# Malicious Code

CSH6 Chapter 16

"Malicious Code"

Robert Guess & Eric Salveggio





## Topics

- Introduction
- Malicious Code Threat Model
- Survey of Malicious Code
- Prevention of Malicious Code Attacks

*CSH6* Chapter 16: "Malicious Code"





## Introduction

- Malicious code / logic
  - *Malware*
  - Hardware, software or firmware intentionally included or inserted in system for unauthorized purpose
- Classification may be difficult
  - Categories overlap because malware may have multiple functions and attributes
    - ✓E.g., virus / worm / Trojan horse / spyware
- Some code may not be intended as malware by creators
  - Context and intent determine whether code is viewed as malicious

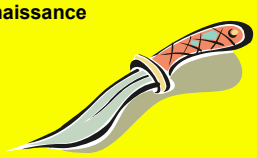




## Malicious-Code Threat Model (1)

ACTOR → ACCESS → ASSET → ACTION → OUTCOME

- Actor: structured or unstructured threats
  - Individuals, organizations, nation-states
- Access: allowed physical or logical path
- Asset: resource of interest
- Action: execution of malicious code or logic
- Outcome
  - Intelligence, surveillance, reconnaissance
  - Disruption of operations
  - Destruction of assets
  - Publicity for cause
  - Negative publicity against victim

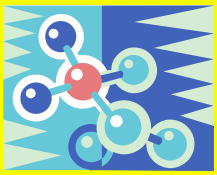






## Malicious Code Threat Model (2)

- Self-replicating Code
- Actors: Origin of Malicious Code Threats
- Actors: Structured Threats
- Actors: Unstructured Threats
- Access vs Action: Vector vs Payload

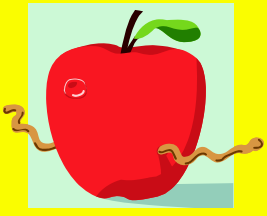






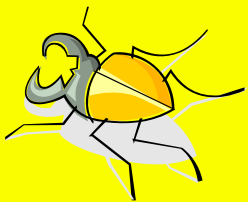
## Self-replicating Code

- Not inherently malicious
- Early experiments (1960s) had no evil intent
  - Darwin (1961) involved memory worms
  - Self-replicating code
  - Competition → resource exhaustion



## Is a Beneficial Virus Possible?

- Ideas for beneficial self-propagating code:
  - Distribute antivirus programs automatically through Internet
  - Install patches on servers in networks
  - Distribute useful information automatically
- Consensus on Problems Preventing Use:
  - What if there's a bug or incompatibility in the self-propagating code?
  - What if the patches are not appropriate for a specific server or network?
  - What if the owner/user does not see the patch as useful?






## Is Writing Malware Illegal in US?

- No explicit law against *writing* malicious code
- No illegality even in *sharing* such code among willing recipients
- Current efforts to define statutes
  - Based on laws banning possession of burglary tools (e.g., lock picks)
  - Require registration and licensing of locksmiths
  - Would treat malware and Trojans in same way
  - No significant progress to date




## Actors: Origin of Malicious Code Threats

- Structured threats
  - Nation-states
  - Corporate criminals
  - Organized crime
- Unstructured threats
  - Rogue actors; e.g.,
    - ✓Individuals
    - ✓Script kiddies




## Actors: Structured Threats

- Well-funded, systematic
- Industrial espionage, information operations, large-scale fraud & theft
- Organized crime responsible for 90% malware
  - Extortionists target online gambling
  - Pump 'n' dump schemes cost $B
  - Industrial espionage using spyware growing
- China major player
  - Major source of attacks
  - PRC PLA doctrine emphasizes asymmetric warfare using information technology
  - Total government control over hacking




## Actors: Unstructured Threats

- Random
- Relatively limited
- Does not target national security
- Relatively minor




## Access vs Action: Vector vs Payload

- *Vector*
  - Agent is avenue of access
  - Physical access via people who can enter premises
  - Network access via Web server, client systems, e-mail attachment, portable device (e.g., infected USB flash drive)
- *Payload*
  - Function (action) inserted in system
  - Malicious logic, remote access software, remote control software

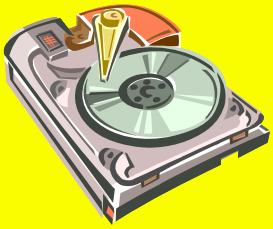
## Survey of Malicious Code

- Viruses
- Worms
- Trojans
- Spyware & Adware
- Rootkits
- Bots & Botnets
- Malicious Mobile Code




## Virus Mechanisms

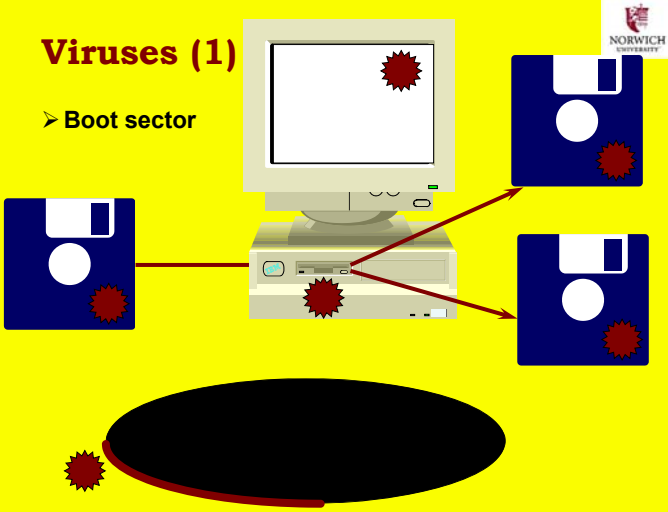
- Boot sector: sector 0 of disk
- File infector: inserts JUMP instruction, adds code, returns to original location and continues loading
- Macro virus: exploits weakness of MS scripting language in Word, PowerPoint, Excel, Access etc.






## Viruses (1)

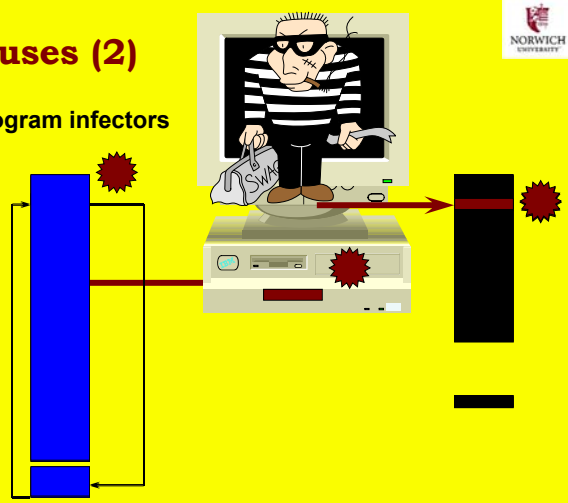
- Boot sector






## Viruses (2)

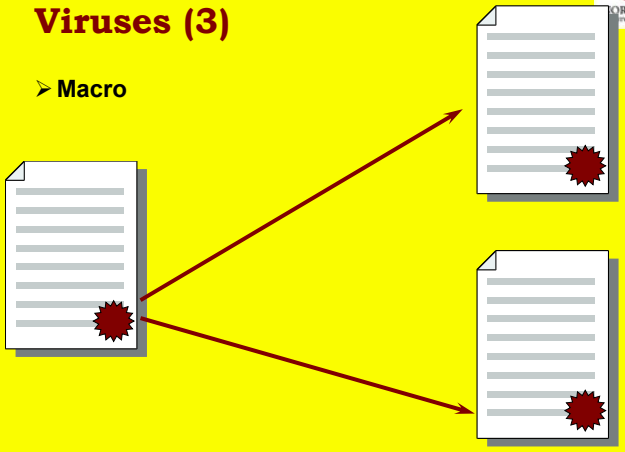
- Program infectors






## Viruses (3)

- Macro






## 1995-1996: Early Macro Viruses

- MS-Word macro virus (concept) released Aug 95
  - ❑MS-Word macro viruses reached more than half all infections in the wild by 2009
- About 1000 types of macro viruses of all types known to date (Sep 2013)
- MS-Excel virus discovered June 96
  - ❑Anti-virus available within days
  - ❑Spreading more slowly than Word macro viruses because of lower rate of exchange of spreadsheets

## 1999-03: Melissa Virus

Friday 26 March: CERT-CC initial reports of fast-spreading new MS-Word macro virus

- Melissa written to infect Word documents
- Uses victim's MAPI-standard e-mail address book
- Sends copies of itself to first 50 people on list
- E-mail message w/ subject line "Important Message From <name>"
- Spread faster than any previous virus
- Followed by similar e-mail-enabled viruses




## Viruses (4)

- Logic Bombs
  - Any malicious code, replicating or not, that delivers a payload as a result of a logic test (e.g., specific date, absence of employee record)
  - Time bombs (set off on a date or category of date) are a subset of logic bombs
- Cross-site scripting malware
  - Exploit flaws in Web application servers & client code
  - In 2005, "Samy" created script that generated >1M "friends" on MySpace using flaw in Internet Explorer to use JavaScript insertion exploit
  - Sentenced to 3 years probation, 90 days community service




## Viruses (5)

- Polymorphic viruses
  - Intended to defeat signature-based antivirus tools
  - Modify themselves at time of replication
- Polymorphic Engine
  - Encrypts code
  - Includes self-decryption capability
  - Dark Avenger wrote MtE (aka Mutation Engine) in late 1980s
    - ✓Programmer from Sofia, Bulgaria
    - ✓Detested Vesselin Bontchev, famous AV expert
    - ✓Also attacked researcher Sarah Gordon by name




## Viruses vs Worms

- Viruses integrate into host code
  - Replicate upon execution of infected code
- Worms are free-standing code
  - Replicate via networks
  - E-mail (e.g., Outlook) especially common vector
- Some worms have viral properties
  - Integrate themselves into e-mail messages and convert them to executable files
  - Frequently conceal executable file type
  - Depend on default suppression of file suffix (e.g., *AnnaKournikova.jpg.vbs.txt*)




## 1987: IBM Christmas Tree Worm

- E-mail sent via IBM internal e-mail network
- Included program to draw ASCII Christmas tree on screen
- Used recipient's e-mail address book to mail itself to everyone on the network
- No mechanism to prevent superinfection
- Overloaded worldwide IBM networks
- Messages escaped from IBM into BITNET




## 1988: The Morris Worm

- Robert T. Morris
  (not a "Robert T. Morris, Jr"!)
  - Cornell University grad student
  - Son of famed NSA cryptographer Robert H. Morris
  - Wrote paper on *sendmail* and *fingerd* vulnerabilities on UNIX systems
  - Seems to have intended to demonstrate significance
- Released a defective version of his demo worm
  - Originally intended to replicate slowly, avoid superinfection
  - In fact grew fast and superinfected systems worldwide

## Morris Worm (cont'd)

- Launched Worm at 17:00 on 2 November 1988
- By 06:00 next morning the Internet was effectively down
  - ~6,000-9,000 systems crashed or taken offline
- Computer scientists worked feverishly all night analyzing the Worm
  - Distributed fixes by telephone and fax (no 'Net)
  - Led to formation of CERT-CC® in Dec 1988
- Morris convicted of violating 1986 Computer Fraud and Abuse Act (18 USC §1030)
  - 400 hours community service + $10K fine




## 1999-12 W.95.Babylonia Virus/Worm

- Extensible virus
- Payload modified remotely
- Trojan virus-dropper
  - Disguised as Y2K bug fix for internet relay chat (IRC) users
- Sent itself other users
- Polled Internet site in Japan
  - Looked for updated plugins




## 2000-05: ILOVEYOU Worm

- E-mail subject *ILOVEYOU*
- E-mail attachment *LOVE-LETTER-FOR-YOU.TEXT.vbs*
- Used all addresses in address book
- Became #1 infectious code in Europe, Asia, USA
- Variants appeared quickly
- Created by 27-yr-old Filipino computer student Onel de Guzman
  - No local laws against spreading viruses
  - Creator given job as programmer! ☹




## 2000-06: Timofonica Worm

- E-mail enabled malware
- Automatically sent *pager* message to block of Telefonica cell phones
- Tried to delete all data on hard disk





## 2001-03: SirCam Worm

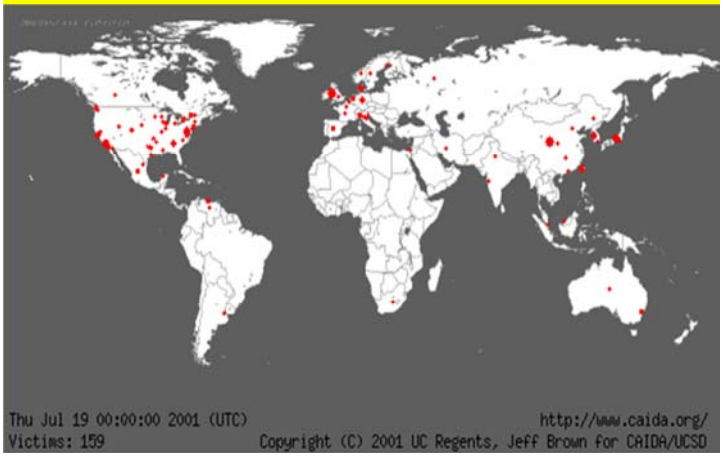
- Propagated on Windows systems
- Used standard e-mail address books
- Infected document, converts to executable
  - Most naïve users turn off suffix display
  - So *myfile.doc.exe* looks like *myfile.doc*
- Created e-mail message with random subject and randomized text asking for comment
- Sent infected file to everyone on e-mail list
- Documents may contain confidential info
- See http://www.cert.org/advisories/CA-2001-22.html




## 2001-06: CodeRed Worm

- Infected vulnerable Web servers
  - Windows NT or Windows 2000 or CISCO equipment
  - running MS-IIS software that has not been *patched*
- Showed message on Web home page:
  HELLO! Welcome to http://www.worm.com! Hacked By Chinese!
- Sent copies of itself to computers in list of IP addresses
- On 20th through 28th of month, tried to swamp specific target with DoS (denial-of-service) attack
  - Original worm attacked numerical address of White House
  - Later versions received instructions from remote *master* computer program controlled by criminal hacker
- See
  http://www.cert.org/advisories/CA-2001-19.html

## Spread of the CodeRed Worm




## Trojans

- Named for the Trojan Horse in the Iliad
- Overt function useful or harmless
- Covert function unauthorized, usually harmful
- Functionality may be associated with all types of malware
  - Worms
  - Standalone programs
- Early Trojans included PC-Cyborg ("AIDS Information Disk") of 1989
  - Replaced autoexec.bat to count boots
  - On 90th boot, encrypted file/directory names
  - Author, Dr Joseph Popp arrested, extradited to US from UK, but never convicted due to mental incompetence




## 2000-01: Haiku Worm (Trojan)


F-Secure (formerly Data Fellows)

- E-mail enabled virus/worm
- Carrier: detailed e-mail message about Haiku generator
  - Actually works — Haiku in Windows box
- Worm code spreads through victim's e-mail address list
- Occasionally downloads and plays a .wav file from a Web site




## Spyware & Adware

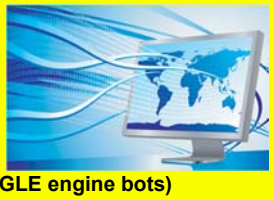
- Software that collects user information without permission
  - Tracking & reporting Web usage
  - Monitoring use of licensed programs
  - Monitoring or blocking copying of music
  - Click-fraud (automatically clicks on ads for profit)
- Spyware serving unwanted ads = *adware*
- *Legal* issue is EULA (end-user license agreement)
  - If no clear statement of functions, spyware/adware may be violation of 18 US1030(a) (Computer Fraud & Abuse Act of 1986)
  - If EULA is clear and user agrees, matter of contract law
  - But many users never read EULA at all…
- Some spyware/adware difficult to uninstall (hides itself)




## Rootkits

- Program that allows covert access after installation
  - Compromise application, library, kernel, hypervisor & hardware levels
  - Early versions replaced Unix components
  - Kernel-level rootkits run as device drivers
- Classic examples: BO & BO2K
  - Back Orifice by Sir Dystic of Cult of the Dead Cow (cDc) presented at DEF CON 6 in 1998
  - Back Orifice 2000 by Dildog of cDc presented at DEF CON 7 in 1999
  - Both provide "remote systems administration"
  - Both used by Trojan droppers
  - BO2K hides itself from discovery

## Bots & Botnets (1)



- Bots
  - Automated processes on the Internet & WWW
  - Carry out specific tasks; e.g.,
    - ✓Web spidering: collecting files from Web (e.g., GOOGLE engine bots)
    - ✓Monitoring conversations on talk channels (e.g., for suppression of profanity or automated responses to questions)
- IRC Bots
  - Internet Relay Chat used for communications
  - IRC bots widespread for criminal activity
- Bot Herders control 100K bots for commercial (criminal) activity such as DDoS, spam

## Bots & Botnets (2)

Nov 15, 2012

- Grum: 18 billion spam messages per day
- Lethic: 28% of all spam in 2012
- Festi: infected 250,000 unique IP addresses
- Cutwail: DDoS attacks vs 100s Websites
- Zeus: 944 Zeus command and control (C&C) servers – botnets steal banking info
- SpyEye: steal consumer banking data (~278 SpyEye C&C servers in use
- Citadel: "…social network allowing users to report bugs and even suggest new features. 2012 has seen a 20 % increase in Citadel Trojan attacks"

Morgan, C. "The Worst Botnets of 2012." Storagecraft (2012-11-15). http://www.storagecraft.com/blog/the-worst-botnets-of-2012/




## Bots & Botnets (3)

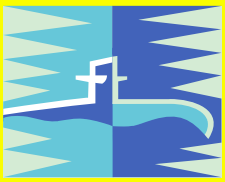
- ZeroAccess: fastest growing botnet: 2M nodes – ad-click fraud
- TDL-4: "…removes competing malware, hides from detection and installs a master boot record. The newest variant of TDL-4 has infected approximately 250,000 unique victims."
- Flashback: 100k Mac computers infected – collects passwords (e.g., Google, Paypal) … infected 10 percent of home networks with Mac computers by Apr 2012

Morgan, C. "The Worst Botnets of 2012." Storagecraft (2012-11-15). http://www.storagecraft.com/blog/the-worst-botnets-of-2012/




## Malicious Mobile Code

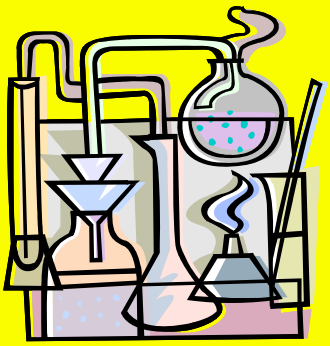
- Web servers host pages with active content
- Mobile code may be written in (e.g.)
  - ActiveX controls
  - Java applets
  - JavaScript
  - Adobe Flash
- Often involved in phishing attacks
- See *CSH6* Chapter 17, Mobile Code.






## Detection of Malicious Code

- Signature-Based
- Network-Based
- Behavioral
- Heuristic






## Signature-Based Malware Detection

- Oldest method of recognizing malware
  - Identify known strings of code/text
  - Defeated by polymorphism
- Hashes
  - Compute cryptographic hash of all executables on system; e.g.,
    - ✓MD5
    - ✓SHA-1
    - ✓Digital signature using public key cryptosystem
  - Identify unauthorized changes (caused by malware) by checking table of hash values




## Network-Based Malware Detection

- Look for effects of running malware; e.g.,
  - Connection to unusual / characteristic server (like IRC)
  - Unusual protocols (not normal for system)
  - Peculiar packets (nor normal for protocol)
- Can establish baseline for behavior
  - Monitor KNOWN-CLEAN system
    - ✓Critically important not to include malicious code in baseline
  - Compare observed behavior with baseline
  - Look for outliers & investigate deviations

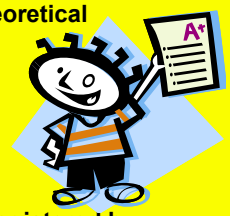
## Behavioral Malware Detection

- Monitor behavior of code
  - Look for violations of security standards; e.g.,
  - Attempting to modify areas of memory outside local stack of process
  - Attempting to raise privilege level
- Sandboxes
  - Run code in restricted environment
  - E.g., Java sandbox
- Virtual machines a form of sandbox
  - Increasingly popular




## Heuristic Malware Detection

- *Heuristic* in this context means *able to change / learn*
- Apply statistical modeling & theoretical behavioral models
  - Computer score / metric to evaluate likelihood that program is legitimate
  - Can detect new variations of malware
    - ✓Even if signature not yet registered by conventional scanners
- Modern antimalware products include option for heuristic scanning
  - Should enable it!







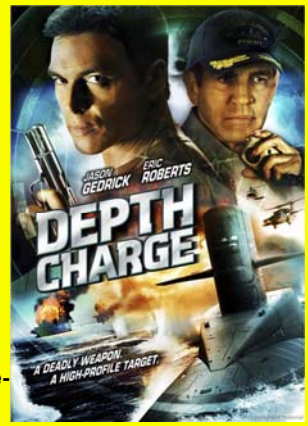
## Prevention of Malicious Code Attacks

- Defense in Depth vs Malware
- Operational Controls vs Malware
- Human Controls vs Malware
- Technical Controls vs Malware




## Defense in Depth vs Malware

- No one AV program can protect against all malware
- Defense in depth uses multiple concurrent strategies
  - Operational controls
  - Human controls
  - Technical controls
- Different approach is to define *orthogonal* systems
  - Function in only one demonstrably correct way
  - But no one wants single-purpose, rigid systems







## Operational Controls vs Malware

- Written policies and procedures
  - Govern introduction of programs into production environment
  - Who can install programs?
  - Acceptable use policies for Internet and e-mail use (*CSH6* Chapter 48, "E-mail and Internet Use Policies")
  - How to respond to suspected attack
  - See *CSH6* Chapter 47, "Operations Security & Production Controls"
- Employment policies & procedures
  - *CSH6* Chapter 45, "Employment Practices & Policies"




## Human Controls vs Malware

- Provide training on malware policies & procedures
- Topics
  - Current threats; e.g.,
    - ✓Advance-fee fraud (Nigerian 419 fraud)
    - ✓Social engineering (see *CSH6* Chapter 29, "Social Engineering & Low-Tech Attacks")
    - ✓Malicious attachments
  - Detecting the threats – not ignoring AV popups!
  - Proper response
    - ✓Contact Help Desk at once

# Technical Controls vs Malware

- Implementing Antivirus Systems
- Host Configuration Controls & Security
- Network-Based Security Controls
- Network Monitoring

See *CSH6*
Chapter 41, "Antivirus Technology"




# Implementing Antivirus Systems

- Use both network-based & host-based systems
- Choose products from different vendors to run concurrently
- Run updates automatically on all systems daily *at least*
- E-mail may require separate appliance/ system to control malware attachments, spam, fraud, phishing…




# Host Configuration Controls & Security

- Automatic updates / patches essential
- Eliminate non-critical software & services
  - Minimize threats that target growing complexity of environment
  - Current software development introduces average of 4.5 errors per 1000 lines of code
  - Inevitably, more code means more errors
  - Simplify environment to degree possible
- Browsers
  - Eliminate if possible
  - Otherwise, apply tight security
  - Use secure Web proxy





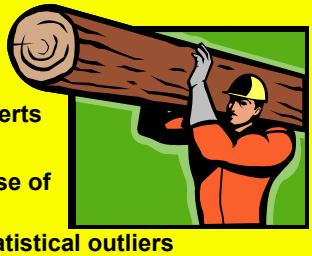
# Network-Based Security Controls

- Configure layered defense to interfere with malware propagation
  - Routers
  - Firewalls
  - Proxies
  - Switched virtual local area networks (VLANs)
- Filter aggressively
  - Bogus inbound network addresses (BOGONs)
    - ✓Packet from an unassigned region of IP address space
  - Spoofed internal addresses
    - ✓Claim to be from inside the target system
  - Packets from hostile countries (e.g., PRC) with whom you need no communications




# Network Monitoring

- Monitor & aggregate data from sensors
  - Device logs
  - Server logs
  - Host logs
  - Intrusion detection alerts
  - Network flow data
- Define historical database of normal behavior
- Look for anomalies – statistical outliers

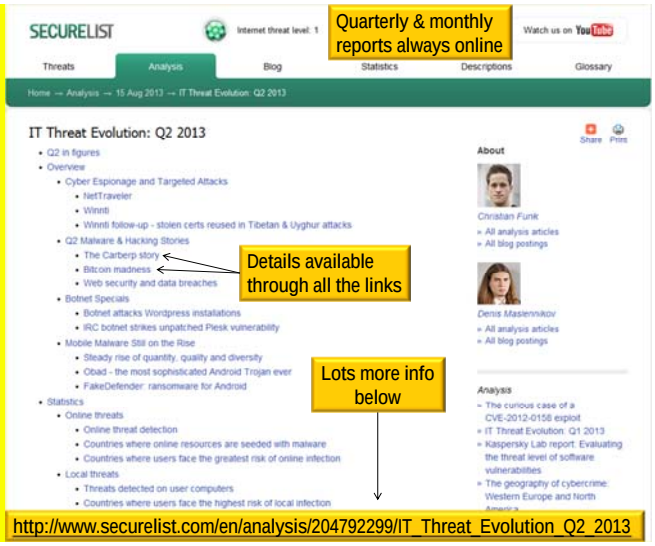





# Awareness Tools

- ICSA Labs
  - https://www.icsalabs.com/products
- Virus Bulletin
  - http://www.virusbtn.com/index
- Avast!
  - http://www.avast.com/virus-monitor
- McAfee Virus Information
  - http://home.mcafee.com/virusinfo
- Microsoft Malware Protection Center
  - http://www.microsoft.com/security/portal/
- Sophos
  - http://www.sophos.com/en-us/security-news-trends.aspx
- Trend Micro
  - http://us.trendmicro.com/us/trendwatch/

## Recent Statistics (Q2 2013)




http://www.securelist.com/en/analysis/204792299/IT_Threat_Evolution_Q2_2013



## Recent Statistics (24 Sep 2013)


Up to date details available online anytime.

http://www.trendmicro.com/us/security-intelligence/index.html





## Current Situation (Sep 2013)

http://www.trendmicro.com/us/security-intelligence/current-threat-activity/malicious-top-ten/index.html

**Top 10 Countries with the Most Number of Botnet C&C Servers**

The top 10 countries with the most number of botnet C&C servers in the first quarter of 2013 are listed below.

| Rank | Country | Share |
|---|---|---|
| 1 | United States | 35.66% |
| 2 | Australia | 10.88% |
| 3 | South Korea | 6.51% |
| 4 | China | 5.72% |
| 5 | Germany | 3.41% |
| 6 | United Kingdom | 2.60% |
| 7 | Brazil | 2.35% |
| 8 | Italy | 2.28% |
| 9 | Taiwan | 2.17% |
| 10 | Chile | 1.71% |

Top 10 Countries with the Most Number of Botnet-Connected Computers

Top 10 Malicious Domains Blocked

Top 10 Malicious URL Country Sources

Top 10 Spam Languages

Top 10 Spammers





# DISCUSSION