CSE 484 / CSE M 584: Intro to Cryptography (cont'd)

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Announcements

- Things Due
  - Lab 1a, due tomorrow
    - Please be cautious about leaving remote IDEs running
  - Lab 1b: don’t delay, more complex sploits

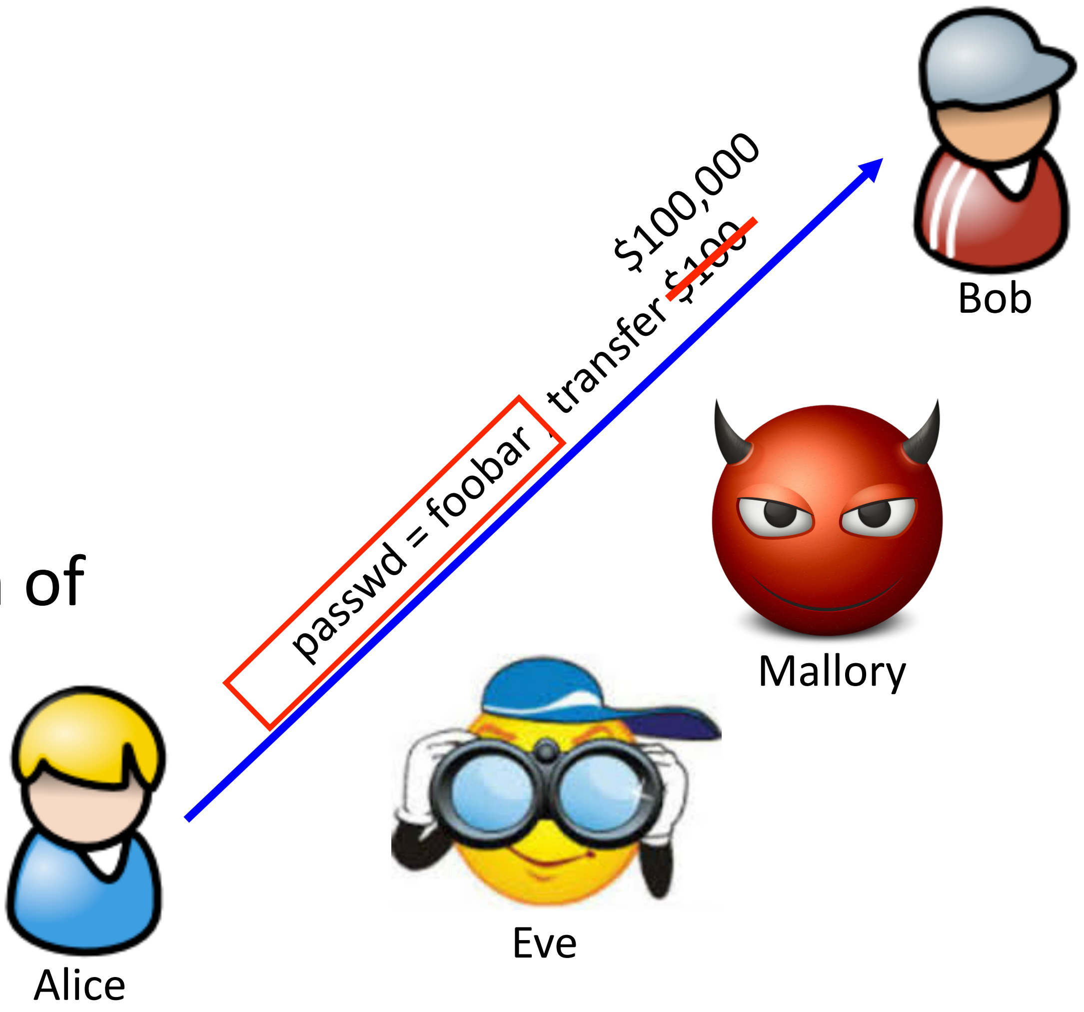
Review: Common Communication Security Goals

Privacy of data:

Prevent exposure of information

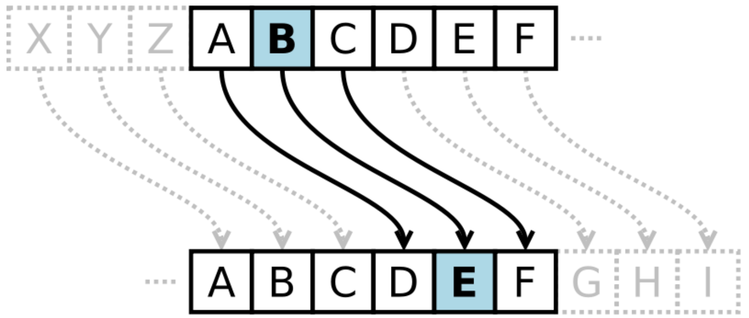
Integrity of data:

Prevent modification of information



Review: History: Caesar Cipher (Shift Cipher)

- Plaintext letters are replaced with letters a fixed shift away in the alphabet.



- Example:
  - Plaintext: `The quick brown fox jumps over the lazy dog`
  - Key: Shift 3

    `ABCDEFGHIJKLMNOPQRSTUVWXYZ`

    `DEFGHIJKLMNOPQRSTUVWXYZABC`
  - Ciphertext: `WKHTX LFNEU RZQIR AMXPS VRYHU WKHOD CBGRJ`

Review: History: Caesar Cipher (Shift Cipher)

- ROT13: shift 13 (encryption and decryption are symmetric)
- What is the key space?
  - 26 possible shifts.
- How to attack shift ciphers?
  - Brute force.

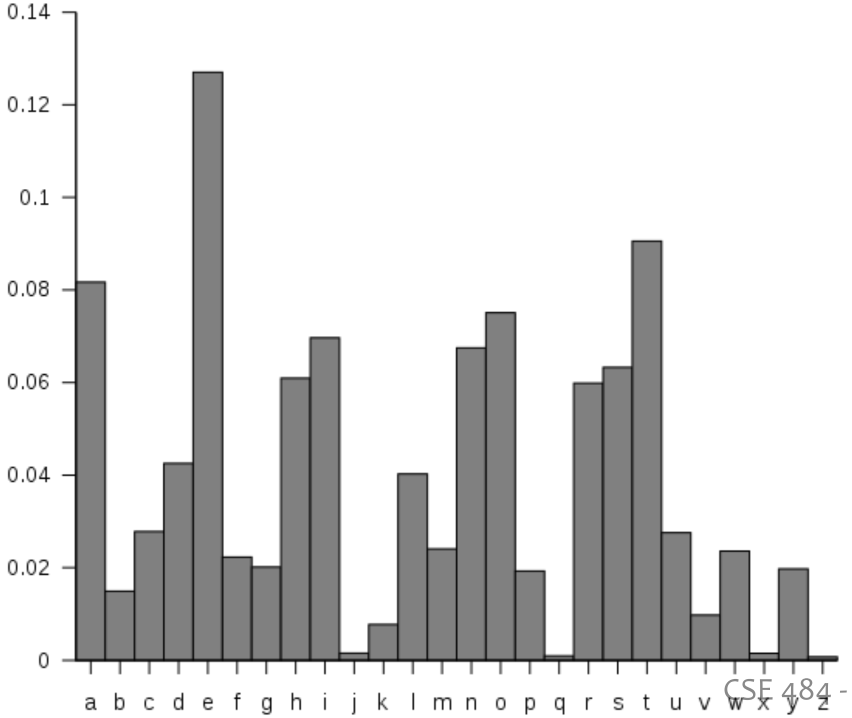
History: Substitution Cipher

- Superset of shift ciphers: each letter is substituted for another one.
- One way to implement: 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?
- How to attack?
  - Frequency analysis.

26! ~= 2^88



Bigrams:

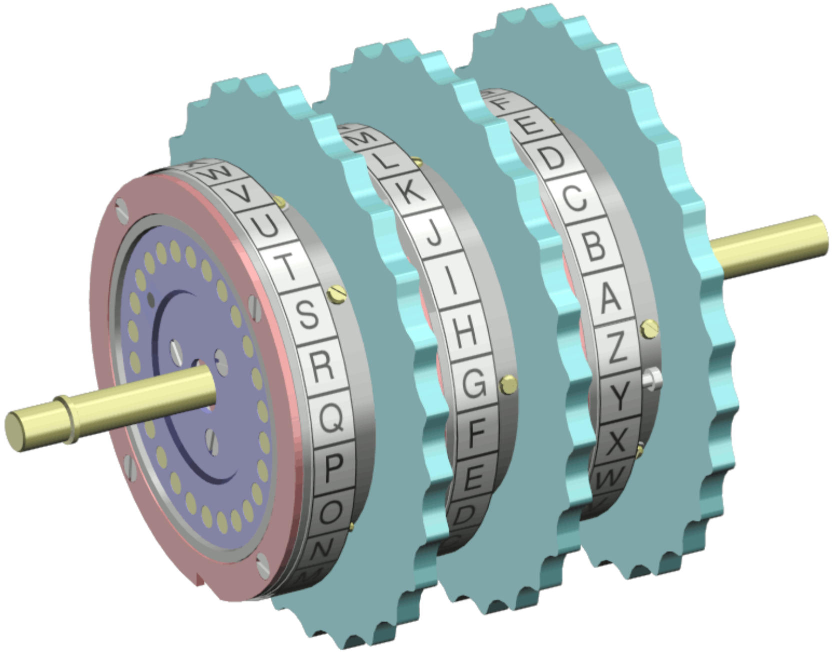
th 1.52%	en 0.55%	ng 0.18%
he 1.28%	ed 0.53%	of 0.16%
in 0.94%	to 0.52%	al 0.09%
er 0.94%	it 0.50%	de 0.09%
an 0.82%	ou 0.50%	se 0.08%
re 0.68%	ea 0.47%	le 0.08%
nd 0.63%	hi 0.46%	sa 0.06%
at 0.59%	is 0.46%	si 0.05%
on 0.57%	or 0.43%	ar 0.04%
nt 0.56%	ti 0.34%	ve 0.04%
ha 0.56%	as 0.33%	ra 0.04%
es 0.56%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

How Cryptosystems Work Today

- **Layered approach:** Cryptographic protocols (like "CBC mode encryption") built on top of cryptographic primitives (like "block ciphers")
- **Flavors of cryptography:** Symmetric (private key) and asymmetric (public key)
- Public algorithms (Kerckhoff's Principle – next slide)
- Security proofs based on assumptions (*not this course*)

- Be careful about inventing your own!
  (If you just want to use some crypto in your system, use vetted libraries!)

Kerckhoff's Principle

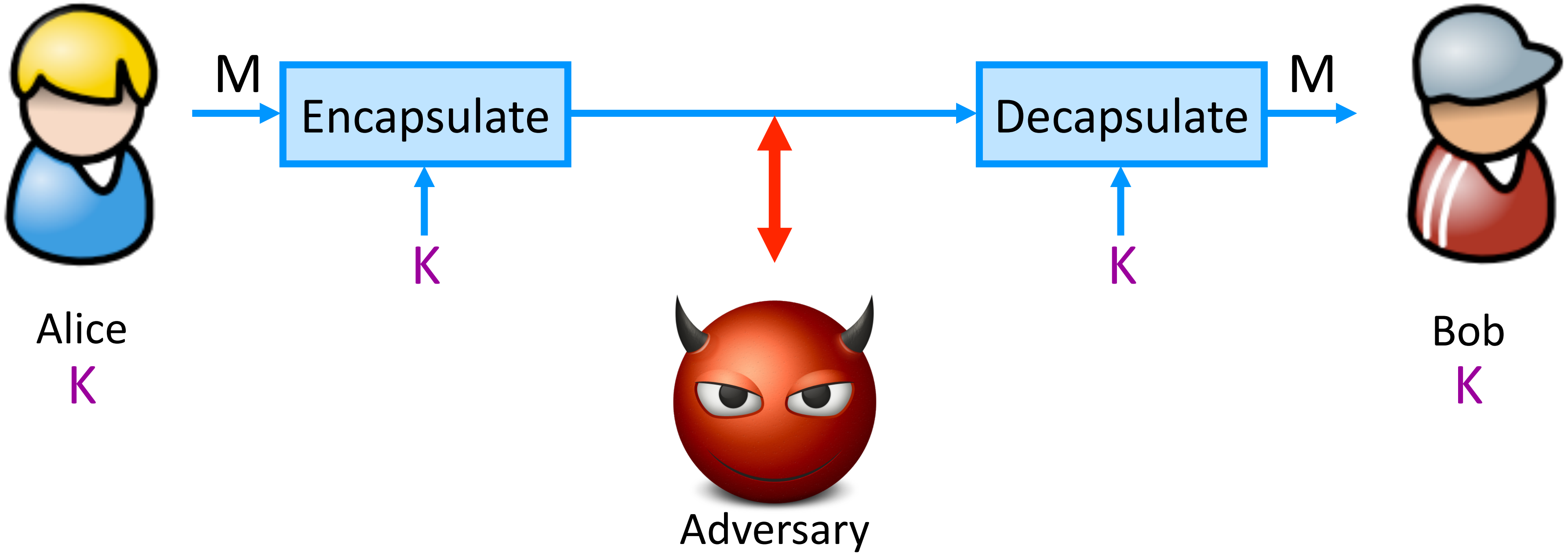
- Security of a cryptographic object should depend only on the secrecy of the secret (private) key.
- Security should not depend on the secrecy of the algorithm itself.
- (Foreshadowing: Need for randomness – the key to keep private)

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 won the Turing Award* ☺

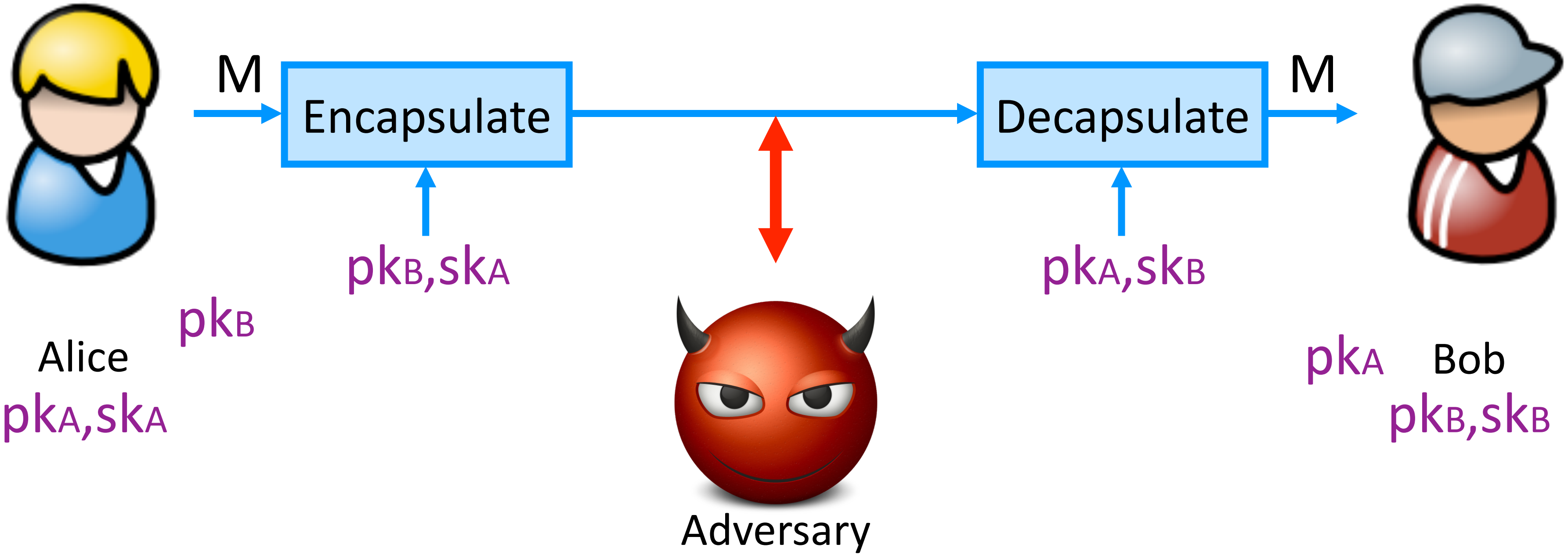
Symmetric Setting

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.



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.

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.

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?
- Key building block: Randomness – something that the adversaries don’t know, can’t predict, can’t figure out

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)

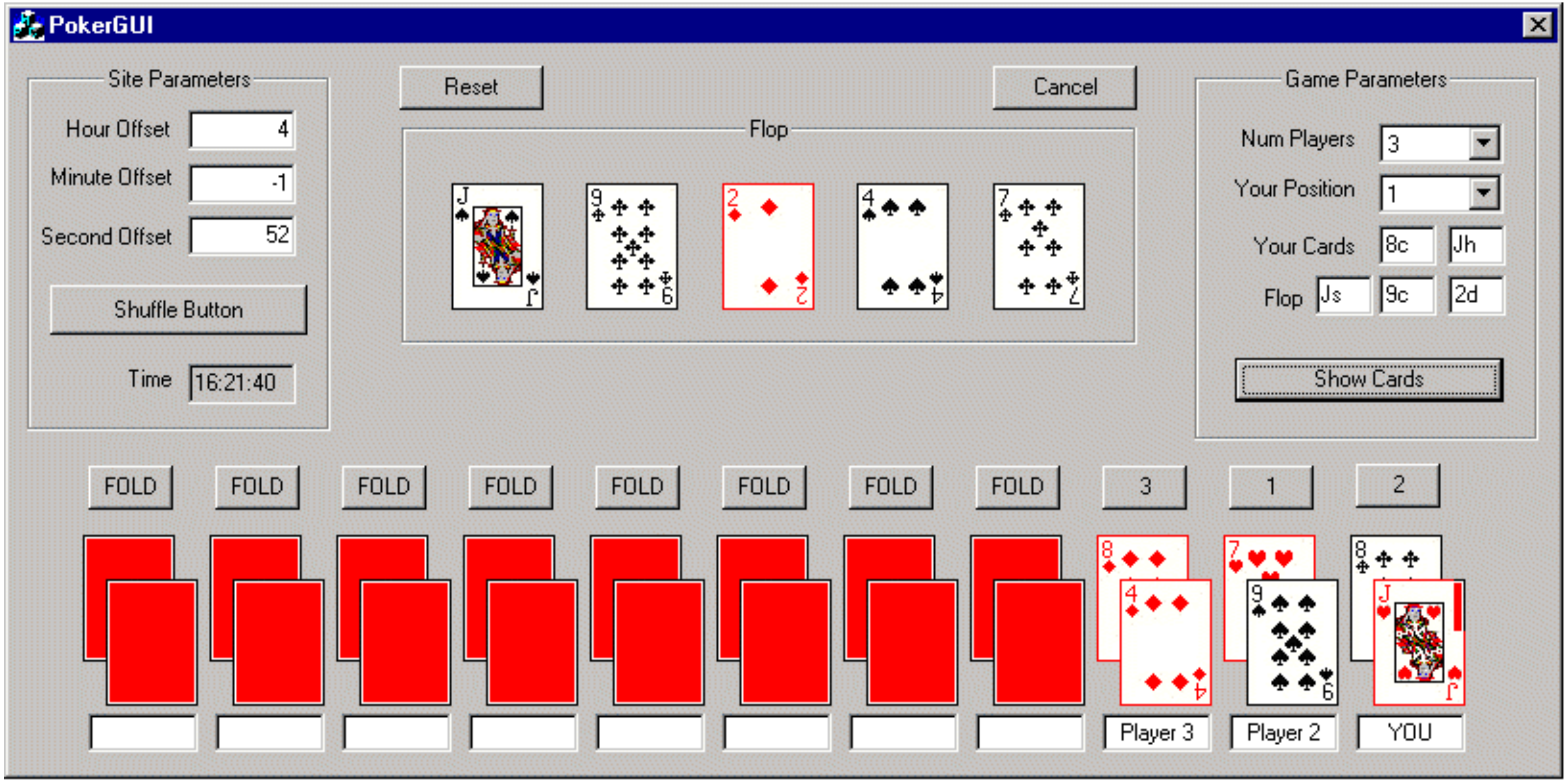
C's rand() Function

- 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"
http://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