Backdoors in Cryptography

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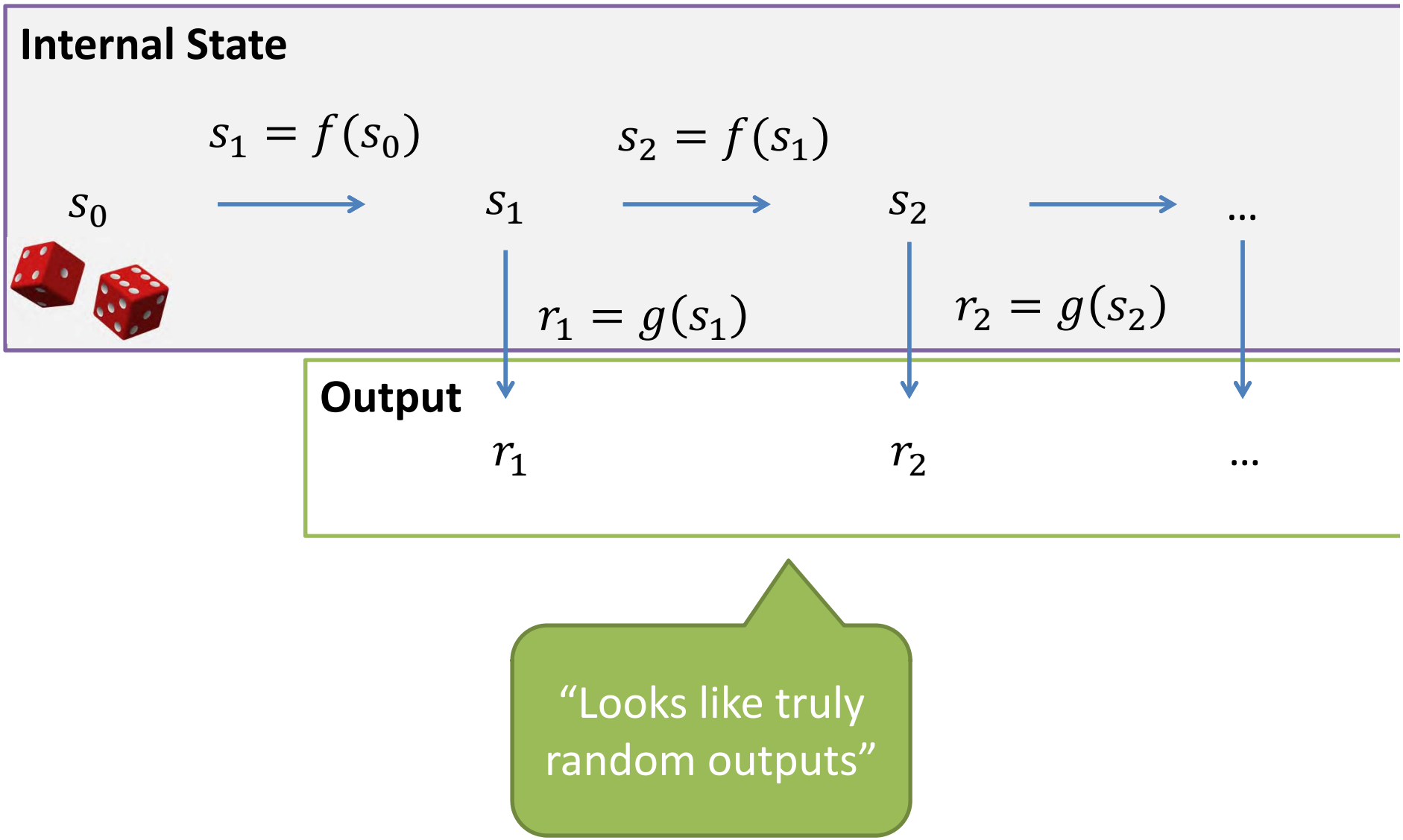
Cryptography

Computational hardness + **Unpredictability**

Pseudorandom generator



Discrete Logarithm Problem

- Logarithm: find x such that

$$3^x = 81$$

- Discrete logarithm problem

$$3^x \; mod \; 47 = 34$$

Easy!
Just try them all!

Discrete Logarithm Problem

- Logarithm: find x such that

$$3^x = 81$$

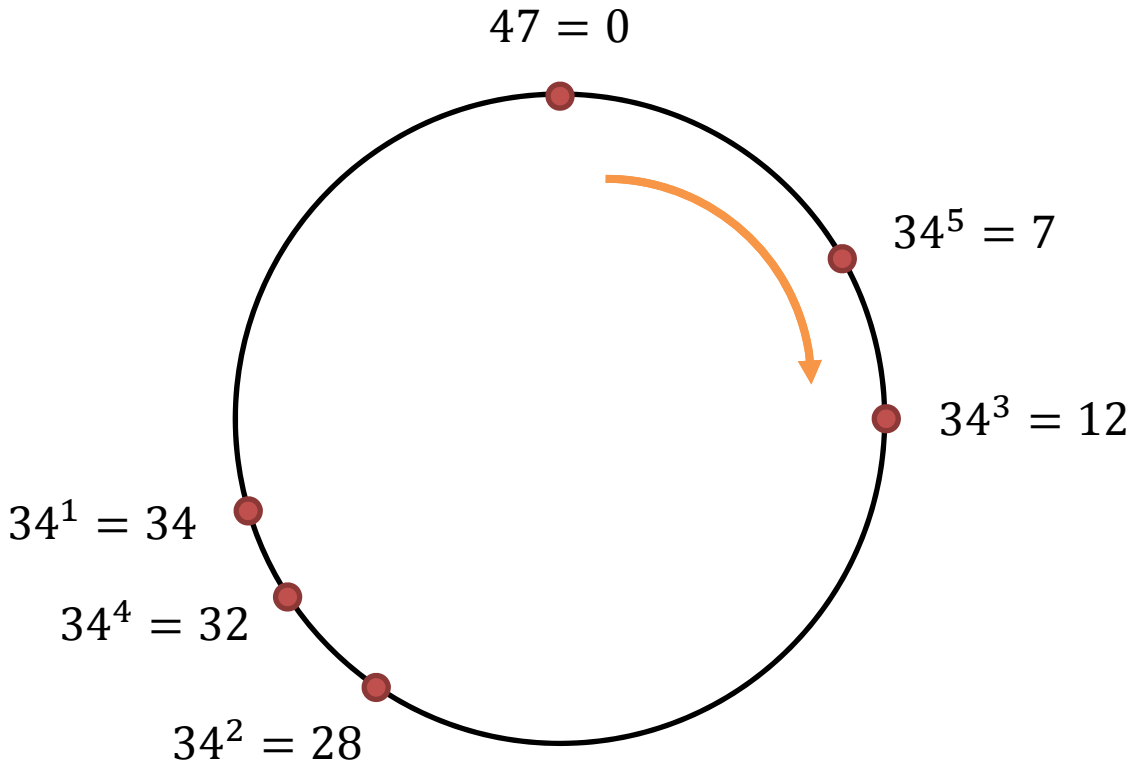
- Discrete logarithm problem

Hard!

$$3^x \; mod \; \underbrace{4 \ldots 7}_{} = \underbrace{3 \ldots 4}_{}$$

1000 digits (3000 bits)

Computing $mod\ 47$



$$34^2 = 1156 = 47 \cdot 24 + 28 \Rightarrow 34^2\ mod\ 47 = 28$$

Dual_EC (Simplified)

- Two hardwired parameters

$$(P, Q)$$

- Initial (truly) random state

$$s_0$$

- Compute next state

$$s_{i+1} = P^{s_i} \; mod \; N$$

- Compute output

$$r_i = Q^{s_i} \; mod \; N$$

mod 47
P=34
Q=3

Dual_EC (Simplified)

Internal State

$s_1 = P^{s_0}$ $\quad$ $s_2 = P^{s_1}$

$s_0 = 22 \longrightarrow s_1 = 18 \longrightarrow s_2 = 16 \longrightarrow \ldots$

$r_1 = Q^{s_1}$ $\quad$ $r_2 = Q^{s_2}$

Output

$r_1 = 6$ $\quad$ $r_2 = 32$ $\quad$ $\ldots$

mod 47
P=34
Q=3
x=7

DUAL_EC **Backdoor**(Simplified)

Internal State

$s_1 = P^{s_0}$ $\quad$ $s_2 = P^{s_1}$

$s_0 = 22 \longrightarrow s_1 = 18 \longrightarrow s_2 = 16 \longrightarrow \ldots$

$r_1 = Q^{s_1}$ $\quad$ $r_2 = Q^{s_2}$

Output

$r_1 = 6$ $\quad$ $r_2 = 32$ $\quad$ $\ldots$

Given x such that

$$P = Q^x$$

Can recover internal state

$$s_2 = r_1^x$$

DUAL_EC **Backdoor** (Simplified)

The user

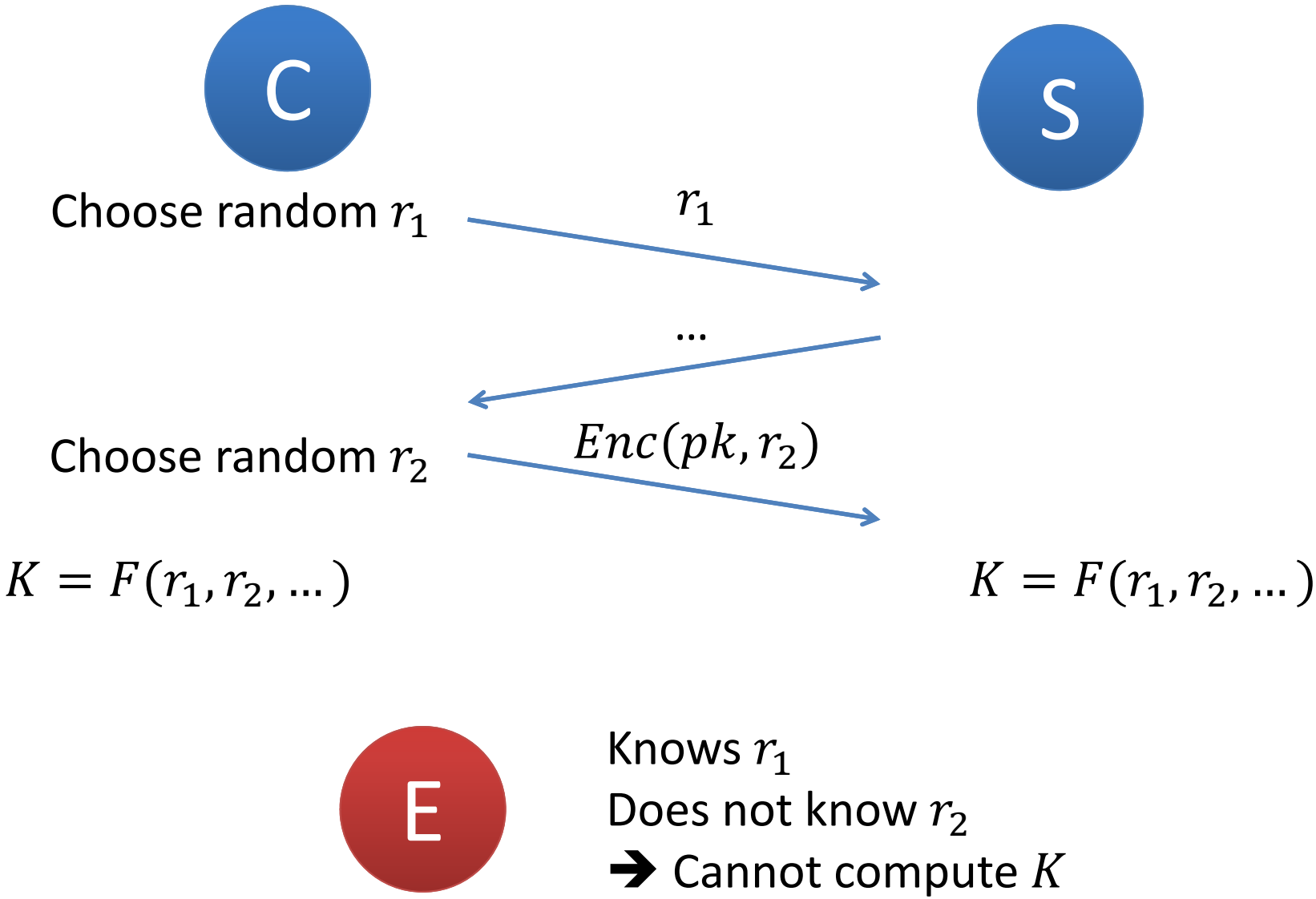
- Two parameters
  $$(P, Q)$$
- Compute next state
  $$s_{i+1} = P^{s_i} \; mod \; N$$
- Compute next output
  $$r_i = Q^{s_i} \; mod \; N$$

The attacker

- Keep x such that
  $$P = Q^x \; mod \; N$$
- Observe any output
  $$r_i$$
- Compute next state
  $$s_{i+1} = r_i^x \; mod \; N$$
- Predict all future outputs!

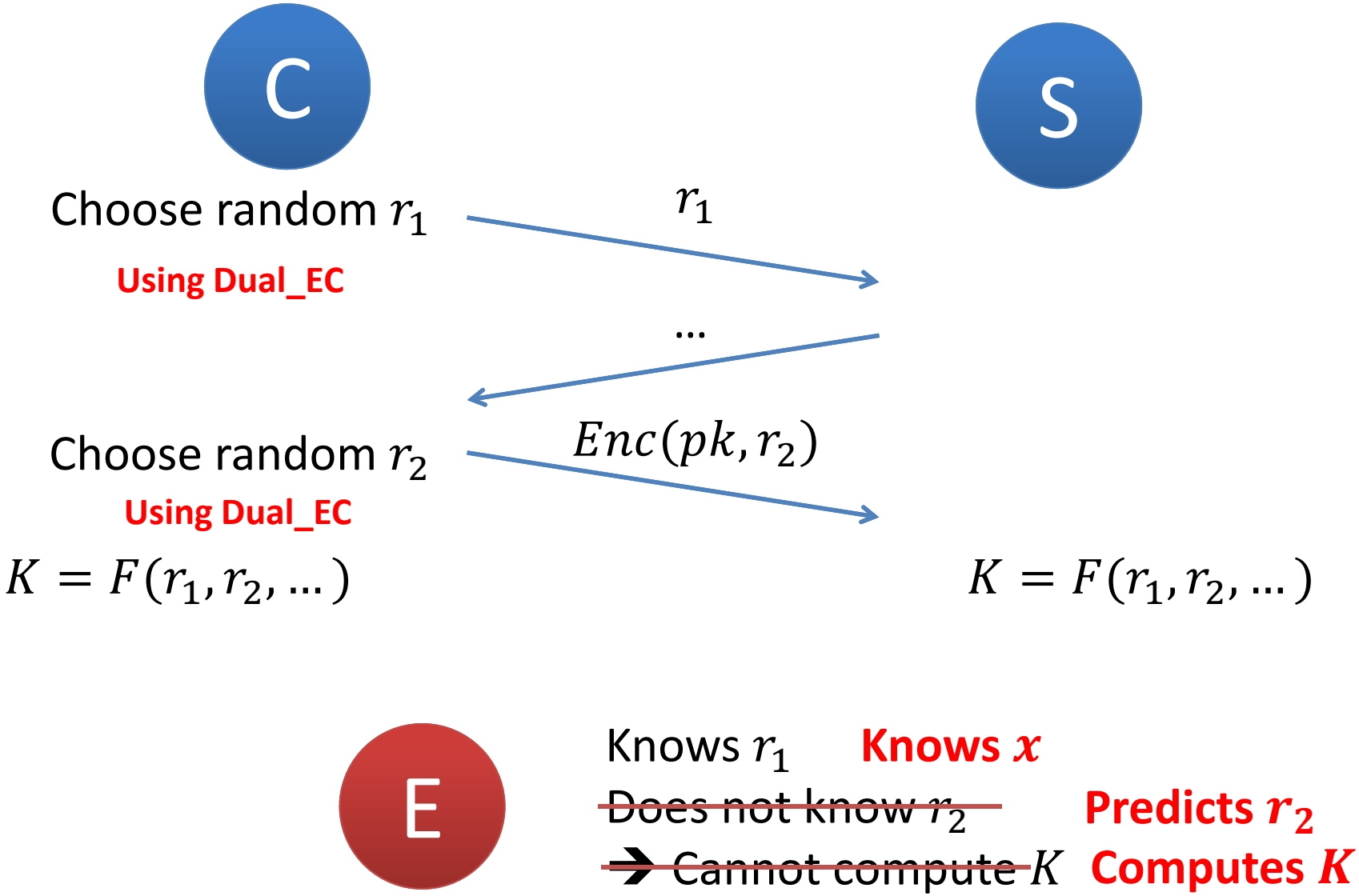
$$s_{i+1} = P^{s_i} = (Q^x)^{s_i} = (Q^{s_i})^x = {r_i}^x \text{ mod N}$$

HTTPS (Simplified)



Knows r_1
Does not know r_2
➔ Cannot compute K

HTTPS with **Backdoor** (Simplified)



- Unless you choose your own parameters, DUAL_EC is a really bad PRNG.

- If you use parameters (P,Q) chosen by an adversary, you grant the adversary the power to eavesdrop virtually any secure connection you can establish over the internet.

- *But this would never happen. Right?*

Dual_EC : a brief history

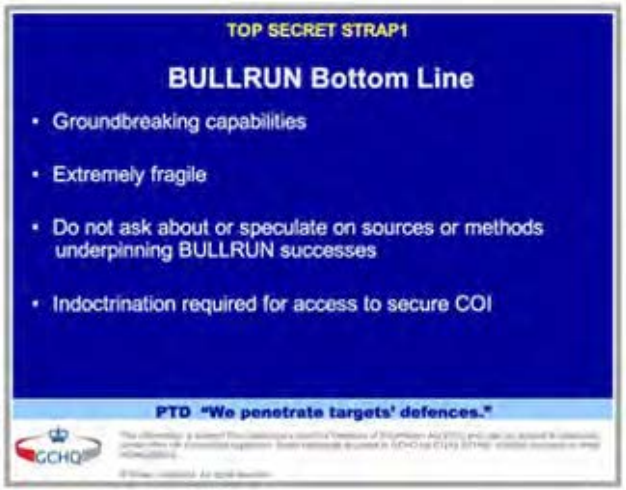
- 2007
  - Dual_EC standardized by NIST with fixed parameters P,Q
  - The standard is criticized at CRYPTO 2007

Conclusion

- WHAT WE ARE NOT SAYING:
  NIST intentionally put a back door in this PRNG
- WHAT WE ARE SAYING:
  The prediction resistance of this PRNG (as presented in NIST SP800-90) is dependent on solving one instance of the elliptic curve discrete log problem.
  (And we do not know if the algorithm designer knew this before hand.)

- 2013
  - Snowden reveals existence of Bullrun program

- (TS//SI//REL TO USA, FVEY) Insert vulnerabilities into commercial encryption systems, IT systems, networks, and endpoint communications devices used by targets.
- (TS//SI//REL TO USA, FVEY) Collect target network data and metadata via cooperative network carriers and/or increased control over core networks.
- (TS//SI//REL TO USA, FVEY) Leverage commercial capabilities to remotely deliver or receive information to and from target endpoints.
- (TS//SI//REL TO USA, FVEY) Exploit foreign trusted computing platforms and technologies.
- (TS//SI//REL TO USA, FVEY) Influence policies, standards and specification for commercial public key technologies.
- (TS//SI//REL TO USA, FVEY) Make specific and aggressive investments to facilitate the development of a robust exploitation capability against Next-Generation Wireless (NGW) communications.



- 2013
  - RSA accused of accepting 10M$ to adopt Dual_EC in their products

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Exclusive: NSA infiltrated RSA security more deeply than thought - study

SAN FRANCISCO | BY JOSEPH MENN

A sign marks the entrance to RAS's facility in Bedford, Massachusetts March 28, 2014.
REUTERS/BRIAN SNYDER

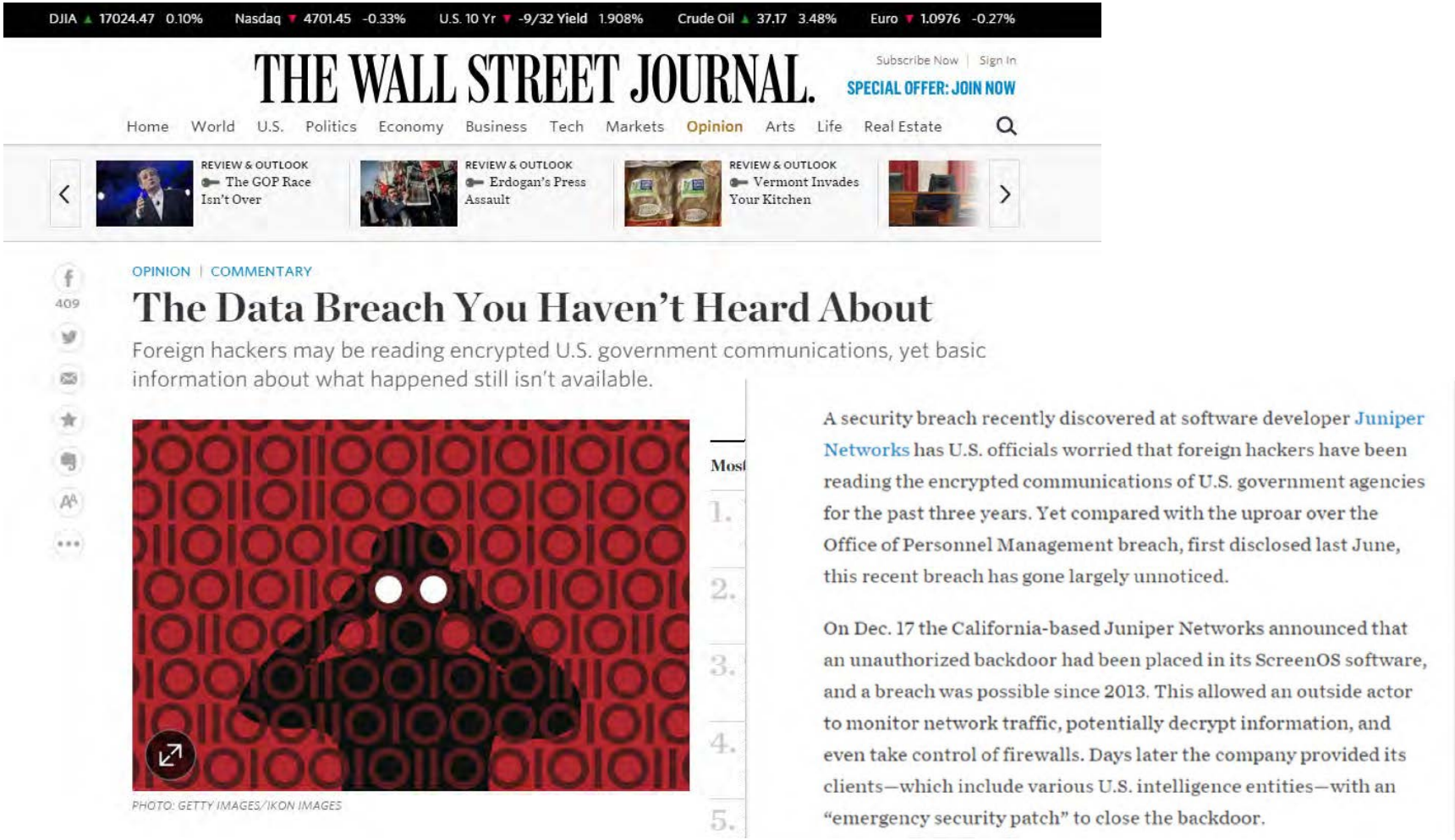
Security industry pioneer RSA adopted not just one but two encryption tools developed by the U.S. National Security Agency, greatly increasing the spy agency's ability to eavesdrop on some Internet communications, according to a team of academic researchers.

Reuters reported in December that the NSA had paid RSA $10 million to make a now-discredited cryptography system the default in software used by a wide range of Internet and computer security programs. The system, called Dual Elliptic Curve, was a random number generator, but it had a deliberate flaw - or "back door" - that allowed the NSA to crack the encryption.

- 2014
  - NIST investigates

```
Subject: [Fwd: RE: Minding our Ps and Qs in Dual_EC]
Date: Wednesday, October 27, 2004 at 12:09:25 PM Eastern Daylight Time
From: John Kelsey
To: larry.basham@nist.gov
---------------------------- Original Message ----------------------------
Subject: RE: Minding our Ps and Qs in Dual_EC
From: "Don Johnson" <DJohnson@cygnacom.com>
Date: Wed, October 27, 200411:42 am
To: "John Kelsey" <john.kelsey@nist.gov>

John,
P=G.
Q is (in essence) the public key for some random private key.

It could also be generated like another canonical G, but NSA kyboshed
this idea, and I was not allowed to publicly discuss it, just in case you
may think of going there.

Don B. Johnson

-----Original Message-----
From: John Kelsey fmailto:john.kelsey@nist.gov]
Sent: Wednesday, October 27, 200411:17 AM
To: Don Johnson
Subject: Minding our Ps and Qs in Dual_EC

Do you know where Q comes from in Dual_EC_DRBG?

Thanks,
-John
```

- 2015
  - Juniper (who had been using Dual_EC but with their own P,Q), discovers that in 2012 someone hacked their servers and changed the constants.



DJIA ▲ 17024.47 0.10% Nasdaq ▼ 4701.45 -0.33% U.S. 10 Yr ▼ -9/32 Yield 1.908% Crude Oil ▲ 37.17 3.48% Euro ▼ 1.0976 -0.27%

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The Data Breach You Haven't Heard About

Foreign hackers may be reading encrypted U.S. government communications, yet basic information about what happened still isn't available.

PHOTO: GETTY IMAGES/IKON IMAGES

Most

1.

2.

3.

4.

5.

A security breach recently discovered at software developer Juniper Networks has U.S. officials worried that foreign hackers have been reading the encrypted communications of U.S. government agencies for the past three years. Yet compared with the uproar over the Office of Personnel Management breach, first disclosed last June, this recent breach has gone largely unnoticed.

On Dec. 17 the California-based Juniper Networks announced that an unauthorized backdoor had been placed in its ScreenOS software, and a breach was possible since 2013. This allowed an outside actor to monitor network traffic, potentially decrypt information, and even take control of firewalls. Days later the company provided its clients—which include various U.S. intelligence entities—with an "emergency security patch" to close the backdoor.

2016

"We cannot build a backdoor that only works for a particular type of government, or only in the presence of a particular court order."

Thanks!
Questions?