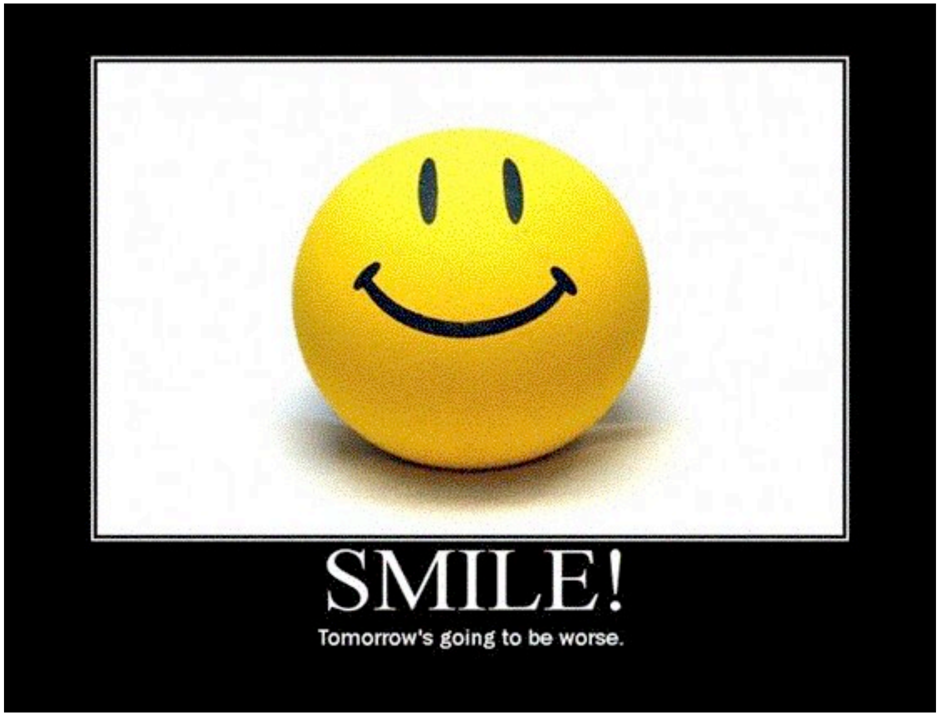
WHAT SOLUTION DO WE USE?

- Automated / Static / Dynamic / Manual
- Questions to ask:
    1. Maturity of your program
    2. Skill level of personnel
    3. Availability of skilled hours
    4. Maturity of the application
    5. Availability of code
    6. Complexity of the application
    7. Technology / language
    8. Availability of test resources
    9. Volume of users
    10. Internal vs. external facing
    11. Data sensitivity
    12. Sensitive functionality
    13. Regulatory requirements



WHAT SOLUTION DO WE USE?

- Sweet… we answered those questions… now what?
- Use common sense, there is no magic formula.. (at least we haven't been able to figure out something perfect)



ONLINE CALCULATOR

www.humperdink.net

Coming Soon: Form based calculator…

Based on the 'MSAMACTA' formula outlined earlier, input variables on your application, and it will recommend the best testing methodology.

Testing Solution	Strengths	Weaknesses	Process Integration
Automated Testing - Dynamic Environment (Vulnerability Scanning)	• Quickly identifiesImplementation vulns • Can identify Operational and Platform vulns	• Many false positives • Most design vulns missed • Noisy traffic for IDS systems • Can impact resources	During testing phase or within post-production deployment environment
Automated / Manual - Dynamic Environment (Penetration Testing)	• Tests actual implementation •Finds issues from an attackers perspective • Can find Implementation, Design and Operational vulns	• Can be slow • Difficulty with some implementation vulnerabilities • Testing can impact production	During testing phase or within post-production deployment environment
Threat Modeling	• Quickly identifies Design vulnerabilities • Can be implemented early in dev cycle	• Ineffective for Implementation and Operational vulns • High personnel impact	Requirements analysis and security design phases of the SDLC

Testing Solution	Strengths	Weaknesses	Process Integration
Manual Testing - Static Environment (Manual Code Review)	•Detailed remediation info • Some methods can quickly identify LHF issues • Able to provide deeper analysis to show impact	• Comprehensive approach can be time consuming •Can require high personnel involvement	During the coding phases of the SDLC or as a component of a comprehensive blended assessment
Automated Analysis - Static Environment (Static Source Code Review Tools)	•Quickly identifies pattern match vulnerabilities • Often faster and cheaper then a manual review	• Few actionable results • Cannot find Design vulns • Cannot find certain classes of Implementation vulnerabilities	During the coding phases of the SDLC or as a component of a comprehensive blended assessment approach
Comprehensive Blended Assessment Methodology	• Efficiency •Accuracy	• Cost and duration	QA & Post Production

CONCLUSIONS

- There is no real ‘solution’
- No single ‘solution’ comprehensively identifies all critical application vulnerabilities or across all vulnerability classes.
- A comprehensive program should include a blend of all of the various testing methodologies available.
- Apply the appropriate testing methodology based on factors such as:
  - Application Risk Profile
  - Criticality
  - Timeframe
  - Availability of Resources
  - Budget