Cryptographic Backdooring

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Agenda

Why this talk?
Backdooring 101
Sabotage tactics
A perfect backdoor
Conclusion

Why this talk?

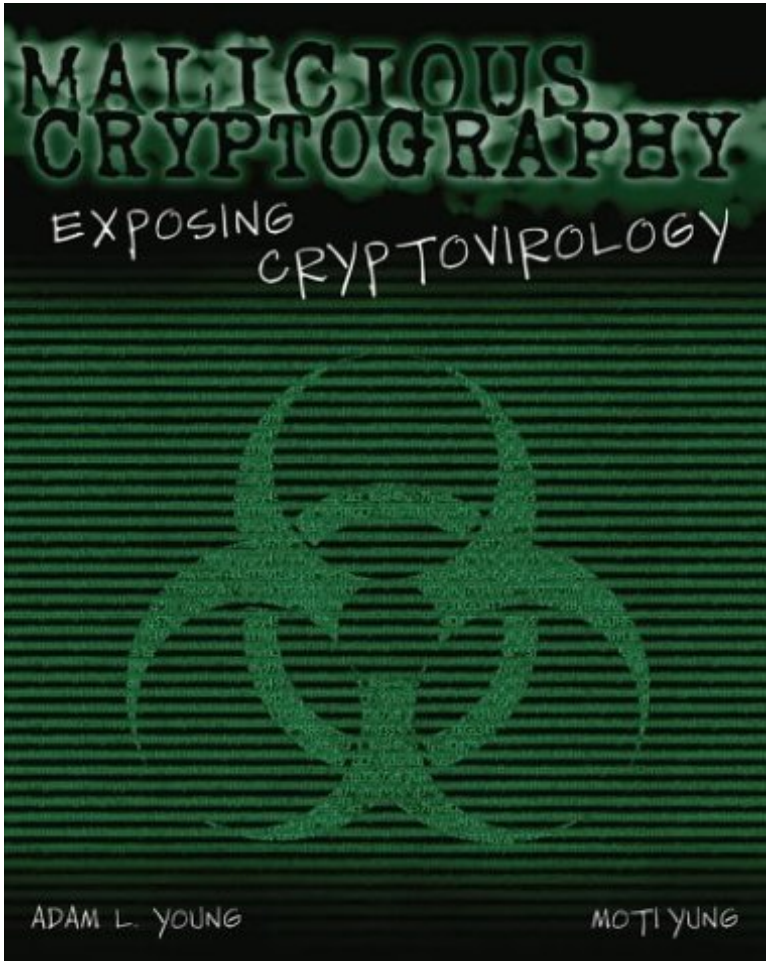
You may not be interested in backdoors, but backdoors are interested in you

(U) Base resources in this project are used to:

- (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.
- (U//FOUO) Maintain understanding of commercial business and technology trends.

NSA's BULLRUN program

Public/academic research mostly inexistant


MALICIOUS CRYPTOGRAPHY
EXPOSING CRYPTOVIROLOGY
ADAM L. YOUNG
MOTI YUNG

Bad reputation

Surveillance, deception, etc.

“a back door for the government can easily —and quietly—become a back door for criminals and foreign intelligence services.”

Security “Front Doors” vs. “Back Doors”: A Distinction Without a Difference

By *Jeffrey Vagle* and *Matt Blaze*

Friday, October 17, 2014 at 2:06 PM

http://justsecurity.org/16503/security-front-doors-vs-back-doors-distinction-difference/

And terrorists etc.

(Like internet and encryption)

Not a great argument IMHO

“It increases the ‘attack surface’ of the system, providing new points of leverage that a nefarious attacker can exploit.”

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matt blaze
@mattblaze

Following

Crypto backdoors are dangerous even if you trust the government not to abuse them. We simply don't know how to build them reliably.

Not well understood, by the public

Especially **crypto** backdoors

Why public research?

Detect backdoors

If you have to implement a backdoor

—for good or not-so-good reasons—

better know how (not) to do it

Backdooring 101

What is a backdoor?

Not a trapdoor

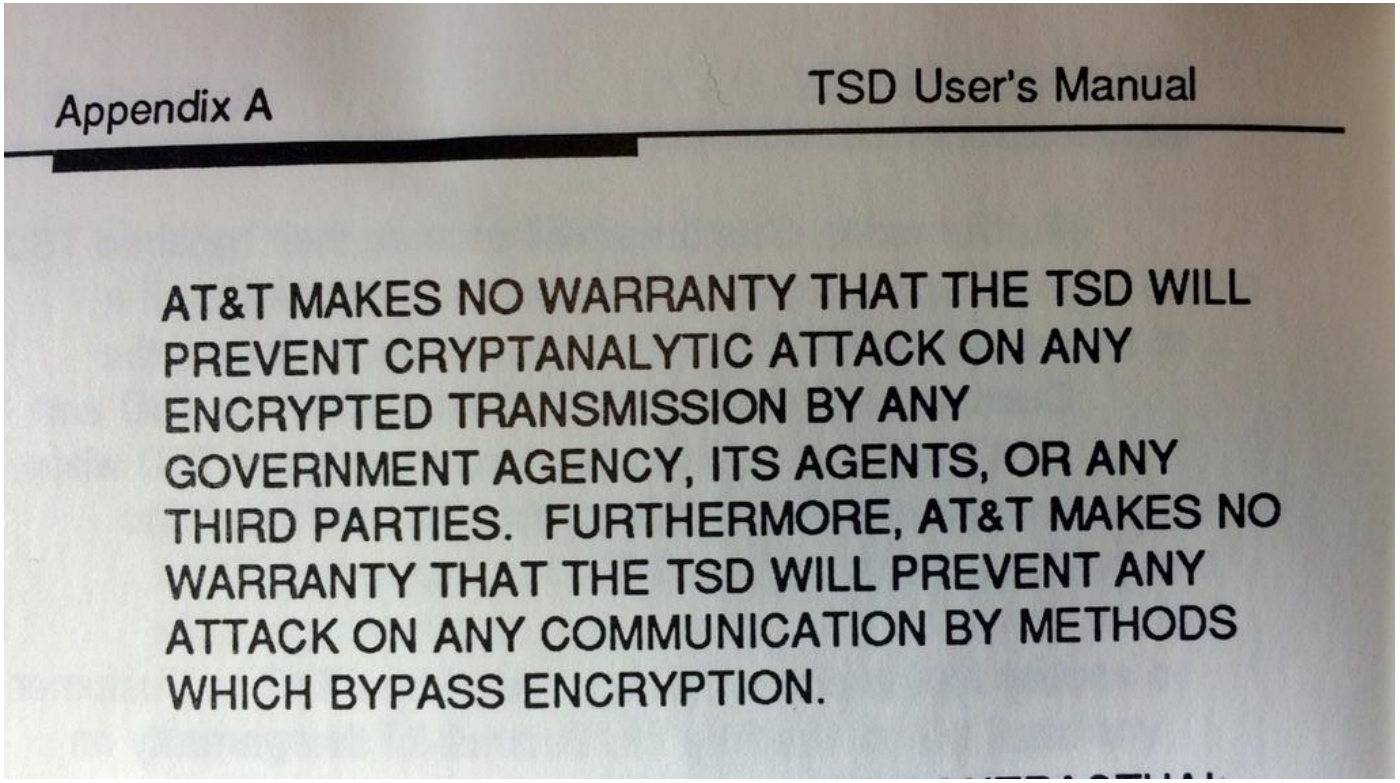
(Covert rather than overt)

“A feature or defect that allows surreptitious access to data”

Weakened algorithms (A5/2, GMR, etc.)

Covert channels
(Exfiltration of keys, etc.)

Key escrow



Clipper chip phone AT&T TSD3600

May be known to exist
(Is lawful interception a backdoor?)

“An undocumented way to get access to a computer system or the data it contains”

Breakthrough silicon scanning discovers backdoor in military chip (DRAFT of 05 March 2012)

Sergei Skorobogatov
University of Cambridge
Cambridge, UK
sps32@cam.ac.uk

Christopher Woods
Quo Vadis Labs
London, UK
chris@quovadislabs.com

Bugs? RCE?

Only if intentional, a.k.a. **bugdoors**

(© The Grugq)

Deniability…

What is a “good” backdoor?

Undetectable

NOBUS

(No one but us, NSA term)

Reusable

Unmodifiable

Forward-secure

Simple

To be continued...

Sabotage tactics

Constants

Choose constants that allow you to compromise the security

SHA-1 round constants

Malicious Hashing: Eve's Variant of SHA-1

Ange Albertini[1], Jean-Philippe Aumasson[2], Maria Eichlseder[3],
Florian Mendel[3], and Martin Schläffer[3]

40 bits modified

Colliding binaries, images, archives

Full control on the content, NOBUS

(BSidesLV/DEFCON/SAC 2014)


```
>crypto_hash *
test0.jpg 13990732b0d16c3e112f2356bd3d0dad1....
test1.jpg 13990732b0d16c3e112f2356bd3d0dad1....
```

https://maliciousshа1.github.io/

2 distinct files, 3 valid file formats

Elliptic curve coefficients

NIST curves' coefficients:
hashes of unexplained 16-byte seeds, e.g.
c49d3608 86e70493 6a6678e1 139d26b7 819f7e90

(Speculation, no public evidence of backdoor)

Notion of **rigidity**

“a feature of a curve-generation process, limiting the number of curves that can be generated by the process”

http://safecurves.cr.yp.to/rigid.html

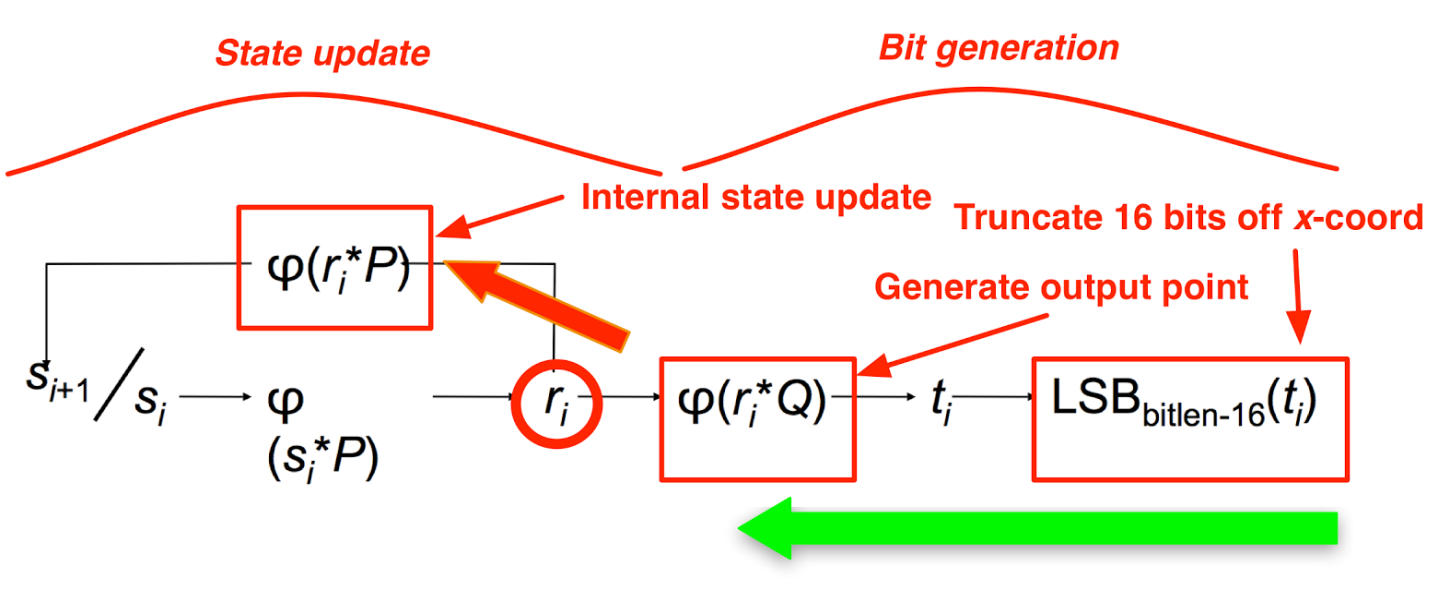
Curve25519	fully rigid ✓	Prime chosen "as close as possible to a power of 2" for efficiency reasons ("save time in field operations"). Prime chosen "slightly below 32k bits, for some k" for efficiency reasons ("no serious concerns regarding wasted space"). k=8 chosen for "a comfortable security level". 2^255-19 chosen above 2^255+95, 2^255-31, 2^254+79, 2^253+51, 2^253+39 "because 19 is smaller than 31, 39, 51, 79, 95". Montgomery curve shape y^2=x^3+Ax^2+x chosen for efficiency ("to allow extremely fast x-coordinate point operations"). (A-2)/4 selected as a small integer for efficiency ("to speed up the multiplication by (A-2)/4"). Curve and twist orders required to be {4*prime,8*prime} for security ("protect against various attacks ... here 4, 8 are minimal"). Primes required to be above 2^252 for security ("theoretical possibility of a user's secret key matching the prime"), ruling out A=358990 and A=464586. A=486662 chosen as smallest positive integer meeting these requirements.
BN(2,254)	fully rigid ✓	p chosen sparse, close to 2^256, within BN family; using u=−(2^62 + 2^55 + 1). p congruent 3 modulo 4 to have z^2+1 irreducible; b=2 to have twist be y^2=x^3+ (1 − 2i).
brainpoolP256t1	somewhat rigid ✓	Several unexplained decisions: Why SHA-1 instead of, e.g., RIPEMD-160 or SHA-256? Why use 160 bits of hash input independently of the curve size? Why pi and e instead of, e.g., sqrt(2) and sqrt(3)? Why handle separate key sizes by more digits of pi and e instead of hash derivation? Why counter mode instead of, e.g., OFB? Why use overlapping counters for A and B (producing the repeated 26DC5C6CE94A4B44F330B5D9)? Why not derive separate seeds for A and B?
ANSSI FRP256v1	**trivially manipulatable**	No explanation provided.
NIST P-256	**manipulatable**	Coefficients generated by hashing the unexplained seed c49d3608 86e70493 6a6678e1 139d26b7 819f7e90.
secp256k1	somewhat rigid ✓	GLV curve with 256 bits and prime order group; prime and coefficients not fully explained but might be minimal
E-382	fully rigid ✓	
M-383	fully rigid ✓	
Curve383187	fully rigid ✓	p is largest prime smaller than 2^383; B=1; A > 2 is as small as possible.
brainpoolP384t1	somewhat rigid ✓	See brainpoolP256t1.
NIST P-384	**manipulatable**	Coefficients generated by hashing the unexplained seed a335926a a319a27a 1d00896a 6773a482 7acdac73.

Limitation: there may be an exponential number of fully-rigid generation methods

Math structure elements

Dual_EC_DRBG

(NSA design, NIST standard)



http://blog.cryptographyengineering.com/2013/09/the-many-flaws-of-dualecdrbg.html

If n s.t. nQ = P is known, the RNG is broken

Key generation

Make session keys predictable

3G/4G AKA

Session keys = hash(master key, **rand**)

Delegate tactical intercepts with low-entropy **rand** values

Precompute and share session keys

(A possibility, not allegations)

Hide weak parameters

RSA

Hide small public exponent

with some tricks to avoid detection

and recover using Boneh-Durfee-Frankel result

Simple Backdoors for RSA Key Generation

Claude Crépeau[1] and Alain Slakmon[2]

(CT-RSA 2003)

Key gen as a covert channel for itself

RSA

Hide bits of prime factors in *n*

Recover using Coppersmith's method

Similar to "Pretty-Awful-Privacy" (Young-Yung)

Simple Backdoors for RSA Key Generation

Claude Crépeau[1] and Alain Slakmon[2]

(CT-RSA 2003)

Lesson: don’t outsource keygen

Implementations

Slightly deviate from the specs
Omit some verifications
etc.

Small subgroup attacks
Omit (EC)DH pubkey validation

A Key Recovery Attack on Discrete Log-based Schemes Using a Prime Order Subgroup*

Chae Hoon Lim[1] and Pil Joong Lee[2]

(CRYPTO 1997)

Small subgroup attacks
Omit (EC)DH pubkey validation

Validation of Elliptic Curve Public Keys

Adrian Antipa[1], Daniel Brown[1], Alfred Menezes[2],
René Struik[1], and Scott Vanstone[2]

(PKC 2003)

“domain parameter shifting attacks”
Omit ECC domain parameters validation

Digital Signature Schemes with Domain Parameters

Serge Vaudenay

(ACISP 2004)

TLS MitM

Incomplete cert verification

“Misuse”

Repeated stream cipher nonces

NOBUS unlikely…

Software

Bugdoors in the crypto

Deniability may be plausible

```
goto fail;
goto fail;
```

Those 2 are probably unintentional

RC4 bugdoor (Wagner/Biondi)

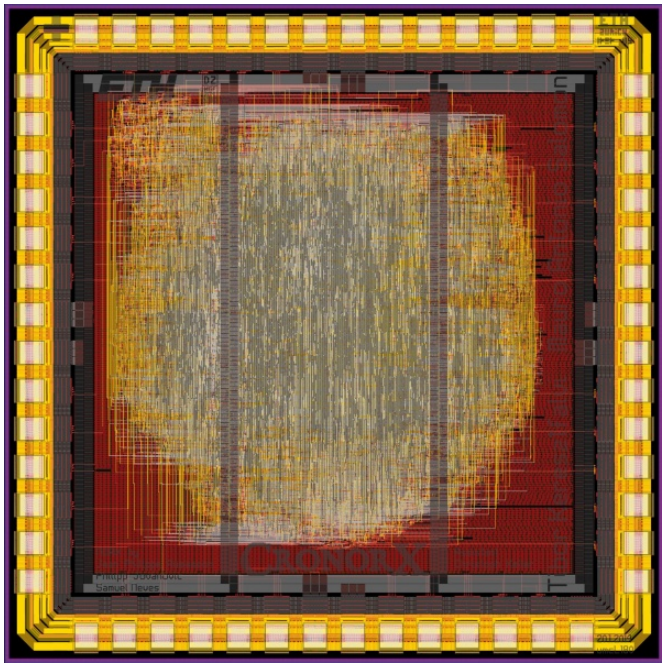
```
#define TOBYTE(x) (x) & 255
#define SWAP(x,y) do { x^=y; y^=x; x^=y; } while (0)

static unsigned char A[256];
static int i=0, j=0;

unsigned char encrypt_one_byte(unsigned char c) {
    int k;
    i = TOBYTE( i+1 );
    j = TOBYTE( j + A[i] );
    SWAP( A[i], A[j] );
    k = TOBYTE( A[i] + A[j] );
    return c ^ A[k];
}
```

Hardware

IC trojans



Malicious modification of a chip

At design (HDL) or fab (netlist)

Detection difficult

Stealthy Dopant-Level Hardware Trojans *

Georg T. Becker[1], Francesco Regazzoni[2], Christof Paar[1,3],
and Wayne P. Burleson[1]

(CHES 2013)

Reversing Stealthy Dopant-Level Circuits

Takeshi Sugawara[1], Daisuke Suzuki[1], Ryoichi Fujii[1], Shigeaki Tawa[1]
Ryohei Hori[2], Mitsuru Shiozaki[2], and Takeshi Fujino[2]

(CHES 2014)

Bug Attacks

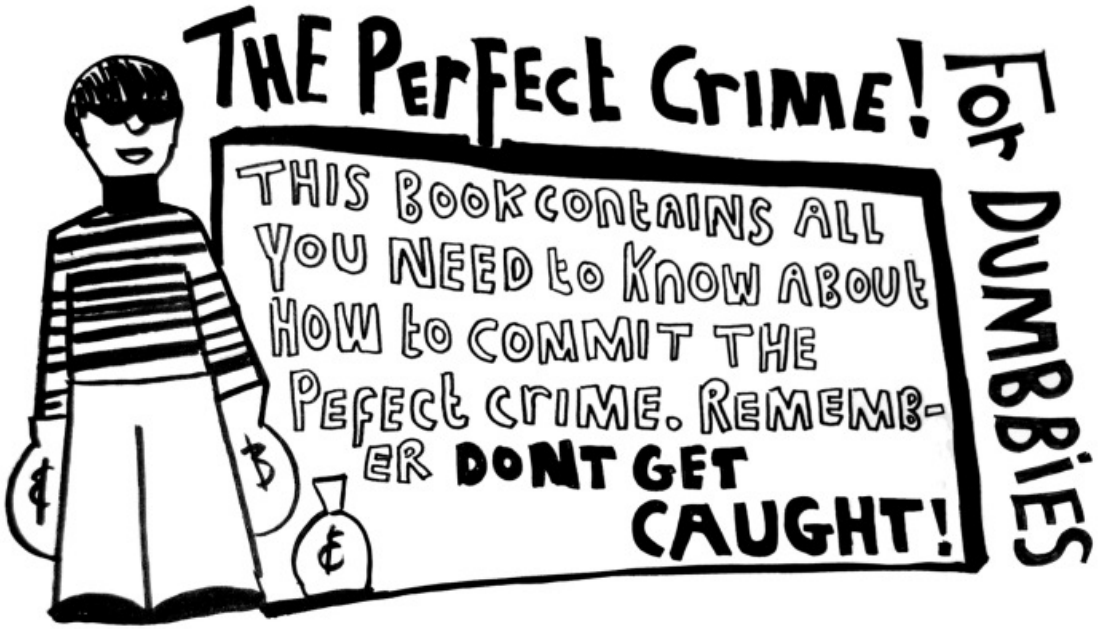
Eli Biham[1], Yaniv Carmeli[1], and Adi Shamir[2]

CPU multiplier X × Y = Z correct
except for one “magic” pair (X, Y)

Exploitable to break RSA, ECC, etc.

2^{128} pairs for 64-bit MUL, detection unlikely

A perfect backdoor



http://phili89.wordpress.com/2010/05/24/the-perfect-crime-project-38/

Covert channel with a malicious RNG

Public-key encryption (NOBUS)

Indistinguishability from random strings (for undetectability)

Compute **X** = Enc(pk, data to exfiltrate)

X should look like a random string

Use **X** as (say) IVs for AES-CTR

Pubkey encryption scheme with ciphertexts indistinguishable from random strings?

Elligator: Elliptic-curve points indistinguishable from uniform random strings

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Tanja Lange[4]
tanja@hyperelliptic.org

Elligator curves

E-382	True ✓	Elligator 2: Yes.
M-383	True ✓	Elligator 2: Yes.
Curve383187	True ✓	Elligator 2: Yes.
brainpoolP384t1	**False**	Elligator 2: No.
NIST P-384	**False**	Elligator 2: No.
Curve41417	True ✓	Elligator 2: Yes.
Ed448-Goldilocks	True ✓	Elligator 2: Yes.
M-511	True ✓	Elligator 2: Yes.
E-521	True ✓	Elligator 2: Yes.

http://safecurves.cr.yp.to/ind.html

RNG circuit must be hidden

(For example in FPGA/PLD, difficult to RE)

Communications and computations appear identical to those of a clean system

Full reverse-engineering:
Backdoor detected but unexploitable, and previous covert coms remain safe

What can be exfiltrated? **RNG state**

Can give past and future session keys, depending on the RNG construction

Many other techniques…

Conclusion

All this is quite basic

And that’s only for crypto

Should we worry about backdoors?

or

First fix bugs and usability issues?

Draw your own conclusions

“a competition to write or modify crypto code that appears to be secure, but actually does something evil.”

Send you submission(s) before Dec 2, 2014

https://underhandedcrypto.com/

Merci!

“Secrets… are the very root of cool.”

William Gibson, *Spook Country*