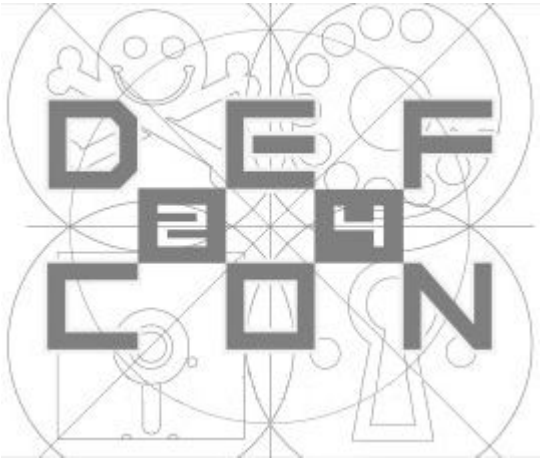
Vulnerabilities 101: How to Launch or Improve Your Vulnerability Research Game

Joshua “jduck” Drake, Zimperium
Steve Christey Coley, MITRE
DEF CON 24
Aug 7th, 2016



Introductions

- About Josh
  - 20-years of VR, Ran iDefense VCP
- About Steve
  - CVE, “Responsible Disclosure” (sorry), CVSS, CWE, ...
- Why we are doing this
  - Currently, there is *way* more insecure code out there than researchers. This isn't guaranteed in 10 years, though.
  - We need more people looking at code that’s deployed in the real world
  - We hope to encourage more people to get involved

Josh & Steve - Intros / Steve to finish

Disclaimers

- This is our opinion only
  - Based on our own career experiences
  - Others have their own opinions
- YOU… proving the cliche… are a unique snowflake
- You'll find your own way, but hopefully we can help you find it faster
- No new 'sploits here

Steve

What is a Vulnerability?

- Vulnerabilities != Exploits
- A Vulnerability resides in the software itself, doing nothing on its own
- An Exploit is a set of steps (possibly manual, or in the form of a program) that interacts with the software in a way that has a non-zero chance of successfully taking advantage of a vulnerability



https://twitter.com/mholt6/status/529797274658807810

Steve

What is a Vulnerability?

- Too many definitions...
  - Roughly: “a mistake in a system’s design or implementation that allows an ‘attacker’ to conduct activities that (1) affect other users and (2) are not explicitly allowed or intended by the developer or sysadmin.”
- “What do you have?” vs. “What do you get?”
  - there must be a difference

Josh

Vulnerability Properties

- "How much help must the victim give you?" (user interaction)
  - None - Automatic
  - Low - "Normal" usage (e.g., clicking on a link is *normal*)
  - High - e.g. "copy this javascript: url into browser"

- "How much luck do you need?"
  - ASLR, unusual configs, narrow race windows

- Vulnerabilities have MANY other properties… Some will become apparent in the rest of this talk.

Josh

What is Vulnerability Research?

The process of analyzing a product, protocol, or algorithm - or a set of related products - to find, understand, or exploit one or more vulnerabilities.

- This process may take minutes, days, months, even years
- Vulnerability Discovery may be used to emphasize finding individual bugs in specific software
- Solving puzzles within puzzles, where you don't know what the puzzle is when you begin

Josh

Why DO Vulnerability Research?

- Realistically, motivations vary per individual
  - Not every researcher will share your motivations
  - Vendors might have experience or only assume certain motivations



(word clouds generated on http://www.wordclouds.com/)

Josh

Vulnerability Related Careers

The need to deal with vulnerabilities spawns a wide variety of career opportunities

- This includes many roles that aren't considered "pure VR" too
- Which job is right for you depends on skills, interest level, and more.
- Here's a few of the myriad potential tasks:

- Discover 'em
- Analyze 'em
- Improve 'em
- Exploit 'em
- Investigate 'em
- Catalog 'em
- Fix 'em
- Communicate 'em
- Coordinate 'em
- Minimize 'em
- Prioritize 'em
- Document 'em

...we'll elaborate more as we continue...

Steve

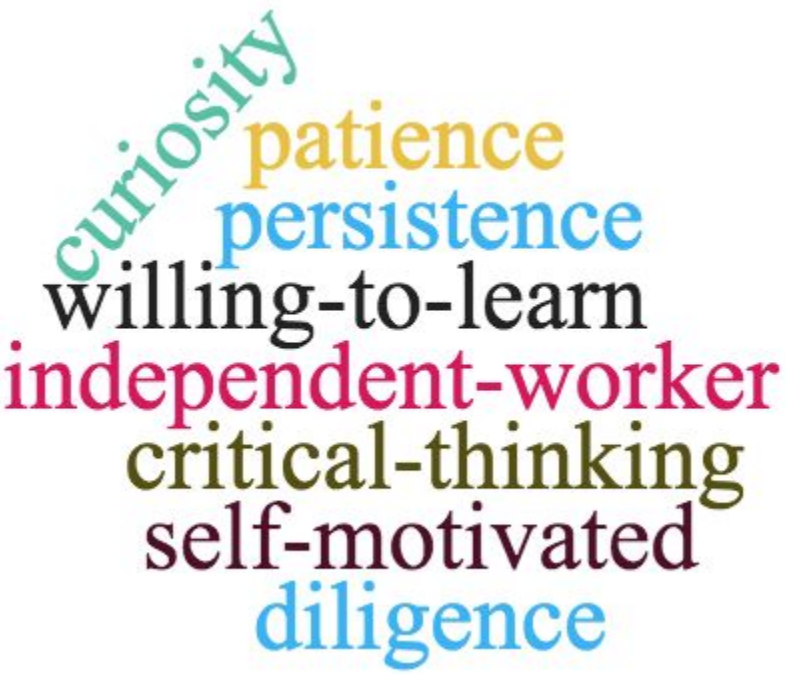
Potential Employers

- No one says you have to get a job doing this stuff. You could do it just for fun (aka a “hobbyist”).
- If you choose to get a job, you could work for (no particular order):
  - Yourself! - bug bounties, black/gray market sales, etc.
  - Consulting firms that value research
  - Security product companies (for marketing value)
  - Software vendors (product security or response team)
  - Regular businesses (internal application security teams)
  - Government contractors (or government directly)
  - Academia (focus is “pure” research)
  - CERTs (analyze and understand real-world attacks)
- Note: not all work gets public recognition

Steve

“Should Have” Personality Traits

- Patience - especially when dealing with people
- Persistence & patience - there will be challenges
- Diligence - details and accuracy are important
- Curiosity - fuel for motivation to learn



Steve

“Nice to Have” Personality Traits

- We feel these traits increase the chances of long-term, repeated success.



Steve

Skills for Long-Term Success

Certain skills, usually acquired over time, seem to lead to long-term success.

- Common attack patterns and logical flows (e.g. logic vulns, CSRF, authZ/authN)
- How to run analysis tools and evaluate their findings
- Clear communication; one (preferably many) of
  - Understanding and respecting your audience(s)
  - Well-structured advisory
  - Describing the issues (for the vendor and/or public)
    - Using common vocabulary
    - Why it's important
    - Steps to reproduce, functional PoC with well-labeled functions, comments, etc.
  - NOTE: perfect English is NOT on this list; the above items are much more important
- Knowledge of "how things work" under the hood: code, protocols, file formats, ...

Clear communication is probably one of the biggest contributors to career success, no matter your specialty (also, less drama due to misunderstandings).

Steve

Key Terms (Vocabulary)

- Attack Surface: the set of all inputs and code paths with which an attacker can interact
- Attack Vector: the route by which an attack is carried out (i.e. email, malicious link, etc.)
- Impact
  - RCE (remote code execution), EoP (escalation of privilege), DoS (denial of service)
- PoC (Proof of Concept)
  - What concept are you proving?! A vulnerability exists? A crash happens? Exploitable?
  - Clearly communicate what you've proven. It will ease your efforts.
- Vulnerability classes
  - Memory corruption, injection (SQLi, XSS, etc.), protocol/specification design, …
  - When the low-hanging fruit fails: "Business logic"
- Vulnerability chains
  - Chains Example: Integer Overflows leading Heap Overflows
- Root cause analysis
  - Ex. XSS in error msg indicating system() or path trav
  - Ex. In C/C++, this is often the first encountered instance of undefined behavior.
  - Deeper analysis - ask yourself 'why?'

NOTE! Many terms have multiple definitions or context-specific usage too..

Steve + Josh

The Firehose: Where to Learn?

- OWASP Top Ten
- SANS/CWE Top 25
- White papers
- Periodic electronic collections
- Videos
- Mailing lists
- Github repos
- Vendor's bug databases
- Vuln scanners
- Intentionally-vulnerable packages

- CTFs / wargames
- Individual researchers
- Vulnerability databases
- Conference talks
- Classes
- Books
- Yearly White Hat Security Top 10 attacks
- Pwnie Awards Nominees
- Bug bounties

See bonus slides for specific references!

Josh

Selecting Your Target (1)

- You can go deep or broad
  - Language, vuln class, exploit technique, detection technique, ...
- Anything you do that contributes to the body of knowledge is valuable
  - Even negative results are useful! (though difficult to admit to)
- Lots of “low-hanging fruit” out there
  - Older code is more likely buggy
  - Complex or overly complex systems are often ripe
  - Large attack surface creates many opportunities
- Software popularity matters
  - Little-used software has lower quality but also lower impact to general public
  - Popular software with extensive vulnerability history is often difficult
- Too buggy means lower rewards or less recognition
  - Sadly, they won’t get better without liberal application of effort

Josh + Steve

Selecting Your Target (2)

- Brand-new or emerging technologies (think Mobile, IoT, etc)
  - Vendor rush-to-market usually means security is at best an afterthought
- Newly-discovered or emerging vulnerability/attack classes
  - Each new class should force a review of ALL products across the board
  - Or, refine a new attack/vuln with new variations, stronger impacts, etc.
- Previously-unanalyzed code
  - Highly likely to contain lots of low-hanging fruit
  - Some targets grow popular without getting proper review / fixes
  - Some targets have been around forever but only recently connected to networks (hello medical devices and automobiles!)
- If you have access to expensive or difficult-to-obtain products: do eeeeeet
- Follow what others are doing ("Pigpile" or "Bandwagon" Effect)
  - Sometimes offends the original researcher(s)
  - Benefit from a base level of published research

Josh + Steve

Techniques and Tools

- Design review
- Threat modeling (e.g., STRIDE)
- Dynamic vs. Static analysis - to run or not to run?
  - Dynamic is analyzing a program by running it - e.g. fuzzing, debugging
  - Static is purely inspection of program code - e.g. auditing, SCA tools
  - Code coverage and accuracy (false/true positives) are important!
  - Real power is achieved by combining: hybrid analysis FTW!
- Code auditing (binary/source)
  - Grep! Pedantic compiler settings! Automated taint checking!
- Automated tools (fuzzers, static code analysis)
  - Risk of false positives
  - Lack of root cause analysis

Josh

Relevant Standards

- Using standards can make it easier to communicate critical vulnerability information across broad groups of people, including consumers, vendors, and others
  - but haters do exist, and haters gonna hate...
- CVE - Common Vulnerabilities and Exposures
  - Numeric identifiers for tracking vulnerabilities
- CWE - Common Weakness Enumeration
  - Hierarchy of developer “mistakes” that lead to vulns
- CAPEC - Common Attack Pattern Enumeration and Classification
  - Common traits of attack methodologies
- CVSS - numeric rating
  - Pros: widely adopted, focused on key characteristics, provides consistency
  - Cons: not as consistent as hoped, difficult to use in non-traditional contexts

Steve

Disclosure Models

- Models
  - Full, Partial, Coordinated (formerly “Responsible”), Non-disclosure
- Reasons for (public) disclosure
  - To inform the parties responsible for fixing
  - To put pressure on unresponsive vendors / get them to care
  - To inform the masses that there’s a problem that needs attention
- Standards Documents
  - ISO standard 29147 (@k8em0, etc.) - focuses on what VENDORS should do
    - **Now freely available!**
  - IETF Draft circa 2002
  - RFPolicy 2.0 circa 2000

Steve

Disclosure Policy Considerations (1)

Every disclosure is a unique snowflake. Your disclosure policy clarifies expectations between you and vendors!



- What if:
  - You can't even find the right contact point?
  - 0-day exploitation is actively occurring?
  - Somebody else publicizes your vuln(s) first?
  - The vendor doesn't respond?

- What is the correct grace period?
  - Design flaws often take a LONG time to fix

Image: http://feelgrafix.com/group/snowflake.html

Steve

Disclosure Policy Considerations (2)

- Impact to consumers who…
  - want to fix immediately
  - can't fix immediately
- Is the vendor acting in good faith?
- Will your actions...
  - make it harder for others to want to work with you in the future?
  - make it more difficult for people to hire you?
- "Is it worth it to disclose at all?"

Again, no one-size-fits-all; follow your moral compass

Steve

Advisory Structure and Contents (1)

Your advisory will be read by various people with different goals. Make it count. Better coordination means a better final advisory.

- Easily identifiable advisory structure
  - Well-labeled sections, different bugs in different segments, etc.
- Background / explanation of software
- Synopsis / abstract (brief)
- Affected software / hardware
  - Vendor name, product name
  - Vulnerable versions
    - Newest fixed and non-fixed vulnerable versions
    - Oldest vulnerable version
  - Best effort as it can quickly become a complex situation
- Vulnerability type(s)

Josh

Advisory Structure and Contents (2)

- Privileges & access required to launch an attack
- Impact of a successful attack
  - Privileges gained; unauthorized operations that can now be conducted; etc.
  - CVSS score, along with full vector
- Detailed Description
  - Level of detail is one of those individual opinion things, but there is a real risk to disseminating attacks
  - Include PoC (details on next slide)
  - Use your moral compass so you can sleep well at night
- Patch availability, mitigations, workarounds
- Key identifiers (CVE, vendor IDs, CERT IDs, etc.)
- Disclosure timeline (discovery, notification, vendor reply, patch, disclosure, etc.)
- Credit to contributors
- References to related work

Josh

Proof-of-Concept Makes Your Case

This key detail often tips the scales, so to speak. Consider including 1 or more:

- Sequence of steps to reproduce, e.g. through the user interface
- Detailed code analysis
  - Affected parameter or field
  - Name of affected function
  - Names of all files/executables involved (eg. login.php & authlib.php)
  - Source/assembly code extracts (or Pseudocode)
    - How does attacker input get to the vulnerable code?
    - Code version
    - Source line numbers / addresses
    - Trim unnecessary code for readability
- Code that demonstrates impact
  - Harmless sample attack, e.g. calc.exe or alert('XSS')
  - Functioning exploit code (snippet, full, or in between)

Josh

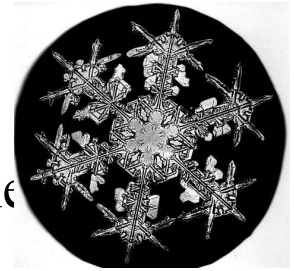
Advisory Formats - Pros and Cons

- Simpler is better
  - Most widespread distribution; no special viewer required
  - Complex formats mean fewer potential readers (due to higher possibility of vulnerabilities)
- Think “plain text”. “Markdown” is a decent compromise.
  - Easy to copy-and-paste key details (also, language translation)
- Please never, EVER PDF!
- If you’re going to make a video...
  - Respect people’s time!
  - Keep it short and sweet, and accompany it with a text advisory.
  - A clear picture is essential
  - Show reproduction steps
  - Give the viewer enough time to read and understand each step

Steve

What to Expect from Vendors

- There are many scenarios, each disclosure is a unique snowflake
  - Inability to find right contact (who might not exist)
  - Unless they're very experienced, you're calling their baby ugly
  - Lack of understanding of the issue
  - Legal threats
  - Acknowledgement of receipt, followed by silence
  - Corporate bureaucracy or politics preventing openness
  - Refusal to share patches with you to re-test
  - Lack of credits
  - Commitment to a fix, but with an unreasonable timeline
  - Disagreement on severity of the issue
  - Release of patch without mentioning a vulnerability at all



Josh

Where to Disclose Publicly

Please post your advisory to at least one source that is archived forever (or archived widely)!

- Mailing lists: Bugtraq, Full-Disclosure, oss-security
- Exploit-DB or other exploit sites
- Vulnerability databases
- Your own blog or website

Then again, maybe you are okay with relying on vendor credits or “hall of fame” -- no separate publication needed.

Josh

Common Mistakes to Avoid (1)

- Testing live sites or networks without permission
- Interacting with a vendor in a way that seems like a threat or blackmail
- Failing to ensure a problem exists
  - E.g., trusting automated tool findings without verifying them
  - Easy to declare a vulnerability exists, but harder to prove it
  - Corollary: if you can't exploit it, maybe somebody else can
- Not verifying whether the issue was already discovered
- Skipping root-cause analysis
  - Often leads you to more interesting findings
- Suggesting poor workarounds (e.g., "uninstall software")
- Over-hyping the severity of your findings

Josh + Steve

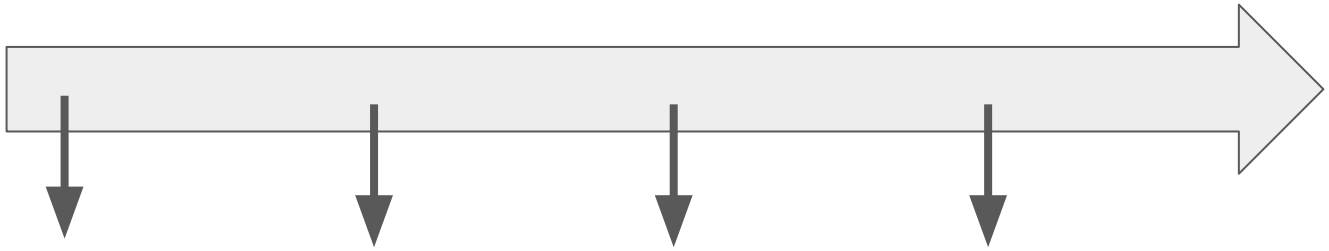
Common Mistakes to Avoid (2)

- Treating multiple attacks, or attack chains, as if they were separate vulnerabilities, even when they originate from a single vulnerability
  - Decision point: “if an issue is fixed, are the other issues still a problem?”
- Copying one of your old advisories to make a new advisory, and forgetting to change all the data for the new vulnerability
  - Start with an empty template!
- Relying too heavily on memes or cultural references
- Assuming developers are stupid and lazy
- Assuming customers can patch instantly

Josh + Steve

Vulnerability Research Growth Stages

(just our take)



Newbie

- Easy vulns
- Easy attacks
- Easy software
- Sometimes wrong
- No clean advisory format

Workhorse

- Mult vulns
- Mult vuln types
- Simple bypasses
- Evolving advisory format

Subject Matter Expert

- Enhances existing techniques
- Early adopter
- White papers / conf speaker
- Root cause analysis
- Clear body of work
- Rarely wrong

"Elite"

- New vuln classes
- New attacks
- New tools
- New bypasses
- Complex chains
- Most popular/heavily-audited software
- Highly specialized

Steve

Growth and Development
(A Perspective)

- Disclaimer! Everyone develops differently; this is just an approximation
- Not everybody wants to be, can be, or needs to be elite
- Malcolm Gladwell's Outliers says it takes about 10,000 hours of focused practice to become an expert
  - Varies based on aptitude and prior experience, e.g. developers pivoting to security
- It can take 3 years or more before you build a reputation
- To progress further, you can:
  - Team up with a peer
  - Find a mentor
    - Be polite and respectful of their time; accept that some will say "no"
- QUIZ: what happens when you're an elite researcher who targets software with low-hanging fruit? Ask @taviso ;-)

Steve

Feelz and Failz: Your "Objective," Technical Research is a Lie

- Vulnerability research is a trying profession/hobby
- FAILZ are inevitable
- FEELZ are inevitable
  - You're (probably) subject to trying to find rationales and logic to explain away your feelz
- Hack/life balance is key
  - But each person has a different balance
- You don't have to be elite to make a difference





Steve

FEELZ ARE OK

- It's normal to:
  - Get frustrated
  - Give up (temporarily or permanently) and look for something else
  - “Waste” time on a promising theory that doesn’t work out
  - Let your pride & ego get in the way of communication or success
  - Believe you're an expert when you’re not
  - Feel you’re weak when others think you’re not
  - Be afraid your work isn’t worthwhile
  - Be unable to see yourself reaching the level of those you respect
  - Feel hurt or embarrassed by criticism from people you respect
- Try to prevent your feelz from negatively affecting anyone…
  - Including yourself!
- Try to temper your emotion and avoid premature celebration

Josh and Steve

FAILZ ARE OK

- Your research heroes and heroines, plumbers and rock stars, whoever they are, *probably*:
  - Failed privately, or before everybody cared about infosec
  - Got “scooped” by bug collisions
  - Were defeated by a technical barrier they couldn’t overcome
  - Couldn’t understand somebody else’s findings
  - Operated in a world where the “rules” weren't yet defined… but today those rules aren't made explicit
  - Over-hyped some findings
  - Recovered, and forgot how they messed up
  - Recovered, but won't admit how they messed up (see: ego)
  - Might misrepresent accomplishments or how easy things were for them
- Failz are not fatal! (usually; we *are* in the age of IoT, unfortunately)

Josh and Steve

Conclusion

- May you fail fast, fail uniquely, and fail well!
- Everybody forges their own path, but others have made the journey before
- Good luck and have fun!

Josh: @jduck

Steve: @sushidude



Image: wocintechchat.com

Backup Slides / Details

Stage 1: Newbie
(Details)

- Easy-to-find vulnerabilities
- Easy-to-conduct, simplistic attacks
- One vulnerability type only
- Misses more important vulns
- Misses nearby issues
- Finds and discloses each bug, one at a time
- Limited to highly insecure, previously-unaudited software
- No “advisories” per se
- Sometimes wrong

Steve

Stage 2: Workhorse
(Details)

- More comprehensive findings - multiple bugs per package
- Multiple types of well-understood vuln/attack classes
- Recognizes simplistic protection mechanisms e.g. blacklists
- Evolves a disclosure policy and approach to working with vendors (or not)
- Evolving, stable advisory format
- Learns new techniques from others and applies them to own work
- Ensures findings are new and references related work

Steve

Stage 3: Subject Matter Expert
(Details)

- Recognizes multiple audiences
- Significant experience in one or more vuln or attack classes
- Develops new enhancements for existing techniques
- Writes white papers or speaks at conferences
- Bypasses common protection mechanisms
- Performs more comprehensive root cause analysis
- Applies experience to previously-uninvestigated product classes
- Creates a noticeable body of work
- Extensive findings for any package audited
- Experience with multiple techniques & methodologies
- Able to find bugs in most packages
- Detailed, well-written advisories with all relevant information
- Rarely wrong (able to be trusted without verification)

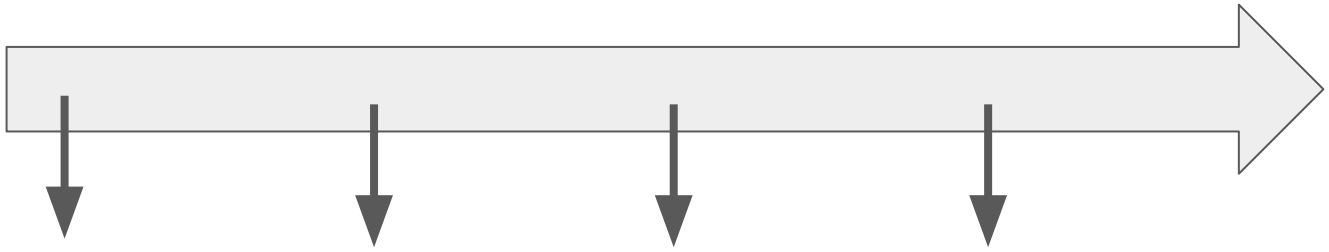
Steve

Stage 4: “Elite”
(Details)

- Hates that term (probably)
- Finds new vuln classes, invents new attack classes, makes new tools
- Bypasses state-of-the-art protection mechanisms
- Anticipates industry-wide developments
- Is “elite” only for a particular specialty
  - NOBODY knows everything anymore
- Finds vulns in any software package, anywhere, anytime*
- Analyzes most popular, secure software
- Finds complex vulnerability chains

* as applied to their particular specialty

Vulnerability Research Process (an attempt…)



Discovery

Finding security bugs by applying various techniques

- Auditing
- Fuzzing
- Manual testing
- etc.

Analysis

Understanding the bugs as much as possible

- Reachability
- Impact
- Affected product(s) and version(s)
- Minimize test cases
- Exploitability

Reporting

Communicating your research with vendors (and potentially the general public)

- Drafting an advisory
- Notifying affected parties
- Coordinating with vendors
- Once remediated, notifying a wider audience

Remediation

Fixing the issues, typically handled by the receiving end (vendor).

- Craft and deploy a fix
- Notifying affected parties
- Coordinating with researchers

Affected parties

- Prioritize, test, and apply patches

References/Links: Research Process

- Presentation
  - Andrew M. Hay - "Bootstrapping A Security Research Project"
    - https://speakerdeck.com/andrewsmhay/source-boston-2016-bootstrapping-a-security-research-project
  - Larry Cashdollar - "How to find 1,352 WordPress XSS plugin vulnerabilities in 1 hour (not really)"
    - http://www.wallofsheep.com/blogs/news/tagged/defcon#larry
  - Nick Jones / MWR Labs, "Bug Hunting with Static Code Analysis"
    - https://labs.mwrinfosecurity.com/assets/BlogFiles/mwri-bug-hunting-with-static-code-analysis-bsides-2016.pdf
- Books
  - Dowd, McDonald, and Schuh: "The Art of Software Security Assessment: Identifying and Preventing Software Vulnerabilities" (the code auditing bible!)
  - "Hacker's Handbook" series, e.g. Drake, Lanier, Mulliner, Fora, Ridley, Wicherski: "Android Hacker's Handbook"
- Documents
  - Phrack Magazine: http://www.phrack.org/
  - PoC||GTFO https://www.alchemistowl.org/pocorgtfo/
  - "Introduction to Vulnerability Theory" - https://cwe.mitre.org/documents/vulnerability_theory/intro.html

References/Links: Tools

- This is far from exhaustive; there are dozens of commercial and freeware software scanners
- Consider: $$$, false-positive rate, false-negative rate, explanations, ...
- Kali Linux - many different tools https://www.kali.org/
- Metasploit https://www.metasploit.com/
- Grep (yes, grep!)

References/Links: Intentionally Vulnerable Software

- OWASP WebGoat https://www.owasp.org/index.php/Category:OWASP_WebGoat_Project
- NIST SAMATE test suites, e.g. Juliet and STONESOUP https://samate.nist.gov/SARD/testsuite.php
- CWE "Demonstrative Examples" for individual entries https://cwe.mitre.org
- Intentionally vulnerable distros, e.g. Damn Vulnerable Linux or https://www.vulnhub.com/

References/Links: Advisory & Disclosure Advice

- Kymberlee Price, "Writing Vulnerability Reports that Maximize Your Bounty Payouts"
  - https://youtu.be/zyp2DoBqaO0
- John Stauffacher, "Geekspeed's Advice for Writing a Great Vulnerability Report"
  - https://blog.bugcrowd.com/advice-for-writing-a-great-vulnerability-report/
- OSVDB "Researcher Security Advisory Writing Guidelines"
  - https://blog.osvdb.org/2013/01/15/researcher-security-advisory-writing-guidelines
- CVRF (Common Vulnerability Reporting Framework)
  - http://www.icasi.org/cvrf/
- Christey advisory format suggestion (2003)
  - http://www.securityfocus.com/archive/1/344559

References/Links: Disclosure Processes

- http://howdoireportavuln.com/
- http://attrition.org/errata/legal_threats/
- ISO 29147 vulnerability disclosure standard http://www.iso.org/iso/catalogue_detail.htm?csnumber=45170
- Christey/Wysopal IETF draft https://tools.ietf.org/html/draft-christey-wysopal-vuln-disclosure-00
- RFPolicy 2.0 https://dl.packetstormsecurity.net/papers/general/rfpolicy-2.0.txt