CSE 484 / CSE M 584: Computer Security and Privacy

Autumn 2019

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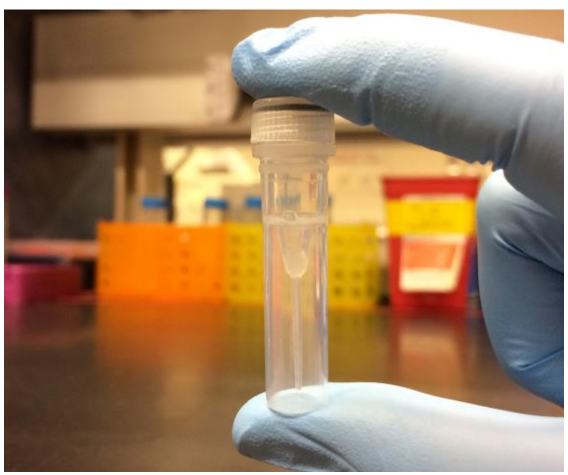
Thanks to Dan Boneh, Dieter Gollmann, Dan Halperin, John Manferdelli, John Mitchell, Franzi Roesner, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Announcements

- Quiz Section Tomorrow: Try Target 5 in Advance (and Target 6 + 7, if time)
- This Week My Office Hours: W 12:30, starting in CSE1 403, then to CSE2 307 at 1pm
- (TA office hours as usual, and great place for lab discussions)
- HW1 – TAs very proactive (thanks!!), but I still want to look at them so will mute again, go through them all, then unmute

Research Discussions

- Monday (10/14): Peter Ney on Bio-Cyber Security and Cell Site Simulators
- Monday (10/21): Karl Koscher on Automotive Cyber Security
- Wednesday (10/23): Ivan Evtimov on Adversarial Machine Learning
- Monday (10/28): Emily McReynolds on Law and Policy



Broad Classes of Security Research

- Measurement
- Analysis / attack exploration
- Building secure systems
- Human-computer interaction

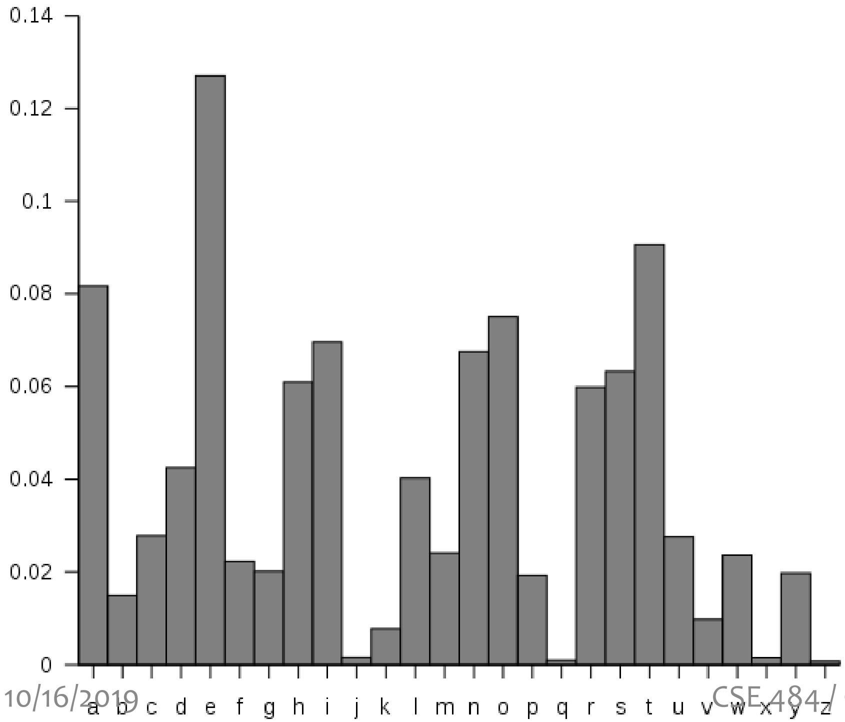
- Guest lectures connected to threat modeling and to buffer overflows as well

History: Substitution Cipher

- Superset of shift ciphers: each letter is substituted for another one.
- Add a secret key
- Example:
  - Plaintext: `ABCDEFGHIJKLMNOPQRSTUVWXYZ`
  - Cipher: `ZEBRASCDFGHIJKLMNOPQTUVWXY`
- "State of the art" for thousands of years

History: Substitution Cipher

- What is the key space? 26! ~= 2^88
- How to attack?
  - Frequency analysis.



Bigrams:

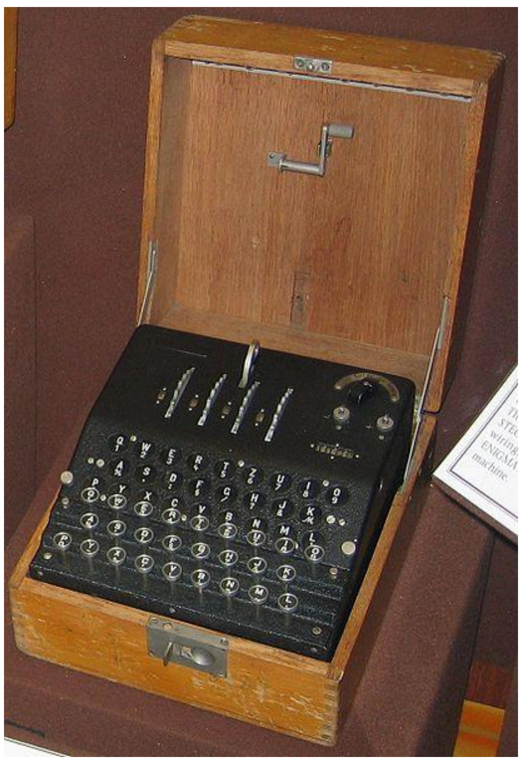
th 1.52%	en 0.55%	ng 0.18%
he 1.28%	ed 0.53%	of 0.16%
in 0.94%	to 0.52%	al 0.09%
er 0.94%	it 0.50%	de 0.09%
an 0.82%	ou 0.50%	se 0.08%
re 0.68%	ea 0.47%	le 0.08%
nd 0.63%	hi 0.46%	sa 0.06%
at 0.59%	is 0.46%	si 0.05%
on 0.57%	or 0.43%	ar 0.04%
nt 0.56%	ti 0.34%	ve 0.04%
ha 0.56%	as 0.33%	ra 0.04%
es 0.56%	te 0.27%	ld 0.02%
st 0.55%	et 0.19%	ur 0.02%

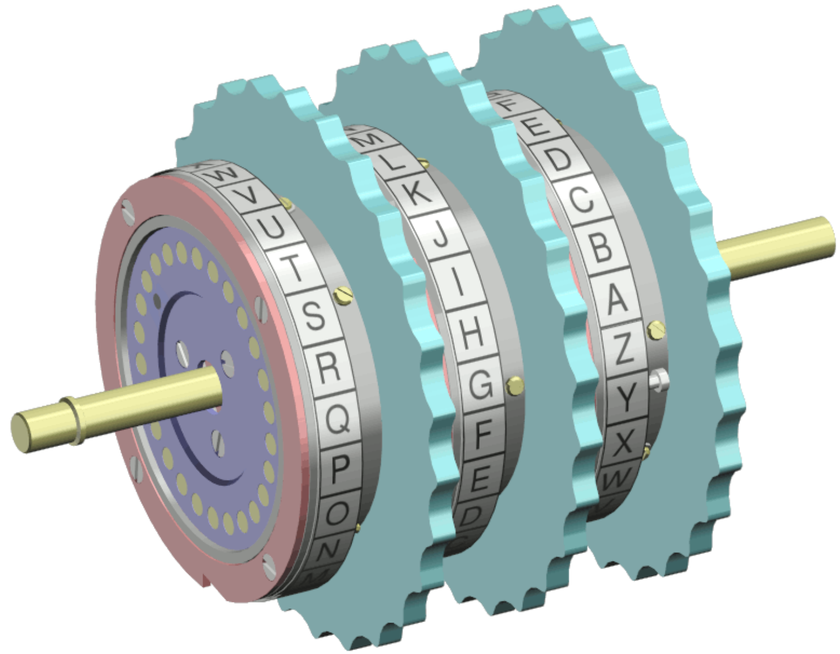
Trigrams:

1. the	6. ion	11. nce
2. and	7. tio	12. edt
3. tha	8. for	13. tis
4. ent	9. nde	14. oft
5. ing	10.has	15. sth

History: Enigma Machine

Uses rotors (substitution cipher) that change position after each key.





Key = initial setting of rotors

Key space?

26^n for n rotors

Received April 4, 1977

A Method for Obtaining Digital Signatures and Public-Key Cryptosystems

R.L. Rivest, A. Shamir, and L. Adleman*

Abstract

An encryption method is presented with the novel property that publicly revealing an encryption key does not thereby reveal the corresponding decryption key. This has two important consequences:

1. Couriers or other secure means are not needed to transmit keys, since a message can be enciphered using an encryption key publicly revealed by the intended recipient. Only he can decipher the message, since only he knows the corresponding decryption key.
2. A message can be "signed" using a privately held decryption key. Anyone can verify this signature using the corresponding publicly revealed encryption key. Signatures cannot be forged, and a signer cannot later deny the validity of his signature. This has obvious applications in "electronic mail" and "electronic funds transfer" systems.

How Cryptosystems Work Today

- Layered approach:
  - **Cryptographic primitives**, like block ciphers, stream ciphers, hash functions, and one-way trapdoor permutations (examples: AES, SHA256, RSA)
  - **Cryptographic protocols**, like CBC mode encryption, CTR mode encryption, HMAC message authentication
- Public algorithms (Kerckhoff's Principle)
- Security proofs based on assumptions (not this course)

- Be careful about inventing your own (fun, but challenging ☺)
- Above terms will make more sense later – right now probably looks like a foreign language ☺

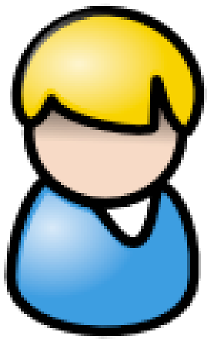
Kerckhoff's Principle

- Security of a cryptographic object should depend only on the secrecy of the secret (private) key.
- Security should not depend on the secrecy of the algorithm itself.

Alice and Bob

- Archetypical characters

Alice



Bob

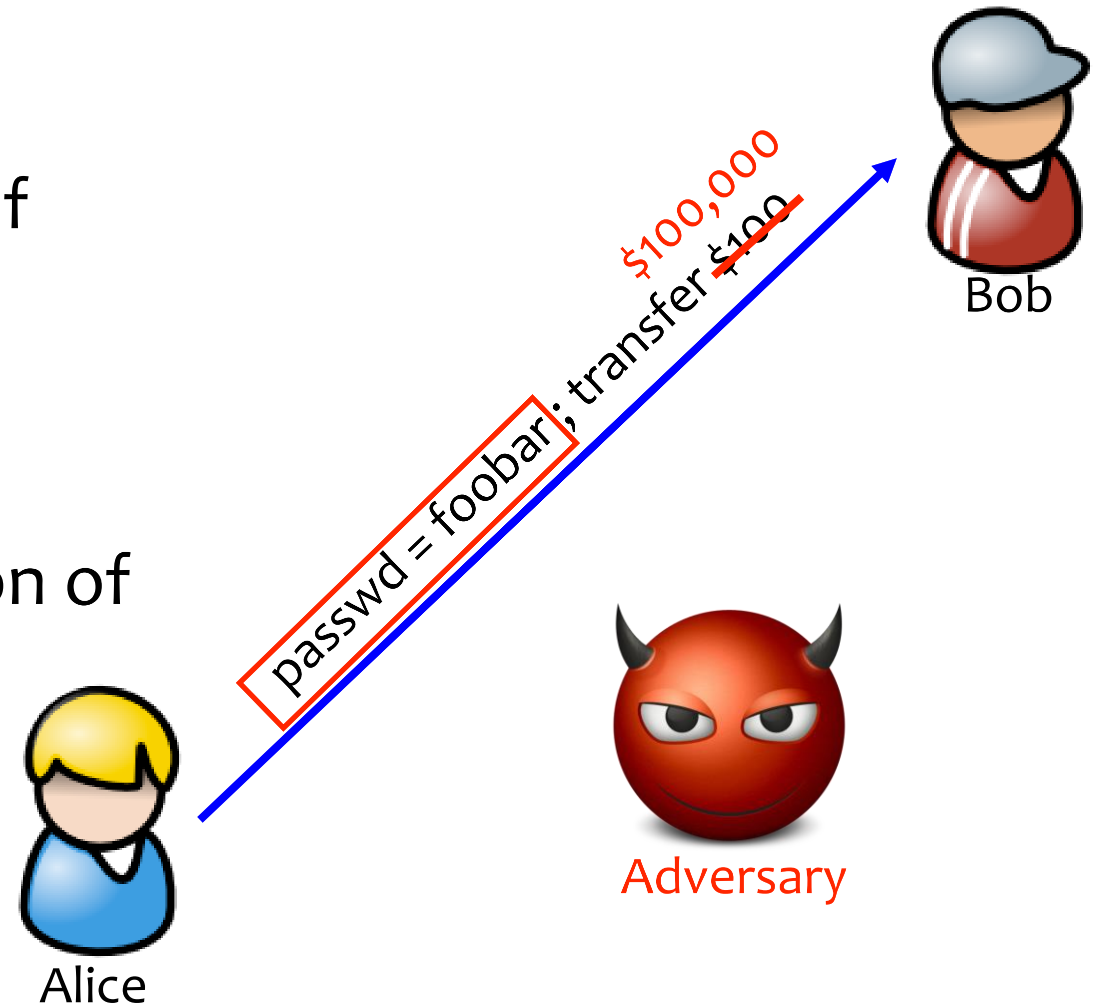
Eve
(eavesdrops)

Mallory
(is malicious)

Common Communication Security Goals

Privacy of data:
Prevent exposure of information

Integrity of data:
Prevent modification of information

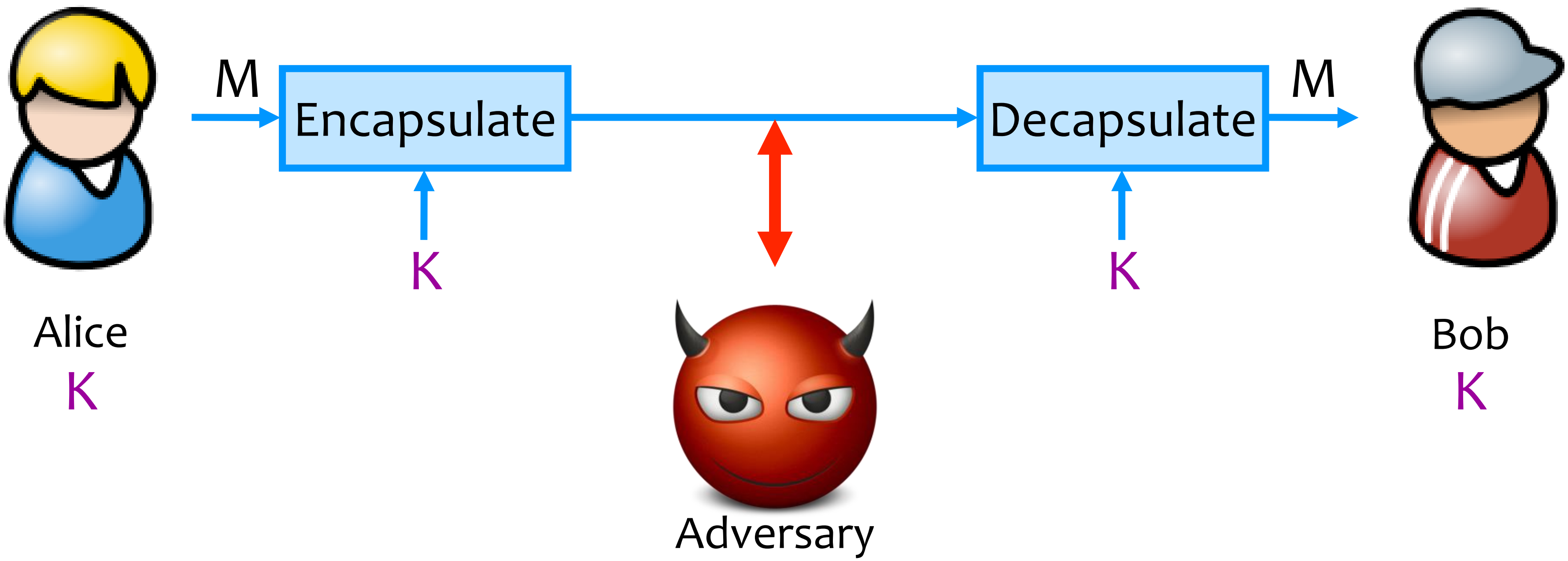


Flavors of Cryptography

- Symmetric cryptography
  - Both communicating parties have access to a shared random string K, called the key.
- Asymmetric cryptography
  - Each party creates a public key pk and a secret key sk.
  - Hard concept to understand!! And revolutionary. Inventors (in non-intelligence community) received Turing Awards.
  - Don’t worry if the “how” does not make sense yet ☺

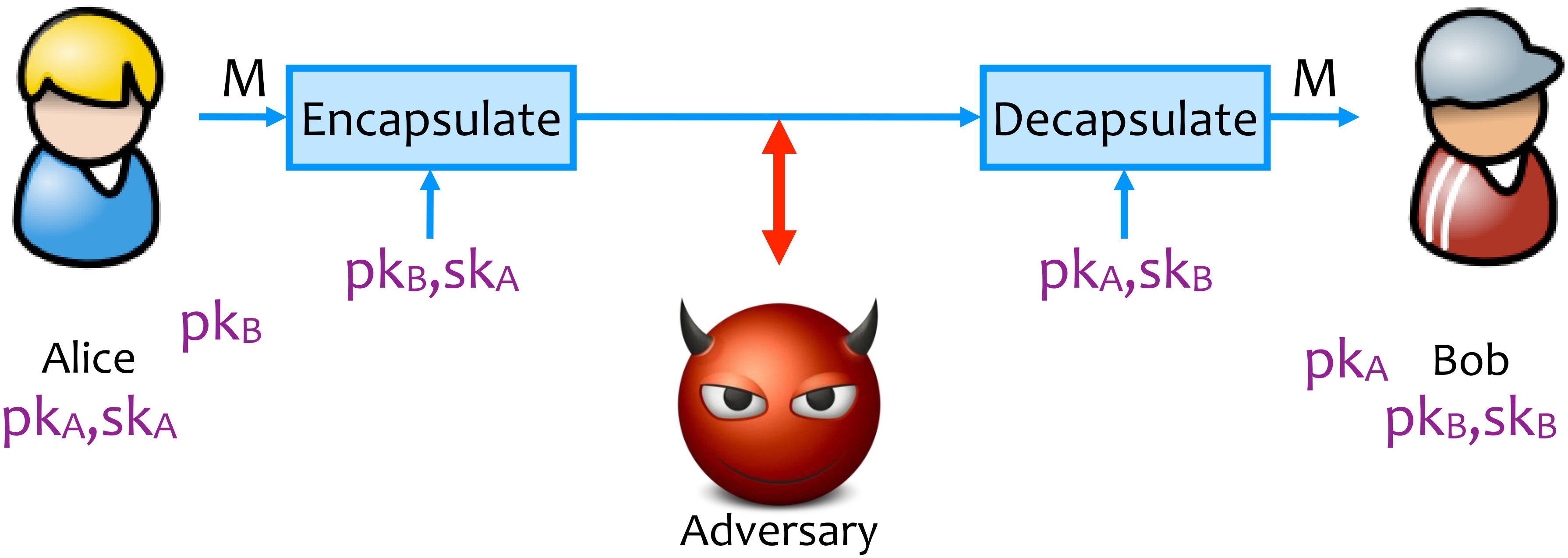
Symmetric Setting

Both communicating parties have access to a shared random string K, called the key.



Asymmetric Setting

Each party creates a public key pk and a secret key sk.
(Physical World Sort-of Analogy: Combination Lock.)



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What Are Tradeoffs Between Symmetric and Asymmetric Crypto?

Flavors of Cryptography

- Symmetric cryptography
  - Both communicating parties have access to a shared random string K, called the key.
  - Challenge: How do you privately share a key?
- Asymmetric cryptography
  - Each party creates a public key pk and a secret key sk.
  - Challenge: How do you validate a public key?

Ingredient: Randomness

- Many applications (especially security ones) require randomness
- Explicit uses:
  - Generate secret cryptographic keys
  - Generate random initialization vectors for encryption
- Other "non-obvious" uses:
  - Generate passwords for new users
  - Shuffle the order of votes (in an electronic voting machine)
  - Shuffle cards (for an online gambling site)

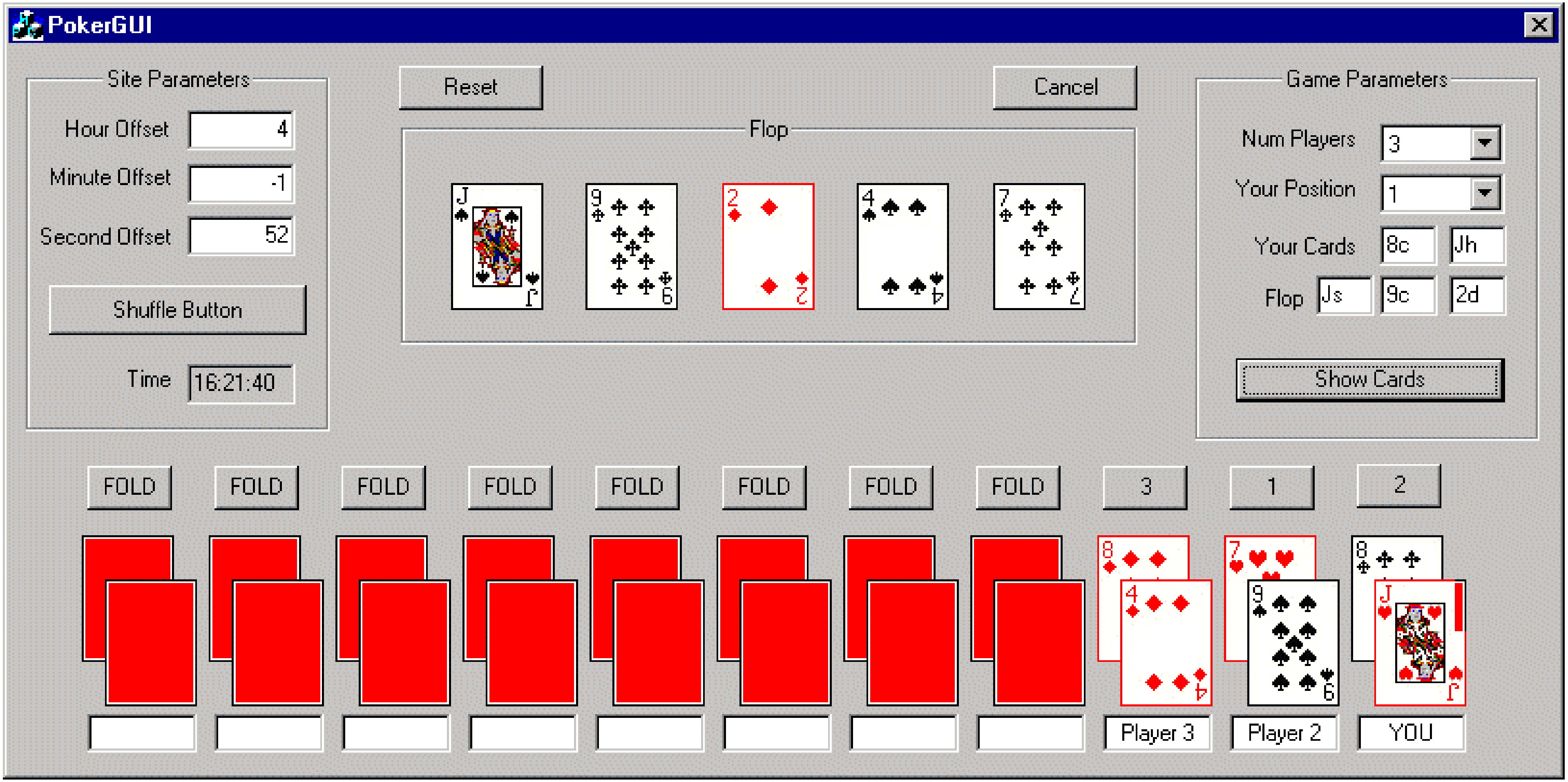
C’s rand() Function

- C has a built-in random function: rand()

```
unsigned long int next = 1;
/* rand:  return pseudo-random integer on 0..32767 */
int rand(void) {
    next = next * 1103515245 + 12345;
    return (unsigned int)(next/65536) % 32768;
}
/* srand:  set seed for rand() */
void srand(unsigned int seed) {
    next = seed;
}
```

- Problem: don’t use rand() for security-critical applications!
  - Given a few sample outputs, you can predict subsequent ones


A World of Action!
Help
Suggestions
Fold in Turn
$0
jonnyboy
brute
mamajoe
RickG
Fold
Check
Bet ($5)
Options
Sit Out
Leave
584330
mamajoe: Hey guys, Big B is in!
Dealer Text



More details: "How We Learned to Cheat at Online Poker: A Study in Software Security"
https://web.archive.org/web/20080305043338/www.cigital.com/papers/download/developer_gambling.php

PS3 and Randomness

> Hackers obtain PS3 private cryptography key due to epic programming fail? (update)

http://www.engadget.com/2010/12/29/hackers-obtain-ps3-private-cryptography-key-due-to-epic-programm/

- 2010/2011: Hackers found/released private root key for Sony's PS3
- Key used to sign software – now can load any software on PS3 and it will execute as "trusted"
- Due to bad random number: same "random" value used to sign all system updates

Obtaining Pseudorandom Numbers

- For security applications, want "cryptographically secure pseudorandom numbers"
- Libraries include cryptographically secure pseudorandom number generators (CSPRNG)
- Linux:
  - /dev/random
  - /dev/urandom - nonblocking, possibly less entropy
- Internally:
  - Entropy pool gathered from multiple sources
    - e.g., mouse/keyboard timings
- Challenges with embedded systems, saved VMs