

# CSE 127: Introduction to Security

## Lecture 15: TLS

**Nadia Heninger and Deian Stefan**

UCSD

Fall 2019

Some material from Dan Boneh, Stefan Savage

# Reminder: Network Attacker Threat Model

Network Attacker:

- Controls infrastructure: Routers, DNS
- Eavesdrops, injects, drops, or modifies packets

Examples:

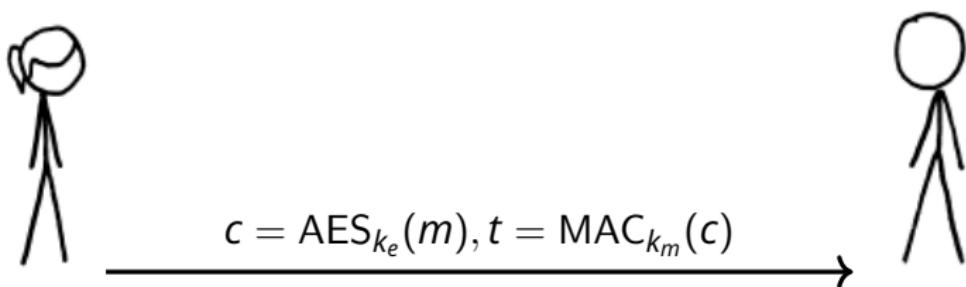
- Wifi at internet cafe
- Internet access at hotels

Goal: Establish a secure channel to a host that ensures

- Confidentiality and Integrity of messages
- Authentication of the remote host

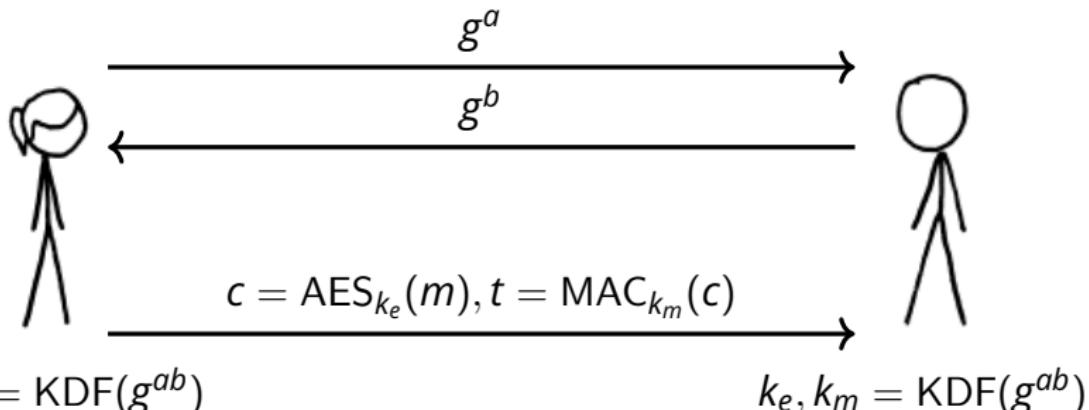
# Constructing a secure encrypted channel

- To ensure confidentiality and integrity: Encrypt and MAC data



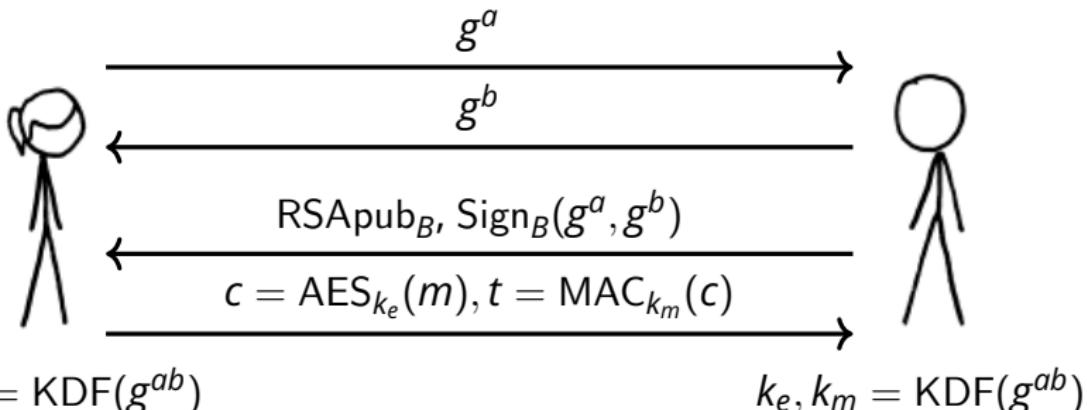
# Constructing a secure encrypted channel

- To ensure confidentiality and integrity: Encrypt and MAC data
- To negotiate shared symmetric keys: Diffie-Hellman key exchange. Key Derivation Function (KDF) maps shared secret to symmetric key.



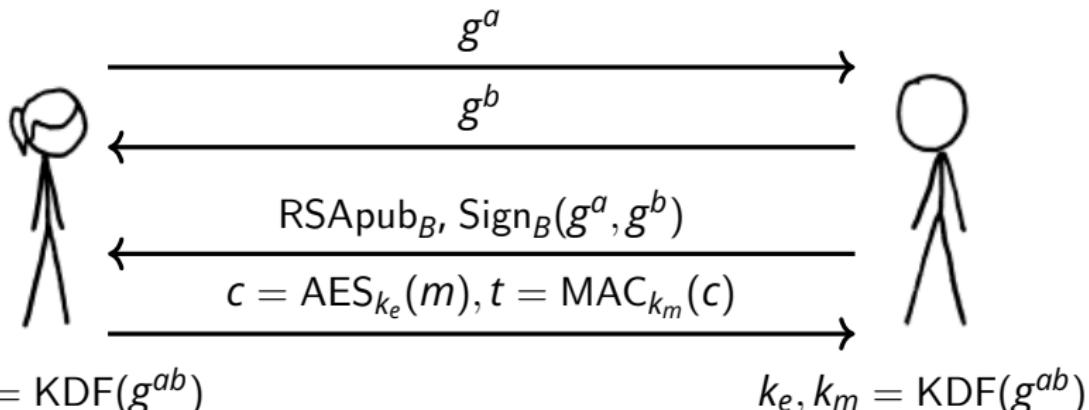
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- To ensure authenticity of endpoints: Digital Signatures



# Constructing a secure encrypted channel

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How does Alice know to trust Bob's public signing key?

# Public Key Infrastructure: Establishing Trust in Keys

Ways to establish trust in keys:

- Meet in person to exchange keys.
  - Not practical at scale over the internet

# Public Key Infrastructure: Establishing Trust in Keys

## Ways to establish trust in keys:

- Fingerprint verification
    - Verify a cryptographic hash of a public key through a separate channel, or “trust on first use” (TOFU).
    - This is used by SSH for host keys.

```
nadiyah$ ssh portal.cs.princeton.edu
oooooooooooooooooooooooooooooooooooooooooooooooooooo
@      WARNING: POSSIBLE DNS SPOOFING DETECTED!      @
oooooooooooooooooooooooooooooooooooooooooooooooooooo
The RSA host key for portal.cs.princeton.edu has changed,
and the key for the corresponding IP address 128.112.155.171
is unknown. This could either mean that
DNS SPOOFING is happening or the IP address for the host
and its host key have changed at the same time.
oooooooooooooooooooooooooooooooooooooooooooooooooooo
@      WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!      @
oooooooooooooooooooooooooooooooooooooooooooooooooooo
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)
It is also possible that a host key has just been changed.
The fingerprint for the RSA key sent by the remote host is
SHA256:9yBBea9Z0ER6asvvtNf6fRXVra6LOQ30VZLtyKVpNc8.
Please contact your system administrator.
```

# Public Key Infrastructure: Establishing Trust in Keys

Ways to establish trust in keys:

- Fingerprint verification
  - Verify a cryptographic hash of a public key through a separate channel, or “trust on first use” (TOFU).
  - This is used by SSH for host keys.
  - This is also used by encrypted messaging apps like Signal

The image shows two screenshots of the Signal app's "Verify identity" feature. The left screenshot shows a blue icon with a white speech bubble and dashed lines. The right screenshot shows a QR code with the text "Tap to scan". Both screenshots show the same UI elements: a back arrow, a title bar, and a main content area.

**Verify identity**

Their identity (they read):

```
05 d9 0e f7 e3 f6 52 cb  
31 1d e1 79 6b 81 fb 8d  
19 b9 84 c5 ea 1e 50 4a  
9b 24 e4 c7 ea 91 a7 1d
```

Your identity (you read):

```
05 40 8b d4 6c 57 22 04  
0c a5 fa 44 76 0e 85 c5  
67 59 7e 57 ea 22 de 8d  
f4 36 79 02 bc 17 56 2e  
5b
```

If you wish to verify the security of your end-to-end encryption with Vera Zasulich, compare the numbers above with the numbers on their device. Alternately, you can scan the code on their phone, or ask them to scan your code. [Learn more](#)

# Public Key Infrastructure: Establishing Trust in Keys

Ways to establish trust in keys:

- Hard code public keys in software
  - “Certificate pinning” used by browsers

# Public Key Infrastructure: Establishing Trust in Keys

Ways to establish trust in keys:

- Certificate Authorities
  - A certificate authority is a kind of commercial trusted intermediary.
  - Certificate Authorities verify public keys and sign them in exchange for money.
  - If you trust the certificate authority, you transitively trust the keys it signs.
  - This is used for TLS, software signing keys.

# Public Key Infrastructure: Establishing Trust in Keys

Ways to establish trust in keys:

- Web of Trust

- In a web of trust, you establish trust in intermediaries of your choice.
- You then transitively trust the keys they sign.
- This is used by PGP.

```
nadiyah$ gpg --edit-key rivest@csail.mit.edu
gpg> trust
pub 1024D/567B4BAD created: 2010-12-19 expires: never usage: SC
      trust: unknown validity: unknown
sub 1024g/EFE31B86 created: 2010-12-19 expires: never usage: E
[ unknown] (1). Ronald L Rivest <rivest@csail.mit.edu>
```

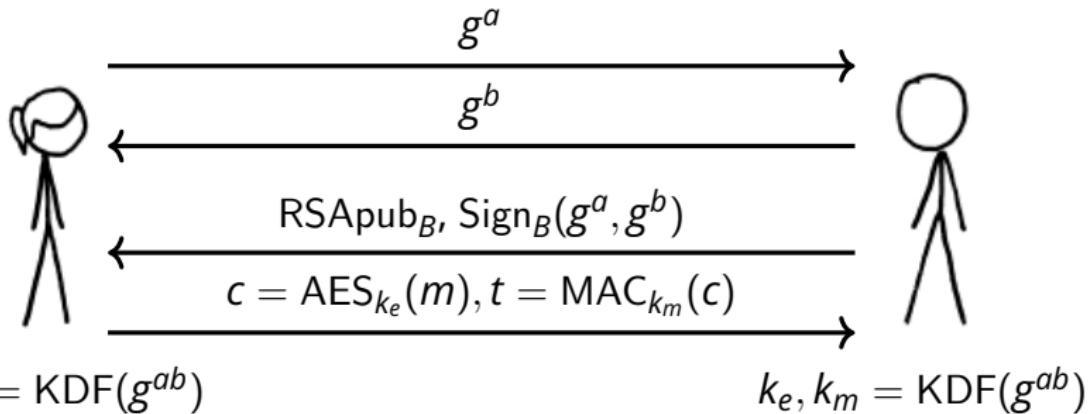
Please decide how far you trust this user to correctly verify other users' keys  
(by looking at passports, checking fingerprints from different sources, etc.)

1 = I don't know or won't say  
2 = I do NOT trust  
3 = I trust marginally  
4 = I trust fully  
5 = I trust ultimately  
m = back to the main menu

Your decision?

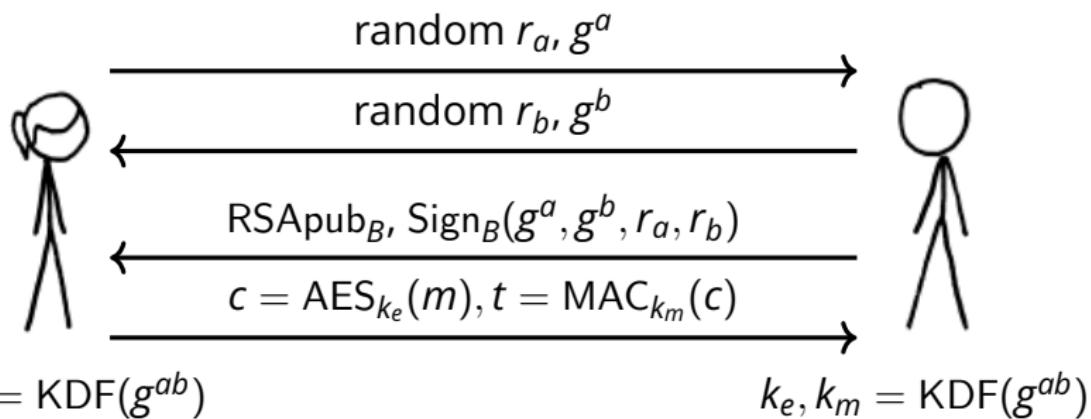
# Constructing a secure encrypted channel

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# Constructing a secure encrypted channel

- To ensure confidentiality and integrity: Encrypt and MAC data
- To negotiate shared symmetric keys: Diffie-Hellman key exchange
- To ensure authenticity of endpoints: Digital Signatures
- To ensure an adversary can't reuse a signature later, add some random unique values ("nonces")



# TLS: Transport Layer Security

- TLS provides an encrypted channel for application data.
- Used for HTTPS: HTTP inside of a TLS session
- Used to be called SSL (Secure Sockets Layer) in the 90s.

SSL 1.0 Terribly insecure; never released.

SSL 2.0 Released 1995; terribly insecure.

SSL 3.0 Released 1996; insecure since 2014.

TLS 1.0 Released 1999; deprecated and will be removed from major browsers in 2020.

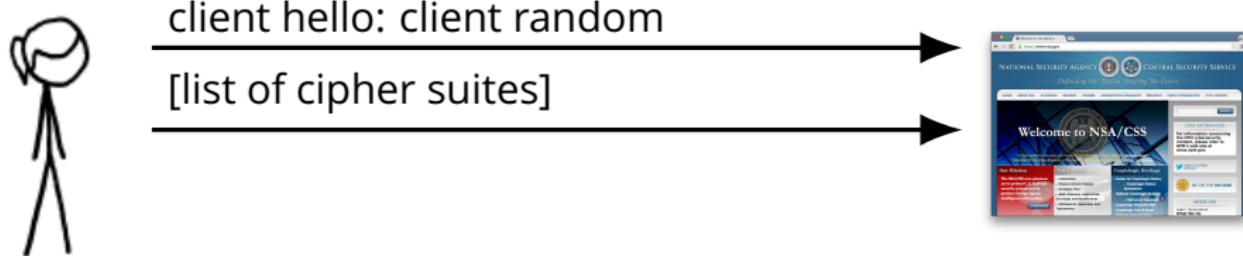
TLS 1.1 Released 2006; deprecated and will be removed from major browsers in 2020.

TLS 1.2 Released 2008. Ok.

TLS 1.3 Standardized in August 2018 and is being rolled out now; major change from TLS 1.2.

# TLS 1.2 with Diffie-Hellman Key Exchange

Step 1: The client (browser) tells the server what kind of cryptography it supports.



Cipher suites: list of options like:

TLS\_ECDHE\_RSA\_WITH\_AES\_128\_GCM\_SHA256

This says to use

- elliptic curve Diffie-Hellman for key exchange
- RSA digital signatures
- 128-bit AES for symmetric encryption
- GCM (Galois Counter Mode) AES mode of operation
- SHA-256 for hash function

# TLS 1.2 with Diffie-Hellman Key Exchange

Step 1: The client (browser) tells the server what kind of cryptography it supports.



client hello: client random

[list of cipher suites]



Cipher suites: list of options like:

TLS\_ECDHE\_RSA\_WITH\_AES\_128\_GCM\_SHA256

Server cipher suite configuration can be confusing and difficult for sysadmins. Many insecure options like

TLS\_DHE\_RSA\_WITH\_DES\_CBC\_SHA

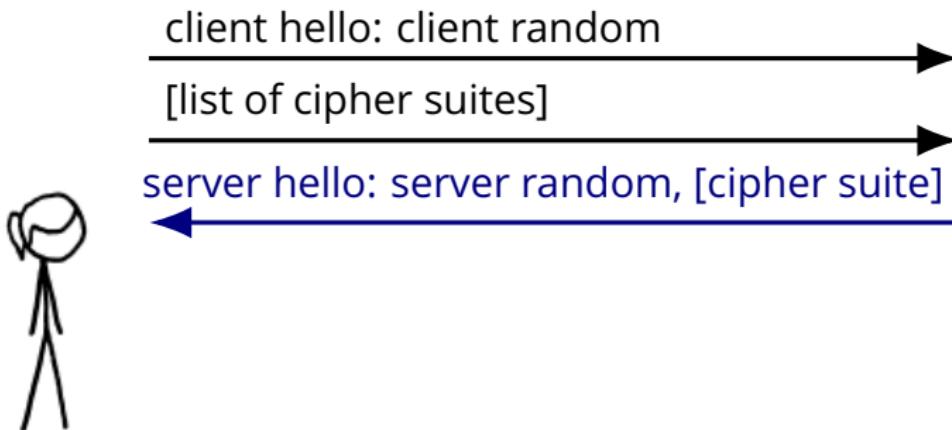
or

TLS\_NULL\_WITH\_NULL\_NULL

Subtle protocol errors around cipher suite negotiation.

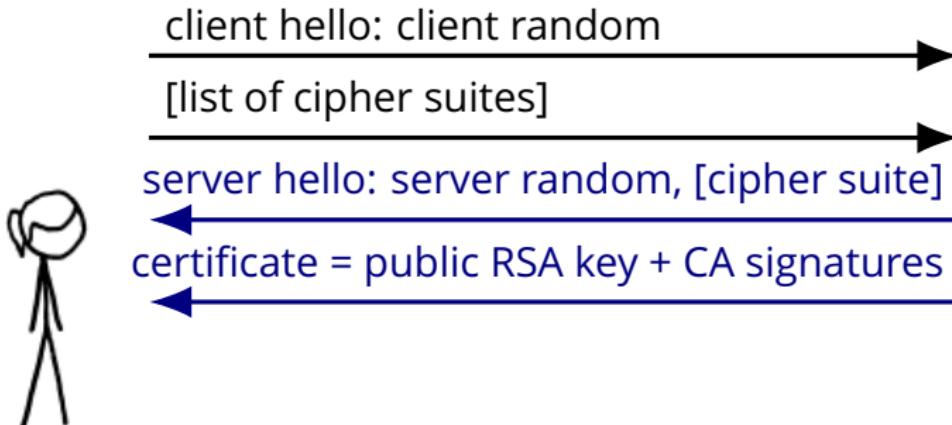
# TLS 1.2 with Diffie-Hellman Key Exchange

Step 2: The server tells the client which kind of cryptography it wishes to use.



# TLS 1.2 with Diffie-Hellman Key Exchange

Step 3: The server sends over its certificate which contains the server's public key and signatures from a certificate authority.



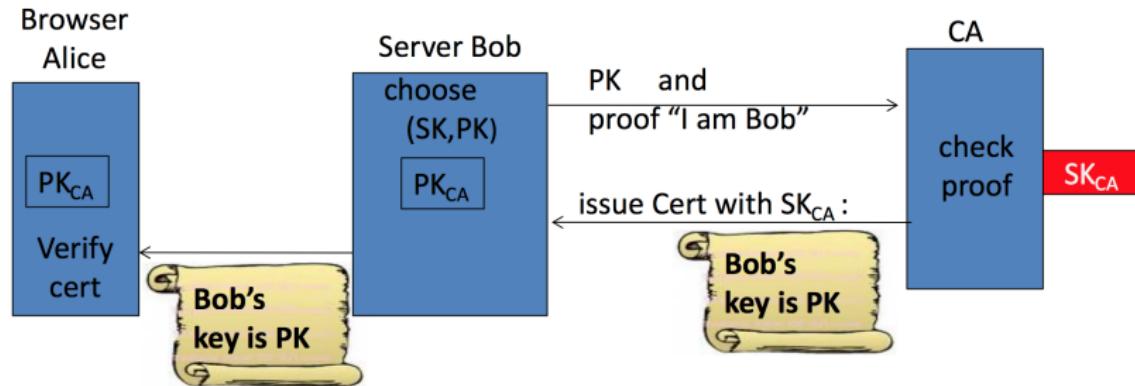
# Certificates and Certificate Authorities in TLS

Website public keys are encoded into certificates.

Certificates signed by CAs.

Browsers come with set of trusted CAs.

To verify a certificate, browsers verify chain of digital certificates back to trusted root CA.



Certificates typically valid for 3 months to multiple years.

# Sample certificate



**mail.google.com**

Issued by: Google Internet Authority G3

Expires: Wednesday, June 20, 2018 at 6:25:00 AM Pacific Daylight Time

This certificate is valid

## ▼ Details

Subject Name

Country US

State/Province California

Locality Mountain View

Organization Google Inc

Common Name mail.google.com



Issuer Name

Country US

Organization Google Trust Services

Common Name Google Internet Authority G3

Serial Number 3495829599616174946

Version 3

Signature Algorithm SHA-256 with RSA Encryption



Public Key Info

Algorithm Elliptic Curve Public Key ( 1.2.840.10045.2.1 )

Parameters Elliptic Curve secp256r1 ( 1.2.840.10045.3.1.7 )

Public Key 65 bytes : 04 D5 63 FC 4D F9 4E 91 ...

Key Size 256 bits

Key Usage Encrypt, Verify, Derive

Signature 256 bytes : 3F FE 04 7B BE B0 32 1D ...



 USERTrust RSA Certification Authority

↳  InCommon RSA Server CA

↳  cse.ucsd.edu



**cse.ucsd.edu**

Issued by: InCommon RSA Server CA

Expires: Monday, January 4, 2021 at 3:59:59 PM Pacific  
Standard Time

 This certificate is valid

▼ Details

Subject Name \_\_\_\_\_

Country US

Postal Code 92093

State/Province CA

Locality La Jolla

Street Address 9500 Gilman Drive

Organization University of California, San Diego

Organizational Unit UCSD

Common Name cse.ucsd.edu

Issuer Name \_\_\_\_\_

Country US

State/Province MI

Locality Ann Arbor

Organization Internet2

Organizational Unit InCommon

Common Name InCommon RSA Server CA

Serial Number 36 F6 DC 47 6F 09 25 8E 94 EF BF 36 65 4F  
E8 98

Version 3

Signature Algorithm SHA-256 with RSA Encryption  
( 1.2.840.113549.1.1.11 )

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Who are we trusting?

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Who are we trusting?

Who is this cert for?

Key ID 1E 05 A3 77 8F 6C 96 E2 5B 87 4B A6 B4 86 AC  
71 00 0C E7 38

Extension Subject Alternative Name ( 2.5.29.17 )  
Critical NO

DNS Name cse.ucsd.edu  
DNS Name cs.ucsd.edu  
DNS Name www-cs.ucsd.edu  
DNS Name www-cse.ucsd.edu  
DNS Name www.cs.ucsd.edu  
DNS Name www.cse.ucsd.edu

Extension Certificate Policies ( 2.5.29.32 )  
Critical NO

Policy ID #1 ( 1.3.6.1.4.1.5923.1.4.3.1.1 )  
Qualifier ID #1 Certification Practice Statement ( 1.3.6.1.5.5.7.2.1 )  
CPS URI [https://www.incommon.org/cert/repository/cps\\_ssl.pdf](https://www.incommon.org/cert/repository/cps_ssl.pdf)  
Policy ID #2 ( 2.23.140.1.2.2 )

Extension CRL Distribution Points ( 2.5.29.31 )  
Critical NO  
URI <http://crl.incommon-rsa.org/InCommonRSAServerCA.crl>

Extension Certificate Authority Information Access  
( 1.3.6.1.5.5.7.1.1 )  
Critical NO

Method #1 CA Issuers ( 1.3.6.1.5.5.7.48.2 )  
URI [http://crt.usertrust.com/InCommonRSAServerCA\\_2.crt](http://crt.usertrust.com/InCommonRSAServerCA_2.crt)

Method #2 Online Certificate Status Protocol  
( 1.3.6.1.5.5.7.48.1 )  
URI <http://ocsp.usertrust.com>

Key ID 1E 05 A3 77 8F 6C 96 E2 5B 87 4B A6 B4 86 AC  
71 00 0C E7 38

Extension Subject Alternative Name ( 2.5.29.17 )

Critical NO

DNS Name cse.ucsd.edu  
DNS Name cs.ucsd.edu  
DNS Name www-cs.ucsd.edu  
DNS Name www-cse.ucsd.edu  
DNS Name www.cs.ucsd.edu  
DNS Name www.cse.ucsd.edu

Extension Certificate Policies ( 2.5.29.32 )

Critical NO

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Qualifier ID #1 Certification Practice Statement ( 1.3.6.1.5.5.7.2.1 )

CPS URI [https://www.incommon.org/cert/repository/  
cps\\_ssl.pdf](https://www.incommon.org/cert/repository/cps_ssl.pdf)

Policy ID #2 ( 2.23.140.1.2.2 )

Extension CRL Distribution Points ( 2.5.29.31 )

Critical NO

URI [http://crl.incommon-rsa.org/  
InCommonRSAServerCA.crl](http://crl.incommon-rsa.org/<br/>InCommonRSAServerCA.crl)

Extension Certificate Authority Information Access  
( 1.3.6.1.5.5.7.1.1 )

Critical NO

Method #1 CA Issuers ( 1.3.6.1.5.5.7.48.2 )

URI [http://crt.usertrust.com/  
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Who is this cert for?

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State/Province MI  
Locality Ann Arbor  
Organization Internet2  
Organizational Unit InCommon  
Common Name InCommon RSA Server CA

Serial Number 36 F6 DC 47 6F 09 25 8E 94 EF BF 36 65 4F  
E8 98

Version 3

Signature Algorithm SHA-256 with RSA Encryption  
( 1.2.840.113549.1.1.11 )

Parameters None

Not Valid Before Thursday, January 4, 2018 at 4:00:00 PM Pacific Standard Time

Not Valid After Monday, January 4, 2021 at 3:59:59 PM Pacific Standard Time

**Public Key Info** \_\_\_\_\_

Algorithm RSA Encryption ( 1.2.840.113549.1.1.1 )

Parameters None

Public Key 256 bytes : FA F9 1A 08 92 86 9C 7B ...

Exponent 65537

Key Size 2,048 bits

Key Usage Encrypt, Verify, Wrap, Derive

Signature 256 bytes : 6F 62 36 46 B7 43 28 04 ...

---

Extension Key Usage ( 2.5.29.15 )  
Critical YES  
Usage Digital Signature, Key Encipherment

Issuer Name \_\_\_\_\_

Country US

State/Province MI

Locality Ann Arbor

Organization Internet2

Organizational Unit InCommon

Common Name InCommon RSA Server CA

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Extension Key Usage ( 2.5.29.15 )

Critical YES

Usage Digital Signature, Key Encipherment

CSE's pub key info

Key ID 1E 05 A3 77 8F 6C 96 E2 5B 87 4B A6 B4 86 AC  
71 00 0C E7 38

Extension Subject Alternative Name ( 2.5.29.17 )

Critical NO

DNS Name cse.ucsd.edu

DNS Name cs.ucsd.edu

DNS Name www-cs.ucsd.edu

DNS Name www-cse.ucsd.edu

DNS Name www.cs.ucsd.edu

DNS Name www.cse.ucsd.edu

Extension Certificate Policies ( 2.5.29.32 )

Critical NO

Policy ID #1 ( 1.3.6.1.4.1.5923.1.4.3.1.1 )

Qualifier ID #1 Certification Practice Statement ( 1.3.6.1.5.5.7.2.1 )

CPS URI [https://www.incommon.org/cert/repository/  
cps\\_ssl.pdf](https://www.incommon.org/cert/repository/cps_ssl.pdf)

Policy ID #2 ( 2.23.140.1.2.2 )

Extension CRL Distribution Points ( 2.5.29.31 )

Critical NO

URI [http://crl.incommon-rsa.org/  
InCommonRSAServerCA.crl](http://crl.incommon-rsa.org/InCommonRSAServerCA.crl)

Extension Certificate Authority Information Access  
( 1.3.6.1.5.5.7.1.1 )

Critical NO

Method #1 CA Issuers ( 1.3.6.1.5.5.7.48.2 )

URI [http://crt.usertrust.com/  
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Method #2 Online Certificate Status Protocol  
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URI <http://ocsp.usertrust.com>

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Critical NO

DNS Name cse.ucsd.edu

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DNS Name www-cse.ucsd.edu

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URI <http://ocsp.usertrust.com>

Where we should  
check for revocation  
information

# Revocation

- Problem: keys get compromised
  - Attacker with a key can impersonate you and read messages encrypted to you
- Key expiration helps, but not enough
- CA and PGP PKIs support revocation
  - "I, Alice, revoke my public key ... do not use it."
  - Signs revocation with her private key
  - Others can verify Alice's signature, stop using key

# Root CAs on OS X

The screenshot shows the 'Keychains' section of the OS X Keychain Access application. The left sidebar has 'login' selected under 'Keychains'. The 'Certificates' section under 'My Certificates' is also selected. A list of certificates is shown, with 'GlobalSign Root CA' highlighted. The right pane displays detailed information about this certificate, including its expiration date (Friday, January 28, 2028) and its role as a 'Root certificate authority'. Below this, a table lists 162 items, which are other certificates in the system.

Name	Kind	Expires	Keychain
Entrust Root Certification Authority - G2	certificate	Dec 7, 2030 at 9:55:54 AM	System Roots
Entrust.net Certification Authority (2048)	certificate	Dec 24, 2019 at 10:20:51...	System Roots
Entrust.net Certification Authority (2048)	certificate	Jul 24, 2029 at 7:15:12 AM	System Roots
ePKI Root Certification Authority	certificate	Dec 19, 2034 at 6:31:27...	System Roots
Federal Common Policy CA	certificate	Dec 1, 2030 at 8:45:27 AM	System Roots
GeoTrust Global CA	certificate	May 20, 2022 at 8:00:00...	System Roots
GeoTrust Primary Certification Authority	certificate	Jul 16, 2036 at 4:59:59 PM	System Roots
GeoTrust Primary Certification Authority - G2	certificate	Jan 18, 2038 at 3:59:59...	System Roots
GeoTrust Primary Certification Authority - G3	certificate	Dec 1, 2037 at 3:59:59 PM	System Roots
Global Chambersign Root	certificate	Sep 30, 2037 at 9:14:18...	System Roots
Global Chambersign Root - 2008	certificate	Jul 31, 2038 at 5:31:40 AM	System Roots
GlobalSign	certificate	Mar 18, 2029 at 3:00:00...	System Roots
GlobalSign	certificate	Jan 18, 2038 at 7:14:07 PM	System Roots
GlobalSign	certificate	Jan 18, 2038 at 7:14:07 PM	System Roots
GlobalSign	certificate	Dec 15, 2021 at 12:00:00...	System Roots
<b>GlobalSign Root CA</b>	<b>certificate</b>	<b>Jan 28, 2028 at 4:00:00...</b>	<b>System Roots</b>
Go Daddy Class 2 Certification Authority	certificate	Jun 29, 2034 at 10:06:20...	System Roots
Go Daddy Root Certificate Authority - G2	certificate	Dec 31, 2037 at 3:59:59...	System Roots
Government Root Certification Authority	certificate	Dec 31, 2037 at 7:59:59...	System Roots
Hellenic Academic and Research Institutions RootCA 2011	certificate	Dec 1, 2031 at 5:49:52 AM	System Roots
Hongkong Post Root CA 1	certificate	May 14, 2023 at 9:52:29...	System Roots
IdenTrust Commercial Root CA 1	certificate	Jan 16, 2034 at 10:12:23...	System Roots
IdenTrust Public Sector Root CA 1	certificate	Jan 16, 2034 at 9:53:32...	System Roots
ISRG Root X1	certificate	Jun 4, 2035 at 4:04:38 AM	System Roots
Izenpe.com	certificate	Dec 13, 2037 at 12:27:25...	System Roots
Izenpe.com	certificate	Dec 13, 2037 at 12:27:25...	System Roots
KISA RootCA 1	certificate	Aug 24, 2025 at 1:05:46...	System Roots

Which CA can issue a certificate for fbi.gov?

Which CA can issue a certificate for google.com?

# CA Hacks and Vulnerabilities

There is a long history of CAs getting hacked or doing the wrong thing.

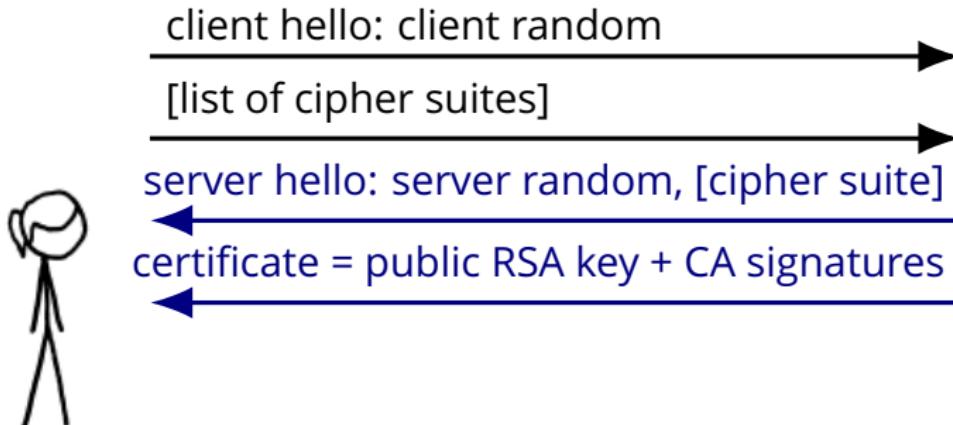
- 2011: Comodo and DigiNotar CAs hacked, used to issue fraudulent certificates for Hotmail, Gmail, Skype, Yahoo Mail, Firefox...
  - Fraudulent certificates later used in man-in-the-middle attack against Iran.
- 2013: TurkTrust issued fraudulent certificate for Gmail.
- 2014: Indian NIC issue certs for Google and Yahoo!
- 2016: WoSign issues cert for GitHub.

## Mitigations:

- Certificate pinning.
  - Hard code certificates for some sites in browser.
- Certificate Transparency.
  - Public append-only log of certificate issuances to track fraudulent certs.

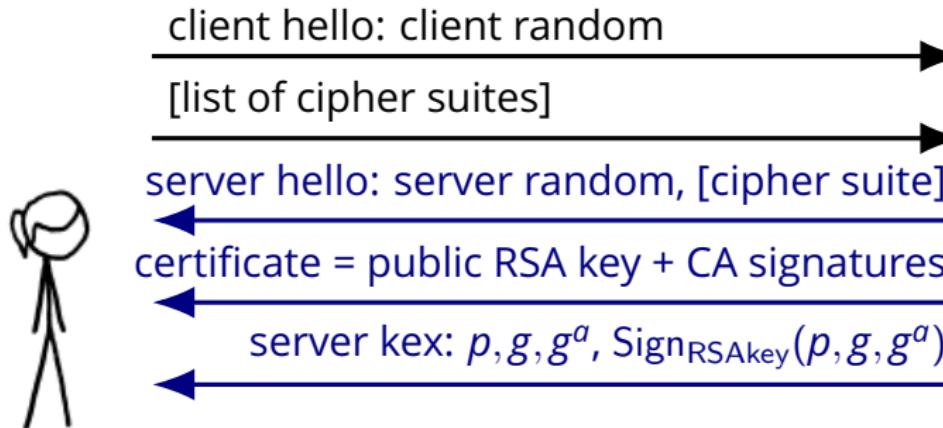
# TLS 1.2 with Diffie-Hellman Key Exchange

Step 3: The server sends over its certificate which contains the server's public key and signatures from a certificate authority.



# TLS 1.2 with Diffie-Hellman Key Exchange

Step 4: The server initiates a Diffie-Hellman key exchange.

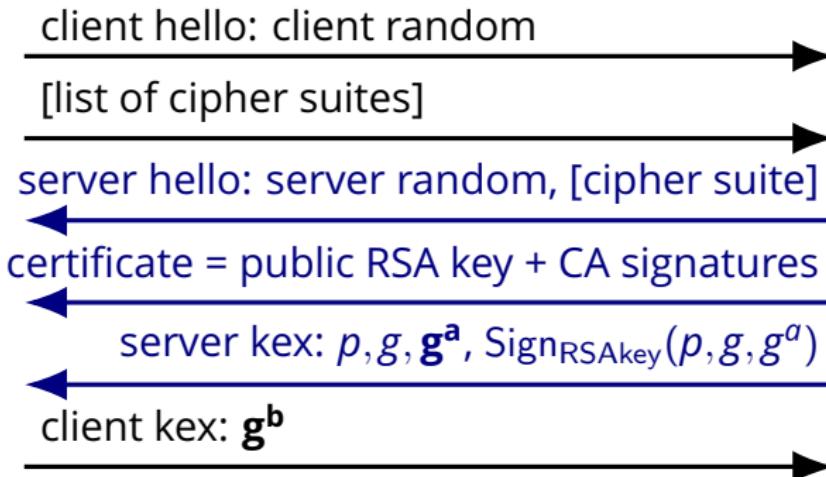


To protect against man-in-the-middle attacks, the server uses its public key to sign the Diffie-Hellman key exchange.

TLS also allows client authentication, but this is rare.

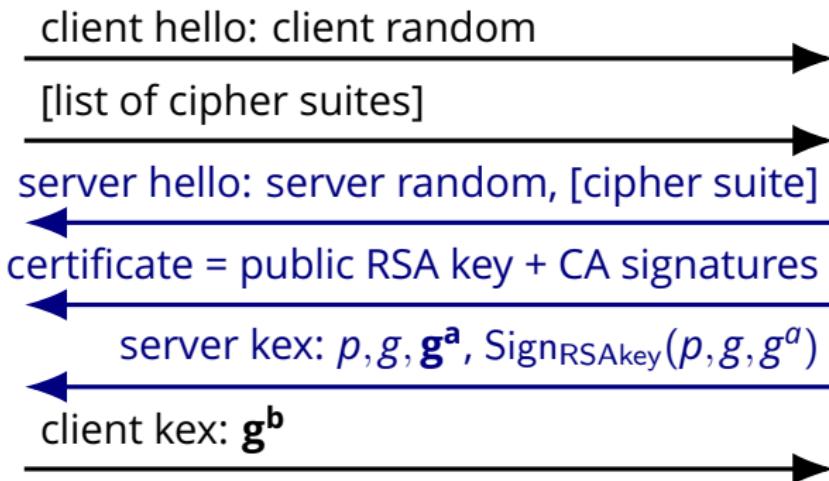
# TLS 1.2 with Diffie-Hellman Key Exchange

Step 5: The client responds with its half of the Diffie-Hellman key exchange.



# TLS 1.2 with Diffie-Hellman Key Exchange

Step 6: The client and server derive symmetric encryption keys from the shared secret using a key derivation function.



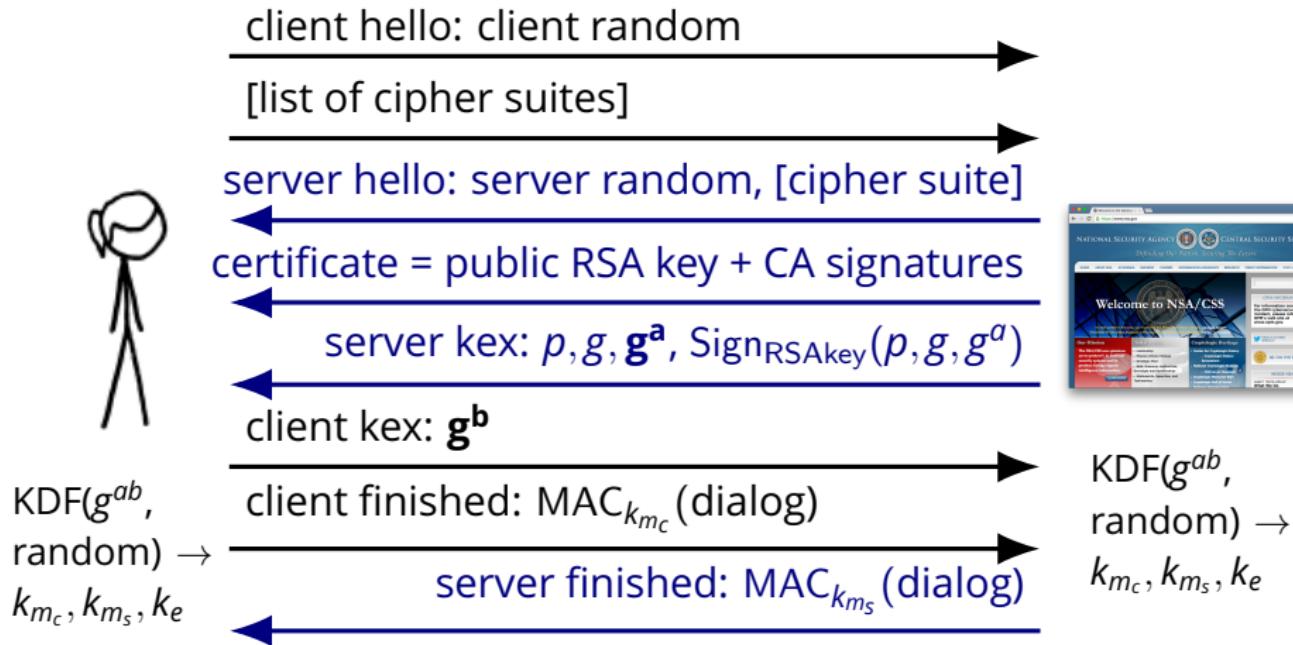
$\text{KDF}(g^{ab},$   
random)  $\rightarrow$   
 $k_{m_c}, k_{m_s}, k_e$



$\text{KDF}(g^{ab},$   
random)  $\rightarrow$   
 $k_{m_c}, k_{m_s}, k_e$

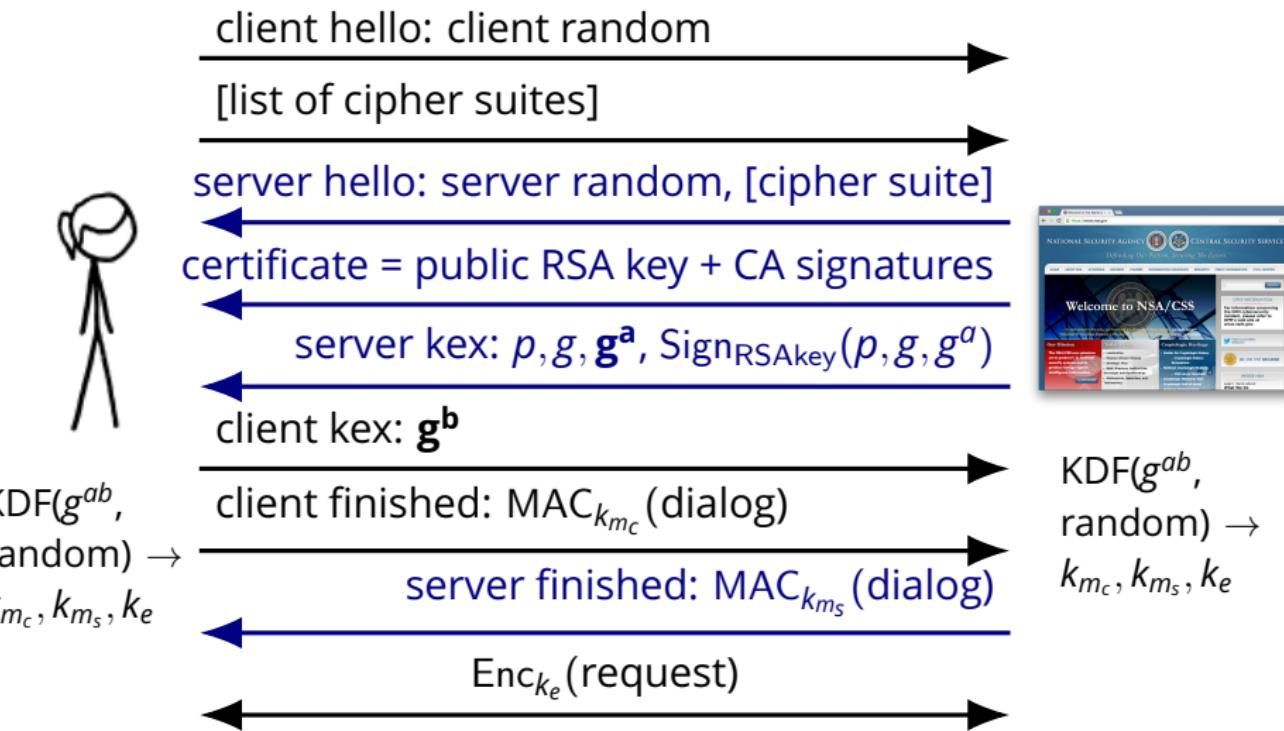
# TLS 1.2 with Diffie-Hellman Key Exchange

Step 7: The client and server verify the integrity of the handshake using the MAC keys they have derived.



# TLS 1.2 with Diffie-Hellman Key Exchange

Step 8: The client and server can now send encrypted application data (e.g. HTTP) using their secure channel.



# TLS 1.2 with RSA Key Exchange

TLS versions prior to 1.3 also supported using RSA public key encryption to share the premaster secret (shared secret master key).

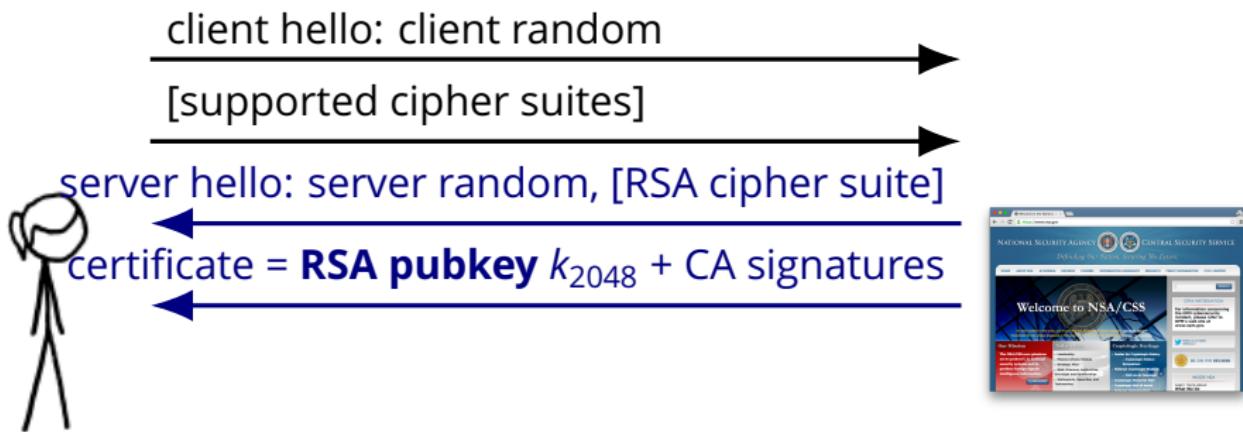
client hello: client random

[supported cipher suites]



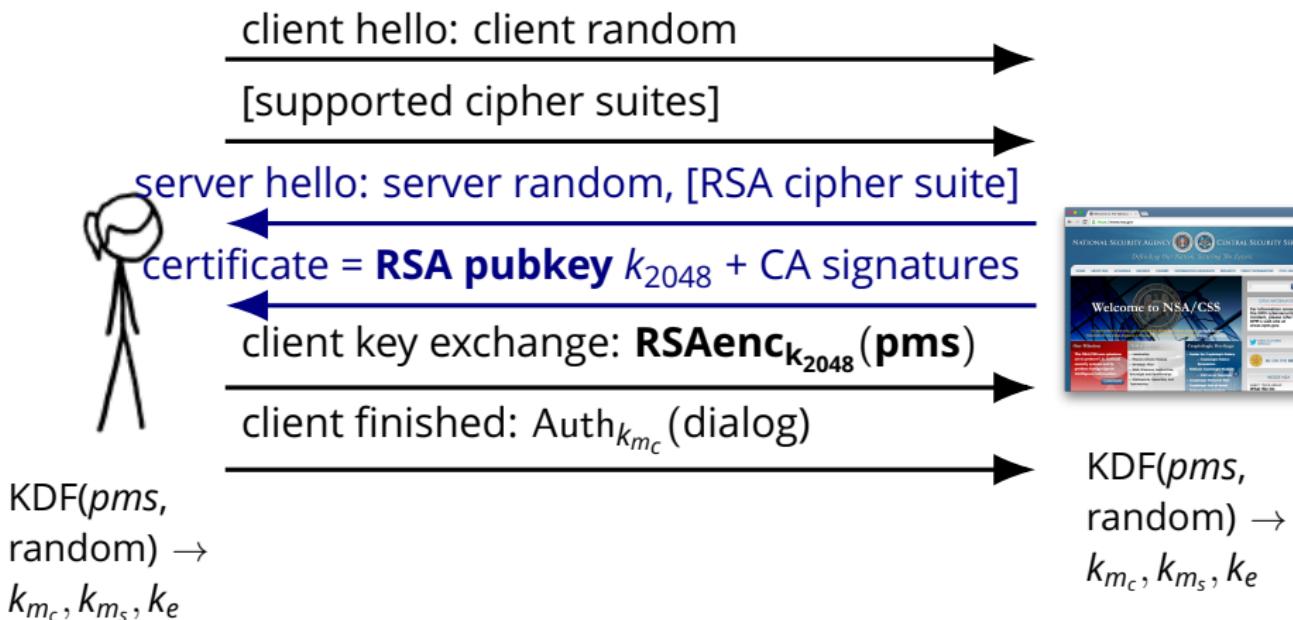
# TLS 1.2 with RSA Key Exchange

TLS versions prior to 1.3 also supported using RSA public key encryption to share the premaster secret (shared secret master key).



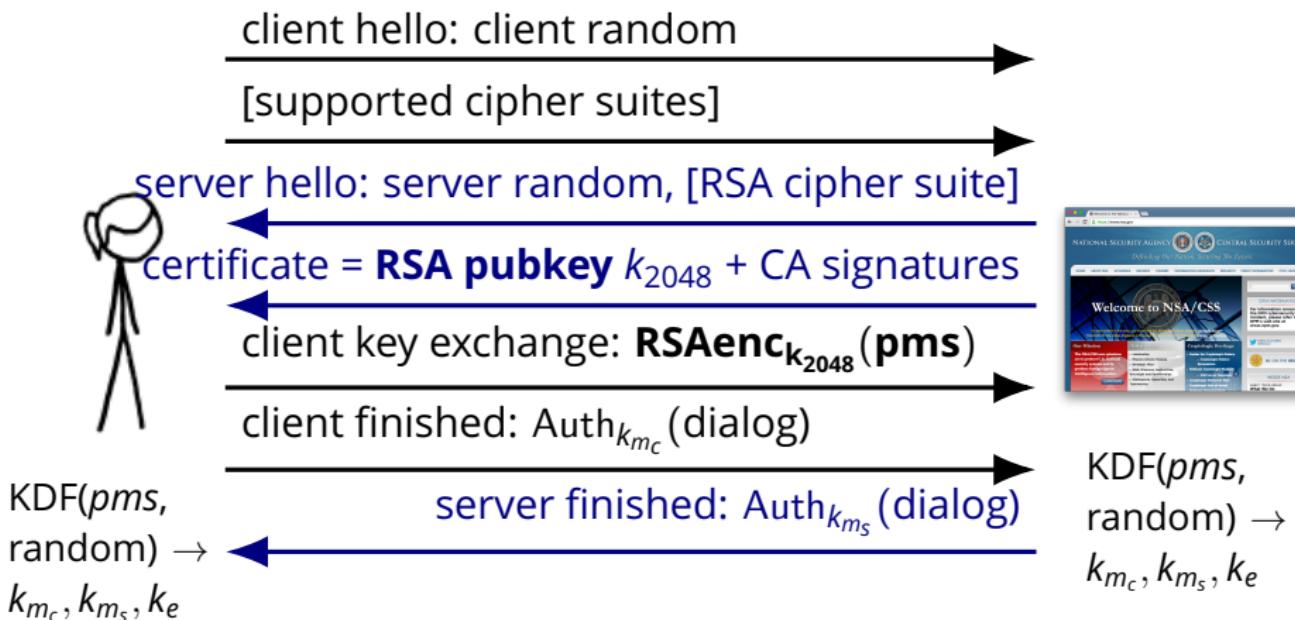
# TLS 1.2 with RSA Key Exchange

TLS versions prior to 1.3 also supported using RSA public key encryption to share the premaster secret (shared secret master key).



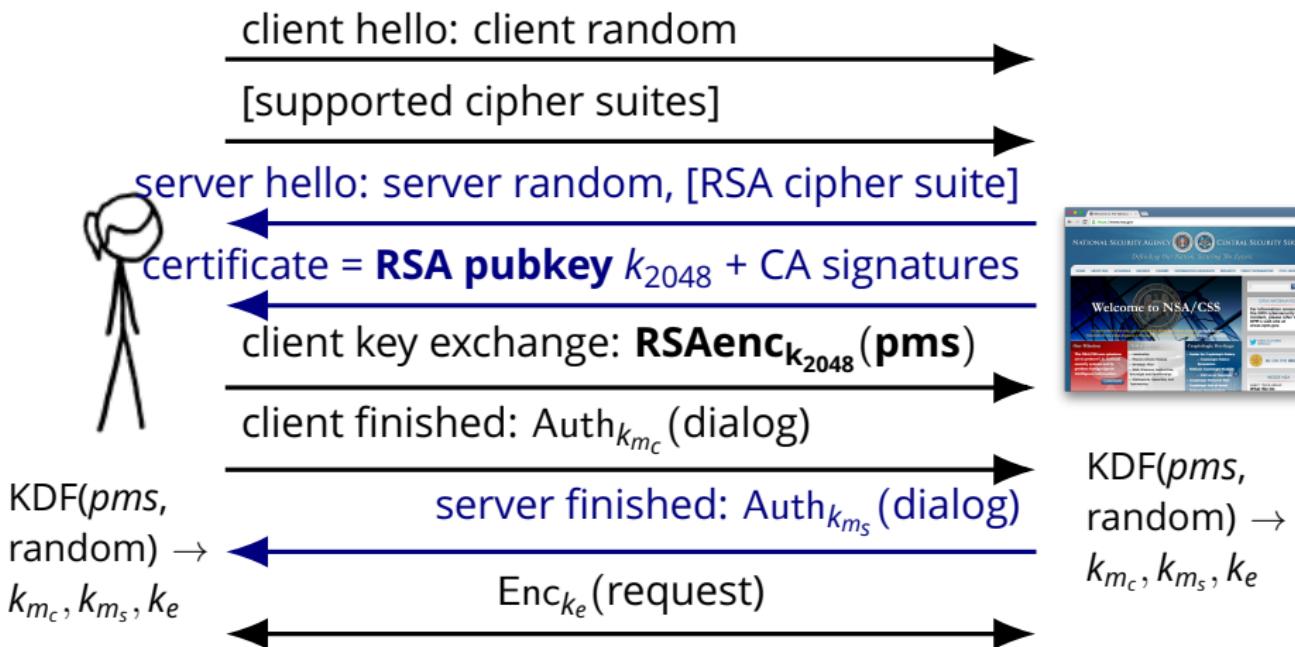
# TLS 1.2 with RSA Key Exchange

TLS versions prior to 1.3 also supported using RSA public key encryption to share the premaster secret (shared secret master key).



# TLS 1.2 with RSA Key Exchange

TLS versions prior to 1.3 also supported using RSA public key encryption to share the premaster secret (shared secret master key).



# What if a private key gets stolen or compromised?

If an adversary obtains a server certificate private key:

- With Diffie-Hellman key exchange, the adversary can:
  - impersonate the server to anyone.
- With RSA key exchange, the adversary can:
  - impersonate the server to anyone.
  - decrypt any traffic from now and any point in the past.

Lavabit employed two stages of encryption for its paid subscribers: storage encryption and transport encryption. Storage encryption protects emails and other data that rests on Lavabit's servers. Theoretically, no person other than the email user could access the data once it was so encrypted. By using storage encryption, Lavabit held a unique market position in the email industry, as many providers do not encrypt stored data.

YOU ARE COMMANDED to appear and testify before the United States district court at the time, date, and place shown below to testify before the court's grand jury. When you arrive, you must remain at the court until the judge or a court officer allows you to leave.

Place: UNITED STATES DISTRICT COURT  
401 Courthouse Square  
Alexandria, Virginia 22314

Date and Time: July 16, 2013 9:30 AM

You must also bring with you the following documents, electronically stored information, or objects (blank if not applicable):

In addition to your personal appearance, you are directed to bring to the grand jury the public and private encryption keys used by lavabit.com in any SSL (Secure Socket Layer) or TLS (Transport Security Layer) sessions, including HTTPS sessions with clients using the lavabit.com web site and encrypted SMTP communications (or Internet communications using other protocols) with mail servers;

Any other information necessary to accomplish the installation and use of the pen/trap device ordered by Judge Buchanan on June 28, 2013, unobtrusively and with minimum interference to the services that are accorded persons with respect to whom the installation and use is to take place;

If such information is electronically stored or unable to be physically transported to the grand jury, you may provide a copy of the information to the Federal Bureau of Investigation. Provision of this information to the FBI does not excuse your personal appearance.

Date: July 11, 2013

CLERK OF COURT

Signature of the Clerk or Deputy Clerk

**UNDER SEAL**

UNITED STATES DISTRICT COURT  
for the  
Eastern District of Virginia

In the Matter of the Search of )  
*(Briefly describe the property to be searched* )  
*or identify the person by name and address)* )  
INFORMATION ASSOCIATED WITH )  
[REDACTED] )  
THAT IS STORED AT PREMISES )  
CONTROLLED BY LAVABIT, LLC )  
Case No. 1:13SW522

**SEARCH AND SEIZURE WARRANT**

To: Any authorized law enforcement officer

An application by a federal law enforcement officer or an attorney for the government requests the search  
of the following person or property located in the \_\_\_\_\_ Northern \_\_\_\_\_ District of \_\_\_\_\_ Texas \_\_\_\_\_

*(Identify the person or describe the property to be searched and give its location):*

See Attachment A

## ATTACHMENT B

### Particular Things to be Seized

#### I. Information to be disclosed by Lavabit, LLC (the "Provider")

To the extent that the information described in Attachment A is within the possession, custody, or control of the Provider, including any emails, records, files, logs, or information that has been deleted but is still available to the Provider, the Provider is required to disclose the following information to the government for each account or identifier listed in Attachment A:

- a. All information necessary to decrypt communications sent to or from the Lavabit e-mail account [REDACTED] including encryption keys and SSL keys;
- b. All information necessary to decrypt data stored in or otherwise associated with the Lavabit account [REDACTED]

Despite the unequivocal language of the August 1 Order, Lavabit dallied and did not comply. Just before the 5:00 pm August 2 deadline, for instance, Levison provided the FBI with an 11-page printout containing largely illegible characters in 4-point type, which he represented to be Lavabit's encryption keys. The Government instructed Lavabit to provide the keys in an industry-standard electronic format by the morning of August 5. Lavabit did not respond.

— 10 —

On the other hand, the results of the present study indicate that the effect of the *lutein* supplement on the visual performance of children is not as strong as that of the *beta-carotene* supplement.

1986. The original work was done by the author in 1986-1987, and the present version is a revised and expanded edition. It includes new material on the history of the Chinese language, the development of Chinese literature, and the impact of Chinese culture on the world. The book also features a comprehensive bibliography and a detailed index.

212 D. J. HALL

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2020 RELEASE UNDER E.O. 14176

1976-77. The first year of the new system was a success, and the second year was even better. The third year, however, was a disaster. The government had promised to increase the budget for the new system by 10%, but instead it was cut by 5%. This led to a significant increase in fees for students, which caused a lot of anger and protest. The government responded by increasing the budget again, but it was too late. By the time the new system was fully implemented, many students had already dropped out or transferred to other schools. The new system was never fully adopted, and the old system remained in place until 1980.

43621791; Final PDF

1. The first step in the process of creating a new product is to identify a market need or opportunity. This can be done through market research, competitor analysis, and customer feedback. Once a need is identified, it is important to define the product's unique value proposition and target audience.

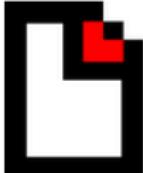
2. The second step is to develop a detailed product plan. This includes defining the product's features, benefits, and pricing strategy. It also involves creating a timeline for development, testing, and launch. A clear product plan is essential for ensuring that the product is developed efficiently and effectively.

3. The third step is to build the product. This involves selecting the right team, tools, and resources to bring the product to life. It may also involve prototyping and testing the product to ensure it meets the desired specifications.

4. The fourth step is to launch the product. This involves marketing the product to the target audience through various channels such as social media, email newsletters, and partnerships. It also involves monitoring the product's performance and making adjustments as needed.

5. The fifth step is to evaluate the product's success. This involves tracking key performance indicators such as sales, user engagement, and customer satisfaction. It also involves gathering feedback from users and using it to inform future product development.

# August 2013



## Lavabit

My Fellow Users,

I have been forced to make a difficult decision: to become complicit in crimes against the American people or walk away from nearly ten years of hard work by shutting down Lavabit. After significant soul searching, I have decided to suspend operations. I wish that I could legally share with you the events that led to my decision. I cannot. I feel you deserve to know what's going on--the first amendment is supposed to guarantee me the freedom to speak out in situations like this. Unfortunately, Congress has passed laws that say otherwise. As things currently stand, I cannot share my experiences over the last six weeks, even though I have twice made the appropriate requests.

What's going to happen now? We've already started preparing the paperwork needed to continue to fight for the Constitution in the Fourth Circuit Court of Appeals. A favorable decision would allow me resurrect Lavabit as an American company.

This experience has taught me one very important lesson: without congressional action or a strong judicial precedent, I would strongly recommend against anyone trusting their private data to a company with physical ties to the United States.

Sincerely,  
Ladar Levison  
Owner and Operator, Lavabit LLC

We reiterate that our review is circumscribed by the arguments that Lavabit raised below and in this Court. We take this narrow course because an appellate court is not a freestanding open forum for the discussion of esoteric hypothetical questions. See Swann v. Charlotte-Mecklenburg Bd.

A CRYPTO NERD'S  
IMAGINATION:

HIS LAPTOP'S ENCRYPTED.  
LET'S BUILD A MILLION-DOLLAR  
CLUSTER TO CRACK IT.

NO GOOD! IT'S  
4096-BIT RSA!

BLAST! OUR  
EVIL PLAN  
IS FOILED!



WHAT WOULD  
ACTUALLY HAPPEN:

HIS LAPTOP'S ENCRYPTED.  
DRUG HIM AND HIT HIM WITH  
THIS \$5 WRENCH UNTIL  
HE TELLS US THE PASSWORD.

GOT IT.



<https://xkcd.com/538/>

"Actual actual reality: nobody cares about his secrets. Also, I would be hard-pressed to find that wrench for \$5."



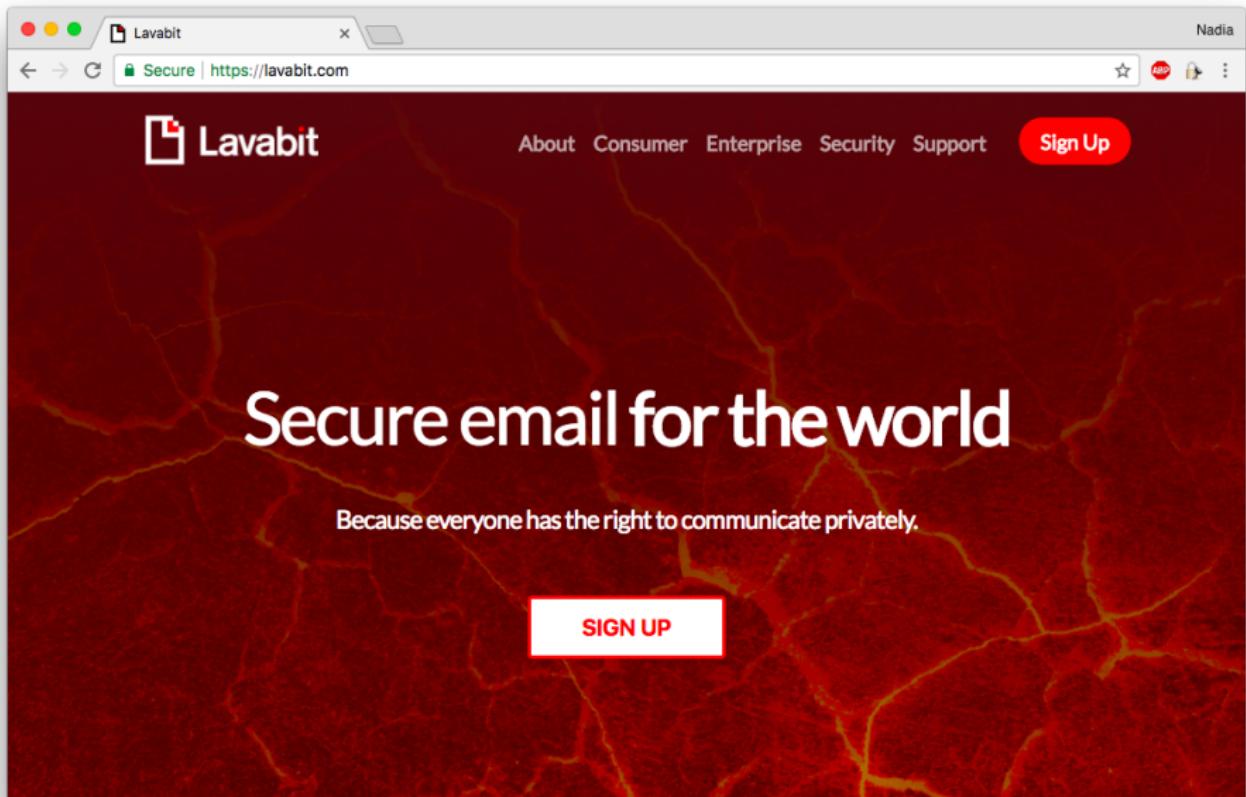
## The server's security certificate is revoked!

You attempted to reach **lavabit.com**, but the certificate that the server presented has been revoked by its issuer. This means that the security credentials the server presented absolutely should not be trusted. You may be communicating with an attacker.

[Back to safety](#)

---

► [Help me understand](#)



A screenshot of the Lavabit website, viewed in a web browser window titled "Lavabit". The address bar shows "Secure | https://lavabit.com". The page has a dark red background with a faint, glowing network or circuit board pattern. At the top left is the Lavabit logo (a white square with a black outline and a small red shape inside). To the right of the logo is a navigation menu with links: "About", "Consumer", "Enterprise", "Security", "Support", and a prominent "Sign Up" button with a red rounded rectangle and white text. The main headline "Secure email for the world" is displayed in large, white, sans-serif font. Below it is a subtitle "Because everyone has the right to communicate privately." and a "SIGN UP" button at the bottom center.

Lavabit

About Consumer Enterprise Security Support

Sign Up

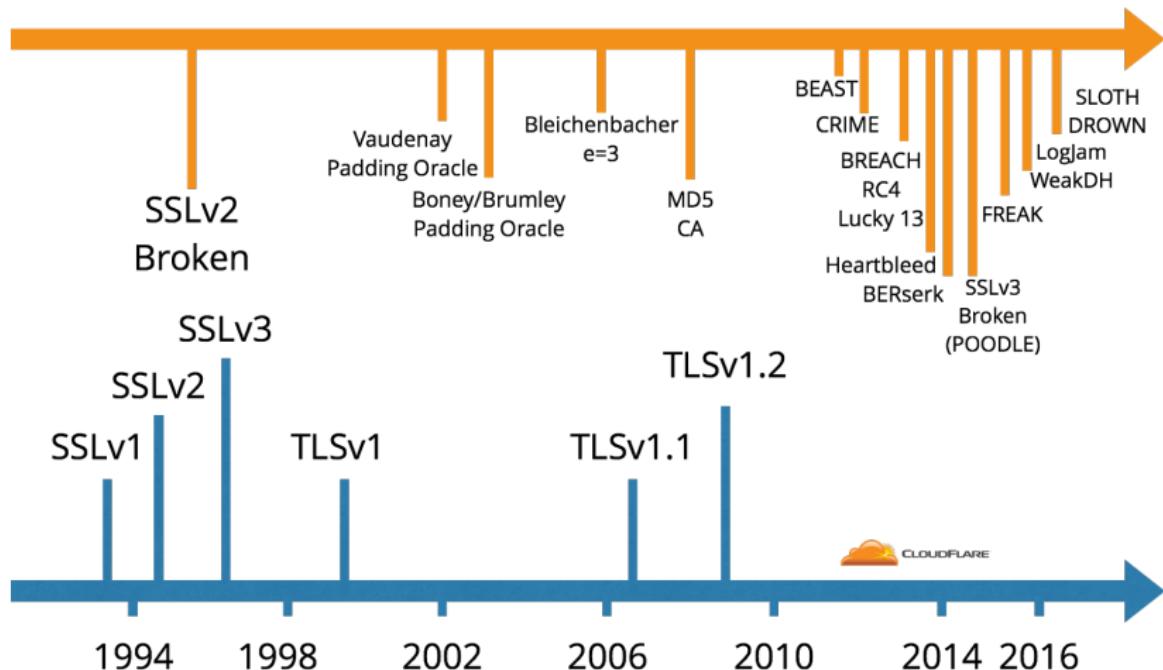
Secure email for the world

Because everyone has the right to communicate privately.

SIGN UP

# TLS v. 1.2 and below have had a lot of vulnerabilities

- Early versions of SSL developed before cryptographic protocol design was fully understood.
- Later protocol versions retained insecure options for backwards compatibility.



# TLS 1.3 is being deployed now

Developed over several years as a collaboration between cryptographers from industry and academia.

Standardized August 2018 by IETF.

Major differences from TLS 1.2 and below:

- RSA key exchange removed.
  - Protects against passive decryption attacks.
- Only secure Diffie-Hellman parameters allowed.
  - Protects against attacks exploiting bad choices of parameters.
- Handshake encrypted immediately after key exchange.
  - Limits the amount of metadata visible to a passive eavesdropper.
- Protocol downgrade protection.
  - Protects against protocol being downgraded to prior insecure versions.

# TLS 1.3 deployment difficulties

TLS 1.3 deployment is slower than it should be.

Major reasons:

- HTTPS proxies extremely common in industry.
- Many of them rely on RSA key exchange to make passive decryption and traffic analysis easier.
- Removing RSA key exchange breaks all these boxes.
- Man-in-the-middle hardware is also quite common.
- Bad implementations have hard-coded values like TLS versions and there is no way to update them.

The “crypto wars” and the historical development of TLS.

# International Traffic in Arms Regulations

April 1, 1992 version

## Category XIII--Auxiliary Military Equipment ...

(b) Information Security Systems and equipment, cryptographic devices, software, and components specifically designed or modified therefore, including:

(1) Cryptographic (including key management) systems, equipment, assemblies, modules, integrated circuits, components or software with the capability of maintaining secrecy or confidentiality of information or information systems, except cryptographic equipment and software as follows:

(i) Restricted to decryption functions specifically designed to allow the execution of copy protected software, provided the decryption functions are not user-accessible.

(ii) Specially designed, developed or modified for use in machines for banking or money transactions, and restricted to use only in such transactions. Machines for banking or money transactions include automatic teller machines, self-service statement printers, point of sale terminals or equipment for the encryption of interbanking transactions.

...

## Timeline of US cryptography export control

- Pre-1994: Encryption software requires individual export license as a munition.
- 1994: US State Department amends ITAR regulations to allow export of approved software to approved countries without individual licenses. 40-bit symmetric cryptography was understood to be approved under this scheme.
- 1995: Netscape develops initial SSL protocol. Includes weakened “export” cipher suites.
- 1996: Bernstein v. United States; California judge rules ITAR regulations are unconstitutional because “code is speech”
- 1996: Cryptography regulation moved to Department of Commerce.
- 1999: TLS 1.0 standardized. Includes weakened “export” cipher suites.
- 2000: Department of Commerce loosens regulations on mass-market and open source software.

# Commerce Control List: Category 5 - Info. Security

(May 23, 2019 version)

a.1.a. A symmetric algorithm employing a key length in excess of 56-bits; not including parity bits; or

a.1.b. An asymmetric algorithm where the security of the algorithm is based on any of the following:

a.1.b.1. Factorization of integers in excess of 512 bits (e.g., RSA);

a.1.b.2. Computation of discrete logarithms in a multiplicative group of a finite field of size greater than 512 bits (e.g., Diffie-Hellman over  $\mathbb{Z}/p\mathbb{Z}$ ); or

a.1.b.3. Discrete logarithms in a group other than mentioned in 5A002.a.1.b.2 in excess of 112 bits (e.g., Diffie-Hellman over an elliptic curve);

...

a. Designed or modified to perform ?cryptanalytic functions.?

# Commerce Control List: Category 5 - Info. Security

(May 23, 2019 version)

2.c. An “asymmetric algorithm” where the security of the algorithm is based on any of the following:

2.c.1. Shortest vector or closest vector problems associated with lattices (e.g., NewHope, Frodo, NTRUEncrypt, Kyber, Titanium);

2.c.2. Finding isogenies between Supersingular elliptic curves (e.g., Supersingular Isogeny Key Encapsulation); or

2.c.3. Decoding random codes (e.g., McEliece, Niederreiter).

Technical Note: An algorithm described by Technical Note 2.c. may be referred to as being post-quantum, quantum-safe or quantum-resistant.

## US Politicians on Cryptography

"The government must be wary of suffocating [the encryption software] industry with regulation in the new digital age, but we must be able to strike a balance between the legitimate concerns of the law enforcement community and the needs of the marketplace." — U.S. Vice President Al Gore, September 1997

"Because, if, in fact, you can't crack that [encryption] at all, government can't get in, then everybody is walking around with a Swiss bank account in their pocket – right? So there has to be some concession to the need to be able to get into that information somehow." — President Obama, March 2016

"To think that Apple won't allow us to get into her cellphone? Who do they think they are?" — US Presidential Candidate Trump, 2016

# Deliberately weakened cryptography in TLS

- SSLv2, SSLv3, and TLS 1.0 included options for weakened cryptography to comply with US export control in the 90s.
- Browsers outside the US were supposed to request weakened cryptography, and those in the US were allowed to request normal strength cryptography.
- Browsers were updated long ago to never request these weakened options once US regulations changed.
- Even though the political situation changed, many servers never removed these options.
- 2015–2016: A series of academic, mostly impractical attacks (FREAK, Logjam, DROWN) show that even current browsers at the time could be vulnerable.