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Speaking with Cryptographic Oracles

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The Speaker and the Presentation

A quick introduction and a few distinctions

The Speaker

- **Daniel Crowley**
- **Web application security d00d**
- **IANAC (I am not a cryptographer)**

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The Presentation Topic

- **Finding and exploiting:**
  - Encryption Oracles
  - Decryption Oracles
  - Padding Oracles
- **With little to no cryptographic knowledge**
  - More crypto knowledge, more useful attacks

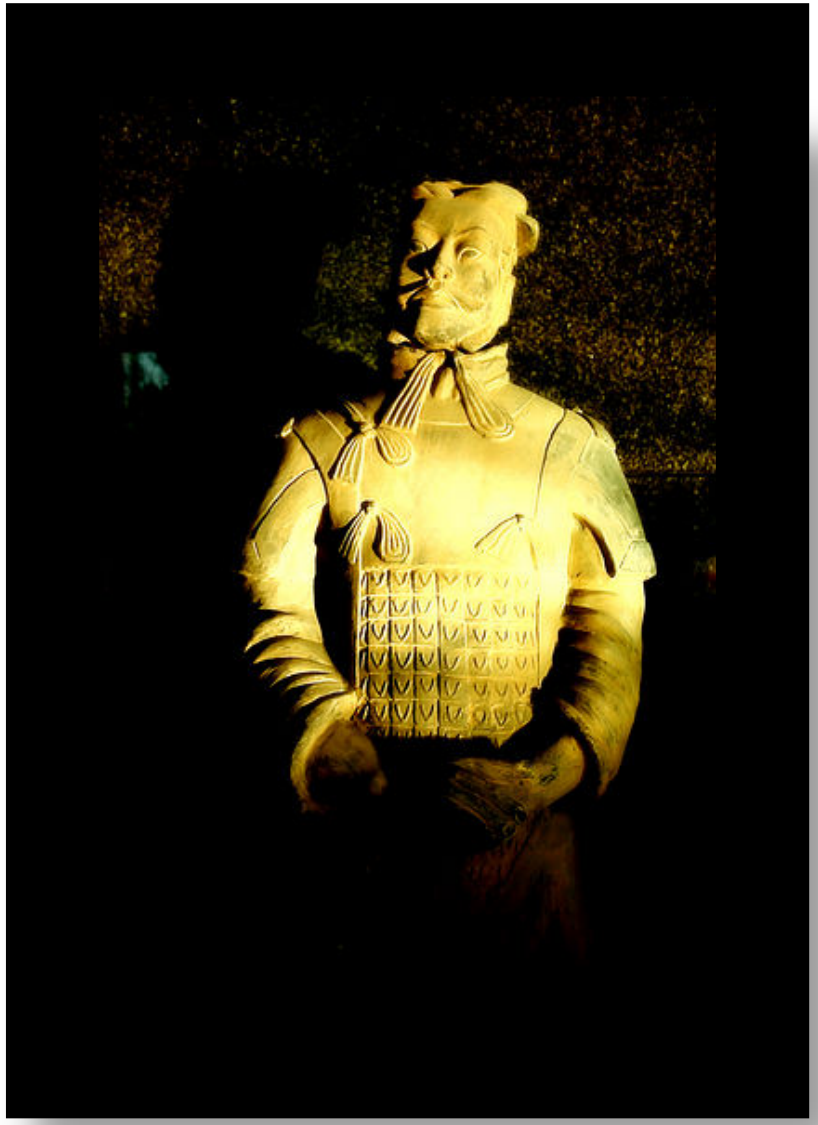
NOT the Presentation Topic

- **The Oracle**
  - We are not being harvested for energy by robot overlords
    - Maybe
- **ORACLE**
  - If you Google "<any crypto word> oracle" it's all you find
- **Google, the Internet Oracle**
  - While awesome, not what we're talking about

NOT the Presentation Topic

- **Crypto g00r00s like Adi Shamir**
  - While also awesome and totally related, not the topic
- **New attacks on old crypto**
  - Mistakes are easy enough to make in implementation
- **How Padding Oracle attacks work**
  - Too much time to explain
  - Too many good resources

For the people playing drinking games



- **APT iPad**
  - APT China, cyber-war
- **Cloud mobile botnet**
  - Cloud cloud Twilight APT Sun Tzu
    - RSA HBGary botnet cloud APT
- **Cyber-war?**
- **LulzSec???**

APT China cyberwar weeaboo, cloud mobile LulzSec.

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Primer on Cryptographic Terms

And some basic mistakes

Very basic terms

- **Cipher**
  - A system for scrambling and unscrambling data to protect it
- **Key**
  - A variable used to permute the cipher
- **Initialization Vector**
  - A second variable used to randomize the cipher
- **Plaintext**
  - The data in readable form
- **Ciphertext**
  - The data in unreadable form
- **Encryption**
  - Turning something you can read into something you can't
- **Decryption**
  - Turning something you can't read into something you can

Stream and Block ciphers

Stream

- **Encrypt one character at a time**
- **Key is used to generate pseudo-random numbers**
- **Those numbers are used to transform plaintext to ciphertext**

Block

- **Encrypt X characters at a time**
  - X is the block size
- **Key is used to directly transform plaintext to ciphertext**

Very basic mistakes

- **Using a keyless cipher**
  - Completely insecure if cipher is ever discovered
- **Reusing keys and/or IVs**
  - Makes Oracle attacks far more dangerous
  - IV reuse can seriously weaken stream ciphers
    - Think WEP
- **Leaking data from crypto operations**
  - Foundation for Oracle attacks

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What is an Oracle?

A system which takes queries and provides answers

- **Queries might be**
  - Plaintext
  - Ciphertext
- **Answers might be**
  - Corresponding plaintext
  - Corresponding ciphertext
  - Info about operation
  - Sample from PRNG

Picture by D Sharon Pruitt – Creative Commons

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Seek the Oracle

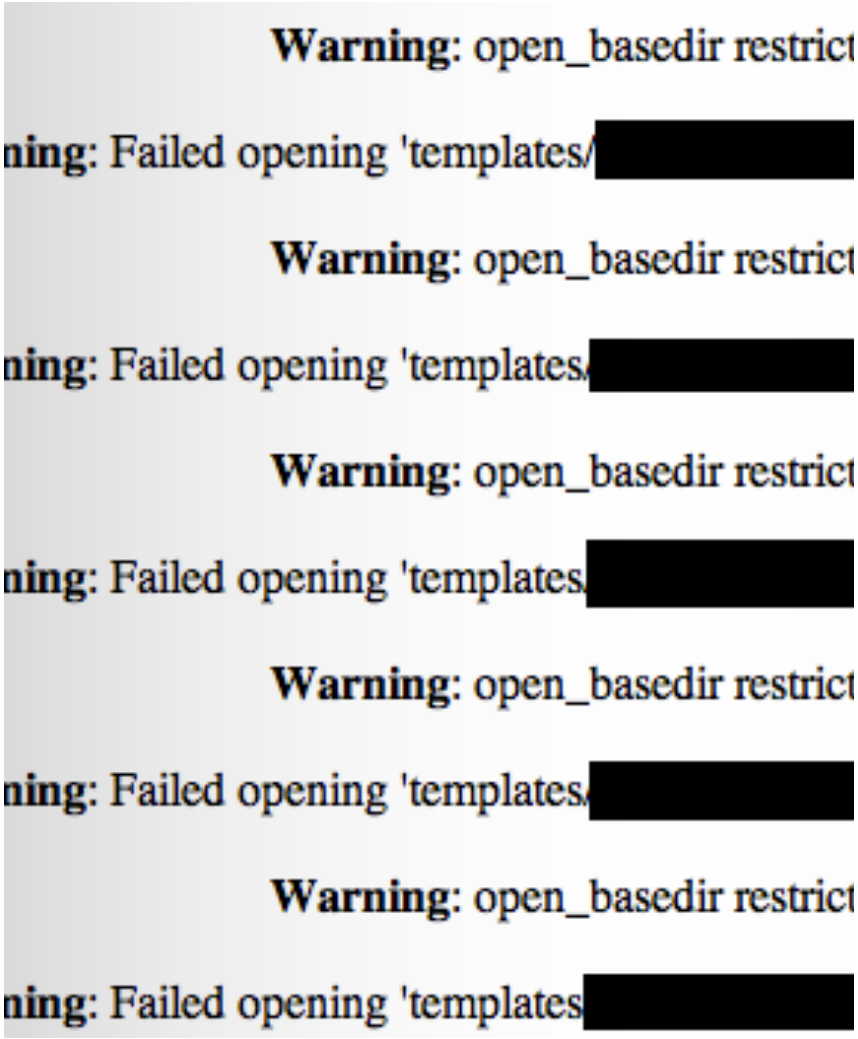
How to identify cryptographic Oracles
From a black-box perspective

Decryption Oracles: Identify input

- **Identify where encrypted input occurs**
  - Identify all points of user input
    - For Web apps: GET, POST, URL, Cookie, headers
  - Identify those which may be encrypted
    - Encrypted data is generally encoded
      - Base64
      - ASCII hex
      - URL encoding
    - Decoded data is likely encrypted if seemingly random
    - Modification of values may result in decryption-related errors

Decryption Oracles: Find decrypted output

- **May be reflected**
  - Normal output
  - Error
- **May be given in later response**
- **May be inferred from modified output**
- **May be stored and not shown**
  - Additional vulnerabilities may reveal output



Decryption Oracles: An example

Scenario

- **Consider "GetPage.php?file=<encrypted_stuff>"**
  - Opens a file to be included based on encrypted input
    - Allows for quick page additions
    - Prevents file inclusion attacks…?
    - Assumes properly encrypted input is sanitary
  - Errors are verbose

Usage

- **Feed the script some ciphertext**
  - Record the "file" the error tells you wasn't found

Encryption Oracles: Find encrypted data

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- **Often found in**
  - Cookies
  - Hidden variables
  - Databases
  - File resident data

Encryption Oracles: Determine point of entry

- **Frequently encrypted data**
  - Client-side state variables
  - Passwords
  - Financial data
  - Anything sufficiently sensitive
- **Being encrypted is not enough**
  - We need to be able to manipulate it
  - And see the ciphertext

Encryption Oracles: An example

Scenario

- **Consider "auth" cookie, encrypted**
  - Username + ":" + password_hash + ":" + timestamp
- **Assume usernames can't contain ":" character**
  - No delimiter injection ☹
- **Timestamp to control expiration**

Usage

- **Register with any username, log in**
- **Copy cookie value and replace any encrypted input with it**
  - Can't use colons or control suffix
    - Might not matter

Padding Oracles

- **Input must be encrypted**
- **Must be a padded block cipher**
- **Valid vs invalid padding is distinguishable**

- **Padding Oracles are essentially decryption oracles**
  - Using the CBC-R technique they are also encryption Oracles
    - May be limited in that the first block will be garbled

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Exploiting Cryptographic Oracles

Against bad crypto and bad crypto usage

Attack 0: Crypto recon examples

- **Check for static key, IV, and deterministic cipher**
  - Encrypt the same plaintext twice
  - Check to see if they are identical
- **Check for stream vs. block ciphers**
  - Encrypt plaintexts of various sizes
  - Compare plaintext size to ciphertext size
- **Check for ECB block cipher mode**
  - Encrypt repeating plaintext blocks
  - Look for repetitive ciphertext

Attack 1: Bad Algorithms

- **Occasionally, people try to make their own algorithms**
  - And they're not cryptographers
    - And it doesn't end well

Real homespun crypto seen in the wild:

- **Each character is replaced with a "random" but unique selection of two or three characters**
- **Characters are separated by the letter "K"**

"hello" might become "KqIKefKPrPKPrPKuJXK"

Attack 1: Bad Algorithms

Is there substitution?

Submit "AAAA" : Get "KLoKLoKLoKLoK"

- **There is!**
- **We can already see patterns, too**

Is there transposition?

Submit "AABB" : Get "KLoKLoKaBeKaBeK"

- **No transposition**
- **We can see more patterns**
- **The "K" seems to be a delimeter**
- **Substitution doesn't change on position**
  - One replacement per letter

Attack 1: Bad Algorithms

Submit "BABA" : Get "KaBeKLoKaBeKLoK"

- **Exactly what we expected**

Submit "abcdefghi…XYZ0123456789" : Get entire key!

- **We now submit one of every character in sequence**
- **The Oracle tells us what each maps to**

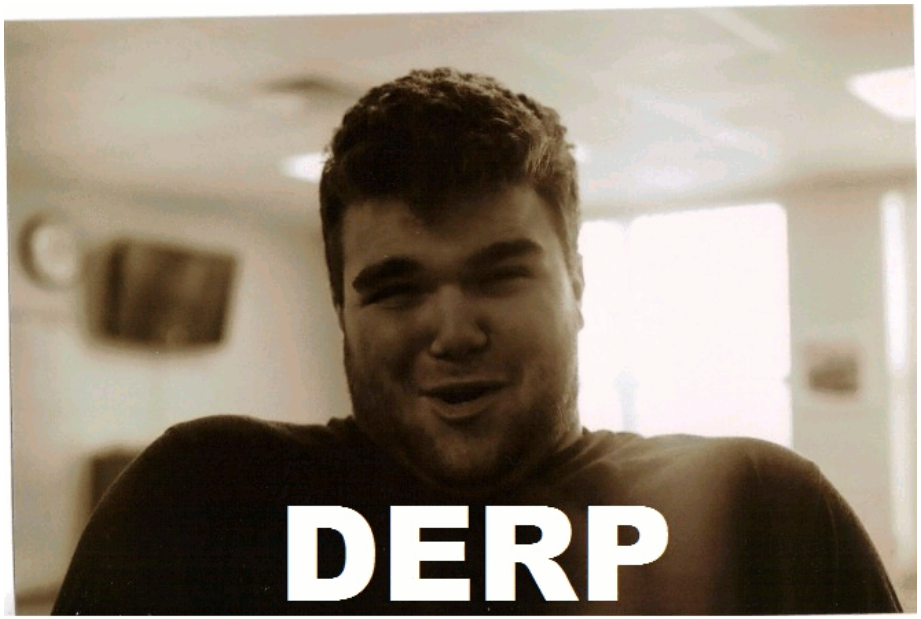
Attack 1 and a half: Revenge of Bad Algorithms

Others use a simple xor operation to encrypt data

P xor B = C

C xor B = P

C xor P = B



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Attack 1.75: Bride of Bad Algorithms

For some simple ciphers like xor

Encryption = Decryption

THUS

Encryption Oracle = Decryption Oracle

THUS

Such ciphers are made completely useless by leaking output

THUS

For God's sake stop using xor

Attack 1: Bad Algorithms

DEMO

Attack 2: Trusted Encrypted Input

- **People tend to reuse keys and IVs**
  - If we can encrypt arbitrary data in one place
  - It may work in another
- **If devs don't think you can mess with input**
  - They probably won't sanitize it
  - Encrypted inputs with MAC aren't totally tamper-proof

Attack 2: Trusted Encrypted Input

- **Encrypted password with MAC in cookie**
  - Checked against database on each request needing auth

- **Find encryption Oracle with the same keys & IV**
  - Use encryption Oracle to encrypt ` or 1=1--
  - Plug resulting value into cookie
  - *Laugh all the way to the bank*

Attack 2: Trusted Encrypted Input

DEMO

Attack 3: Let the client have it, it's encrypted

I. **Find a decryption Oracle**

II. **Find encrypted data**

III. **Decrypt that sucka**

IV. **?????**

V. **PROFIT!!!**

This attack also relies on key/IV reuse

Attack 3: Let the client have it, it's encrypted

DEMO

What encryption?

- **If you can find**
  - An encryption Oracle
  - A decryption Oracle
- **You can encrypt or decrypt any data**
  - As long as keys and IVs are reused
    - Algorithm doesn't matter
    - Padding doesn't matter
    - Cipher mode doesn't matter

All encryption which uses the same key and IV is now useless

Questions?

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