This Is The End

Putting CS161 in Context: Nick's Self Defense Strategies...

- ***How*** and ***why*** do I protect myself online and in person...
  - ***How*** I decide what to prepare for (and what not to prepare for)
  - ***Why*** I've drunk the Apple Kool-Aid™
  - ***Why*** I use my credit card everywhere but not a debit card
  - ***What*** I would do as a real-world software engineer
- And my future nightmares:
  - What do I see as the security problems of tomorrow...

My Personal Threats:
The Generic Opportunist

- There are a ***lot*** of crooks out there
  - And they are rather organized...
- But at the same time, these criminals are generally economically rational
  - So ***this*** is a bear race: I don't need perfect security, I just need ***good enough*** security
- I use this to determine security/convenience tradeoffs all the time
  - So no password reuse (use a password manager instead)
  - Full disk encryption & passwords on devices:
    Mitigates the damage from theft
  - Find my iPhone turned on:
    Increases probability of theft recovery

My Personal Threats: The ***Lazy*** Nation State

- OK, I'm a high ***enough*** profile to have to worry about the "Advanced Persistent Threats"...
  - Trying for a reasonably high profile on computer policy issues
  - A fair amount of stuff studying the NSA's toys and other nation-state tools
  - But only at the Annoying Pestilent Teenager level:
    I'm worth some effort but not an extraordinary amount
- So its only ***slightly*** more advanced than the everyday attackers...
  With one ***huge*** exception: Crossing borders
  - Every nation maintains the right to conduct searches of all electronic contents at a border checkpoint

My Border Crossing Policy: Low Risk Borders

- Not very sensitive borders: Canada, Europe, US, etc...
  - I use full disk encryption with strong passwords on all devices
    - Primary use is to prevent theft from also losing data
  - I have a ***very robust*** backup strategy
    - Time machine, archived backups in a safe deposit box, working sets under version control backed up to remote systems...
- So, as the plane lands:
  - Power off my devices
    - Device encryption is only ***robust*** when you aren't logged in
  - Go through the border
- If my devices get siezed...
  - "Keep it, we'll let the lawyers sort it out"

High Risk Borders

- Middle East or, if, god forbid, I visit China or Russia...
  - Need something that doesn't just resist compromise but can also ***tolerate compromise***
- A "burner" iPhone SE with a Bluetooth keyboard
  - The cheapest secure device available
  - Set it up with ***independent*** computer accounts for both Google and Apple
    - Temporarily forward my main email to a temporary gmail account
    - All workflow accessible through Google apps on that device
  - Bluetooth keyboard does leak keystrokes, so don't use it for passwords but its safe for everything else
- Not only is this device very hard to compromise...
  - But there is very low value in ***successfully compromising it***: The attacker would only gain access to dummy accounts that have no additional privileges
- And bonus, I'm not stuck dragging a computer to the ski slopes in Dubai...
  - Since the other unique threat in those environments is the "Evil maid" attack

My Personal Threats: The Russians... Perhaps

Click Trajectories: End-to-End Analysis of the Spam Value Chain

Kirill Levchenko* Andreas Pitsillidis* Neha Chachra* Brandon Enright* Márk Félegyházi‡ Chris Grier†
Tristan Halvorson* Chris Kanich* Christian Kreibich†◇ He Liu* Damon McCoy*
Nicholas Weaver†◇ Vern Paxson†◇ Geoffrey M. Voelker* Stefan Savage*

- This is the paper that killed the Viagra® Spam business
  - A $100M a year set of organized criminal enterprises in Russia... And they put the ***organized*** in organized crime...
- I've adopted a ***detection and response*** strategy:
  - The Russians have higher priority targets: The first authors, the last authors, and Brian Krebs
  - If anything suspicious happens to Brian, Kirill, or Stefan, ***then*** I will start sleeping with a rifle under my bed

Excluded Threats: Sorta…

- Intimate Partner Threats…
  - But I've had at least one colleague caught up with that.
- Agressive Nation States…
  - $50M will buy the latest version of Pegasus malcode
- The US government…
  - The surveillance powers of the US government are awesome and terrifying to behold…

Passwords and 2-Factor....

- I ***love*** security keys:
  - I have one in each of my main computers...
    and one on the keychain
- ANY site that supports multiple security keys has that as the primary 2-factor method
  - Both more convenient ***and*** more secure than the alternatives...
- I also religiously use a password manager
  - "Credential stuffing" is the biggest threat individuals face
- I personally use 1password, but others are equally good
  - In particular you can get LastPass premium through software@berkeley

The Apple Kool-Aid...

- The iPhone is perhaps the most secure commodity device available...
  - Not only does it receive patches but since the 5S it gained a dedicated cryptographic coprocessor
- The ***Secure Enclave Processor*** is the trusted base for the phone
  - Even the main operating system isn't fully trusted by the phone!
- A dedicated ARM v7 coprocessor
  - Small amount of memory, a true RNG, cryptographic engine, etc...
  - Important: A collection of ***randomly*** set fuses
    - Should not be able to extract these bits without taking the CPU apart:
      Even the Secure Enclave can only use them as keys to the AES engine, not read them directly!
  - But bulk of the memory is shared with the main CPU
- GOOD documentation:
  - The iOS security guide is something you should at least skim….
    I find that the design decisions behind how iOS does things make ***great*** final exam questions
- But it isn't perfect: Nation-state actors will pay big $ for exploits
  - So keep it patched
  - And iOS 14.5: New Emoji and ***turning on PAC all over the place!***

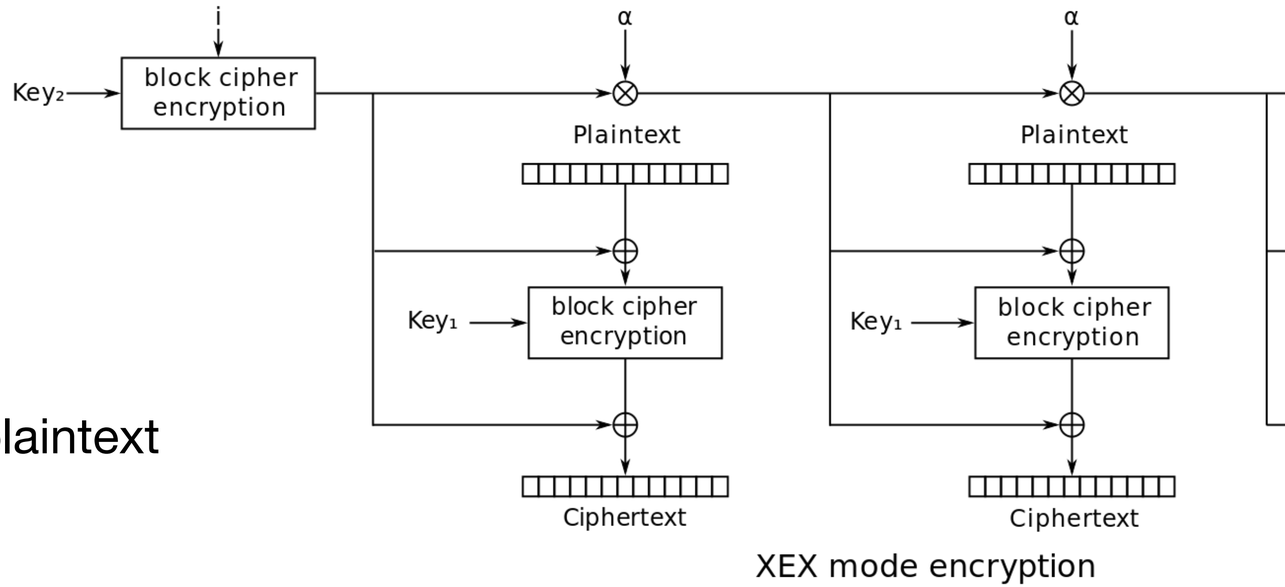
The Roll of the SEP...
Things ***too important*** to allow the OS to handle

- Key management for the encrypted data store
  - The CPU has to ask for access to data!
- Managing the user's passphrase and related information
- User authentication:
  - ***Encrypted*** channel to the fingerprint reader/face recognition camera
- Storing credit cards
  - ApplePay is cheap for merchants ***because it is secure***:
    Designed to have very low probability of fraud!

AES-256-XEX mode

- A ***confidentiality-only*** mode developed by Phil Rogaway...
  - Designed for encrypting data within a filesystem block ***i***
    - Known plaintext, when encrypted, can't be replaced to produce known output, only "random" output
  - Within a block: Same cypher text implies different plaintext
  - Between blocks: Same cypher text implies nothing!
  - α is a galios multiplication and is very quick:

    In practice this enables parallel encryption/decryption



XEX mode encryption

- Used by the SEP to encrypt its own memory...
  - Since it has to share main memory with the main processor
- Opens a limited attack surface from the main processor:
  - Main processor can replace 128b blocks with ***random*** corruption

User Passwords...

- Data is encrypted with the user's password
  - When you power on the phone, most data is completely encrypted
- The master key is PBKDF2(password || on-chip-secret)
  - So you need ***both*** to generate the master key
  - Some other data has the key as F(on-chip-secret) for stuff that is always available from boot
- The master keys encrypt a block in the flash that holds all the other keys
  - So if the system can erase this block effectively it can erase the phone by erasing just one block of information
- Apple implemented ***effaceable storage***:
  - After x failures, OS command, whatever...
    Overwrite that master block in the flash securely
  - Destroy the keys == erase everything!

Background: FBI v Apple

- A "terrorist" went on a rampage with a rifle in San Bernardino...
  - Killed several people before being killed in a battle with police
- He left behind a work-owned, passcode-locked iPhone 5 in his other car...
- The FBI ***knew*** there was no valuable information on this phone
  - But never one to refuse a good test case, they tried to compel Apple in court to force Apple to unlock the phone...
- Apple has serious security on the phone
  - Effectively everything is encrypted with PBKDF2(PW||on-chip-secret): >128b of randomly set microscopic fuses
    - Requires that ***any*** brute force attack either be done on the phone or take apart the CPU
  - Multiple timeouts:
    - 5 incorrect passwords -> starts to slow down
    - 10 incorrect passwords -> optional (opt-in) erase-the-phone

What the FBI wanted...

- Apple provides a ***modified*** version of the operating system for the Secure Enclave which...
  - Removes the timeout on all password attempts
  - Enables password attempts through the USB connection
  - Enables an ***on-line*** brute force attack..
    but with a 4-digit PIN and 10 tries/second, you do the math...
- Apple ***cryptographically signs the rogue OS version!***
  - A horrific precedent:
    This is ***requiring*** that Apple both create a malicious version of the OS and sign it
    - If the FBI could compel Apple to do this, the NSA could too...
      It would make it ***impossible*** to trust software updates!

Updating the SEP To Prevent This Possibility...

- The SEP will only accept updates ***signed by Apple***
- The FBI previously asked for this capability against a non-SEP equipped phone
  - "Hey Apple, cryptographically sign a corrupted version of the OS so that we can brute-force a password"
- How to prevent the FBI from asking again?
- Now, an OS update (either to the base OS and/or the SEP) requires the user to be logged in ***and input the password***
  - "To rekey the lock, you must first unlock the lock"
  - The FBI can only even ***attempt*** to ask before they have possession of the phone since once they have the phone they must also have the passcode
  - So when offered the chance to try again with a "Lone Wolf's" iPhone in the Texas church shooting, they haven't bothered
- At this point, Apple has now gone back and allows auto-updates for the base OS
  - (but probably not the SEP)

The Limits of the SEP...
The host O/S

- The SEP can keep the host OS from accessing things it shouldn't...
  - Credit cards stored for ApplePay, your fingerprint, etc...
- The SEP can ***use*** the random secret but not read it...
  - Can encrypt with it but can't read it
- But it can't keep the host OS from things it is supposed to access
  - All the user data when the user is logged in...
- So do have to rely on the host OS as part of ***my*** TCB
  - Fortunately it is updated continuously when vulnerabilities are found
    - Apple has responded to the discovery of very targeted zero-days in <30 days
  - And Apple has both good sandboxing of user applications and a history of decent vetting
    - So the random apps are ***not*** in the Trusted Base.

The SEP and Apple Pay

- The SEP is what makes ApplePay possible
  - It handles the authentication to the user with the fingerprint reader/face reader
    - Verifies that it is the user not somebody random
  - It handles the emulation of the credit card
    - A "tokenized" Near Field Communication (NFC) wireless protocol
    - And a tokenized public key protocol for payments through the app
- ***Very hard*** to conduct a fraudulent transaction
  - Designed to enforce user consent at the SEP
- ***Disadvantage***: The fingerprint reader is part of the trust domain
  - Which means you need special permission from Apple to replace the fingerprint reader when replacing a broken screen

I ***love*** ApplePay...

- It is a ***faster*** protocol than the chip-and-signature
  - NFC protocol is designed to do the same operation in less time because the protocol is newer
- It is a ***more secure*** protocol than NFC on the credit card
  - Since it actually enforces user-consent
- It is more ***privacy sensitive*** than standard credit card payments
  - Generates a unique token for each transaction:
    Merchant is not supposed to link your transactions
- Result is its low cost:
  - Very hard to commit fraud -> less cost to transact
- I use it on my watch all the time

Transitive Trust in the Apple Ecosystem...

- The most trusted item is the iPhone SEP
  - Assumed to be rock-solid
  - Fingerprint reader/face reader allows it to be convenient
- The watch trusts the phone
  - The pairing process includes a cryptographic key exchange mediated by close proximity and the camera
  - So Unlock the phone -> Unlock the watch
- My computer trusts my watch
  - Distance-bounded cryptographic protocol
  - So my watch unlocks my computer
- Result? I don't have to keep retyping my password
  - Allows the use of ***strong passwords everywhere*** without driving myself crazy!

Credit Card Fraud

- Under US law we have very good protections against fraud
  - Theoretical $50 limit if we catch it quickly
  - $0 limit in practice
- So cost of credit card fraud for me is the cost of recovery from fraud
  - Because fraud ***will happen***:
  - The mag stripe is all that is needed to duplicate a swipe-card
    - And you can still use swipe-only at gas pumps and other such locations
  - The numbers front and back is all that is needed for card-not-present fraud
    - And how many systems
- What are the recovery costs?
  - Being without the card for a couple of days...
    - Have a second back-up card
  - Having to change all my autopay items...
    - Grrrr....

But What About "Debit" Cards?

- Theoretically the fraud protection is the same...
- But two caveats...
  - It is easier to not pay your credit card company than to claw money back from your bank...
  - Until the situation is resolved:
    - Credit card? It is the credit card company's money that is missing
    - Debit card? It is ***your*** money that is missing
- Result is debit card fraud is more transient disruptions...

So Two Different Policies...

- Credit card: Hakunna Matata!
  - I use it without reservation, just with a spare in case something happens
  - Probably 2-3 compromise events have happened, and its annoying but ah well
    - The most interesting was $1 to Tsunami relief in 2004...
      was a way for the attacker to test that the stolen card was valid
- Debit card: Paranoia-city...
  - It is an ATM-ONLY card (no Visa/Mastercard logo!)
  - It is used ONLY in ATMs belonging to my bank
    - Reduce the risk of "skimmers": rogue ATMs that record cards and keystrokes

And Banking Information...

- ***Watch*** your bank account transactions
  - In case of fraud, you have protection but you need to notice
- Bank accounts are particularly vulnerable:
  - The information on a cheque is all the data needed to transfer to/from an account!

Assume *GASP* I have to Work for a Living...

- I get to my new work environment and have to adopt/start a project...
  - I am going to want to prevent as many security problems as possible before they become problems...
- Two options:
  - New Project
  - Existing Project

New Project:
Chose Your Language...

- Question: "Do I need real-time (<10ms) response?"
  - More precisely: If my program pauses for 10-50ms does anyone care?
- If the answer is "NO", I can use a garbage collected language
  - My personal preference will be go:
    The concurrency model is such that I can easily take advantage of modern multicore systems
  - And how many bugs did the type-system catch?
- If the answer is "Yes"...
  - The old answer would be "use C/C++": it is the lack of a GC that tended to require C/C++ here...
  - But today: Rust. Learning curve is a @#)(*#)(* (So I haven't learned it yet)

Existing Project: C/C++

- Step 1: Turn on ***all*** compiler and OS mitigations in the build flow
  - Stack canaries: Stop simple stack overflows
    - There are "security" appliances from major vendors like Cisco that don't do this!
  - ASLR: adds defense in depth
    - Need two vulnerabilities: one which allows reading memory in order to break randomization
  - If possible: Run on a 64b platform & OS
  - If the stars align: Run on Arm 8.3 and turn on PAC
- Step 2: Add rate limits
  - Change any auto-restart after crash to add an increasing delay:
    First 10 immediate
    Later an exponential increase (1, 2, 4, 8, 16 minutes...)
  - Seriously disrupts brute-force attacks

Existing Project: C/C++

- Look at the continuous integration testing flow...
  - If you don't have such a testing flow already, create one!
    - Both explicit test cases, testing code, and fuzz testing... Do it all!
- Once you do, add a few more machines to your test infrastructure...
  - Now on those machines run the same tests but within **`valgrind`** or a similar tool
  - Valgrind slows down the program by an order of magnitude so you can't run it on your main flow, but it will catch a lot of memory problems before they become problems!
- Aside: Computers are cheap!
  - "Oh, to do this I need a 8-core computer with 32 GB of RAM and a 1 TB ssd. And ideally quiet because I need to stick it under my desk? Hey boss, I need an $850 computer..."

Existing Project: Command Injection

- Grep for every call to **`system`** and direct SQL
  - Search the entire code-base
- Now refactor ***every instance*** into a call to **`execve`** or prepared statements
  - Do ***not accept the excuse*** that "this particular invocation is known safe" because...
- Now do some include/compiler/language tricks so any code which calls **`system`** etc fails to build!
  - And if you are doing a new project, make sure that is already in place!

New or Existing Project: Web Security...

- Time to block common web exploits:
  - Turn on HTTPS only: Use LetsEncrypt
- Actually require a modern browser to access:
  - Enables mitigations not otherwise possible
- Set ***all*** cookies right:
  - Every one should have **`secure`** and **`same-site`** set
    - Don't want to have to distinguish between "important" and "unimportant"!
- Ensure that all toolkits have CSRF protection as well
  - Because the boss may overrule the "only modern browsers" restriction!

New or Existing Project: Content Security Policy...

- Now the annoying part: Enabling a content-security-policy!
  - Well, annoying if an existing project
- For CSP to prevent XSS we can't have ***any*** inline JavaScript!
  - All JavaScript needs to be in separate files not inline in order to allow CSP to prevent xss attacks
- Also make sure ***all*** user input passes through the XSS-busting filter rules
  - It may be a "denylist" rule but it is a well structured one

And a bit more hardening... Containment and sandboxing

- All servers should run in a **`chroot`** jail and execute as a minimum privileged user process after that
  - Limits access to a subsection of the filesystem:
    No more path traversal problems and a lot of mitigation
  - Limit the rights of the user account:
    Even a compromise now has to work within bounds
- Even better, can you use the chrome sandbox?
  - Limits a program to only a fixed set of defined capabilities
- Idea is even if you exploit the program the attacker has to escape the sandbox as well

And Now:
Ask Me Anything!