CSE 127: Introduction to Security

Lecture 15: TLS

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UCSD

Fall 2019

Material from Nadia Heninger, Dan Boneh, Stefan Savage

Reminder: Network Attacker Threat Model

Network Attacker:

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

Examples:

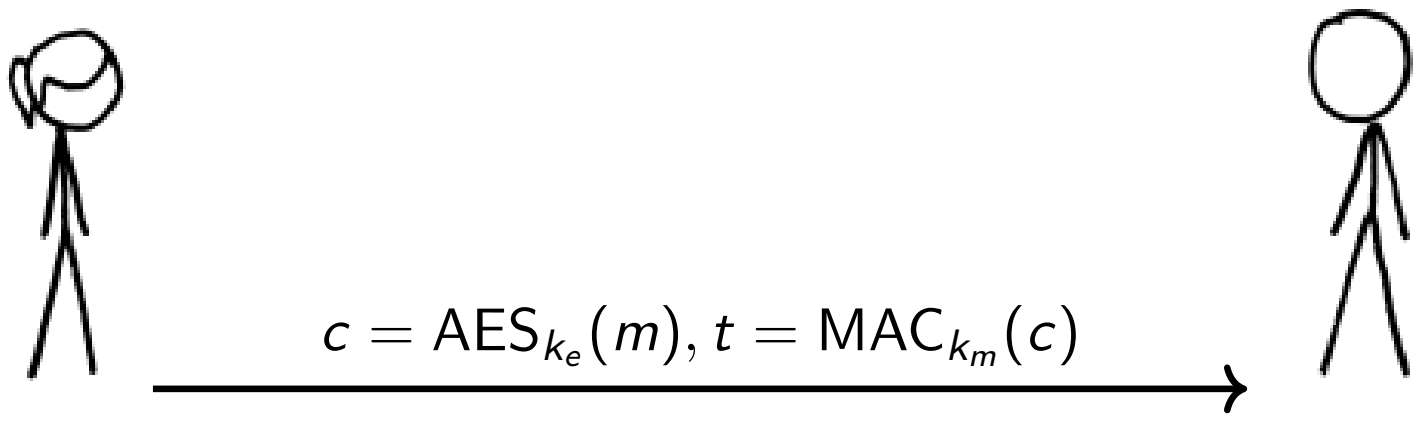
- Wifi at internet cafe
- Internet access at hotels

Goal: Establish a secure channel to a host that ensures

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

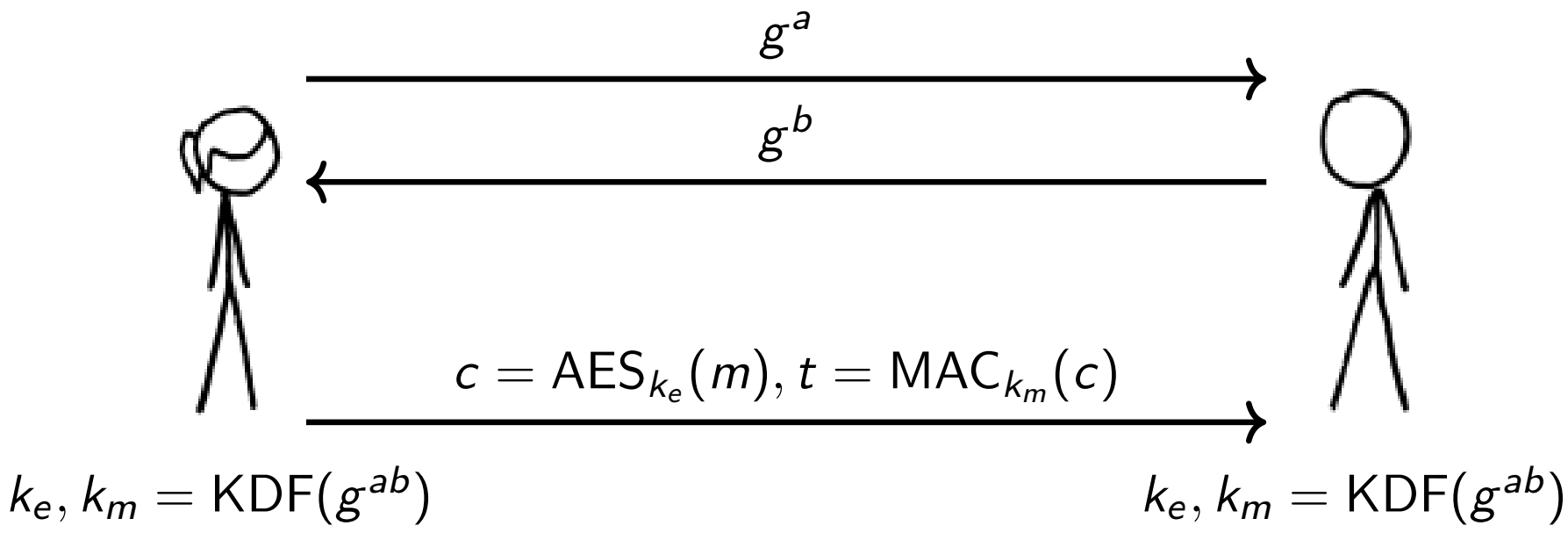
Constructing a secure encrypted channel

- 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.



Constructing a secure encrypted channel

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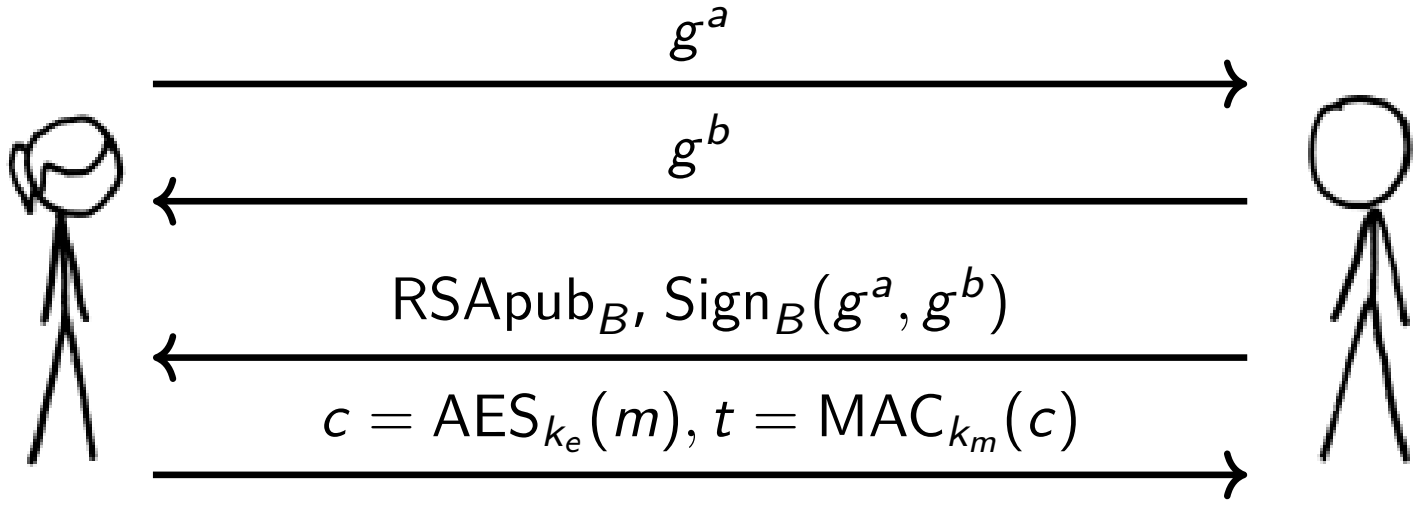
- To ensure authenticity of endpoints: Digital Signatures



$k_e, k_m = \text{KDF}(g^{ab})$ $k_e, k_m = \text{KDF}(g^{ab})$

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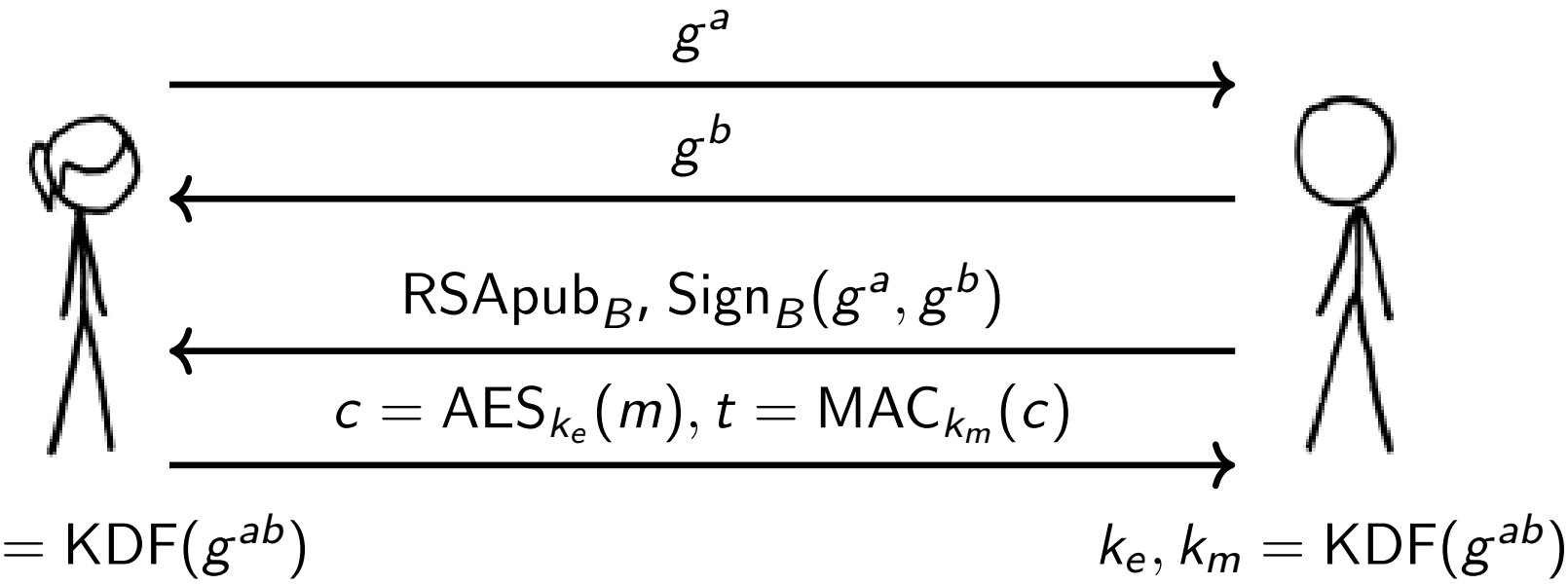


How does Alice know to trust Bob's public signing key?

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:

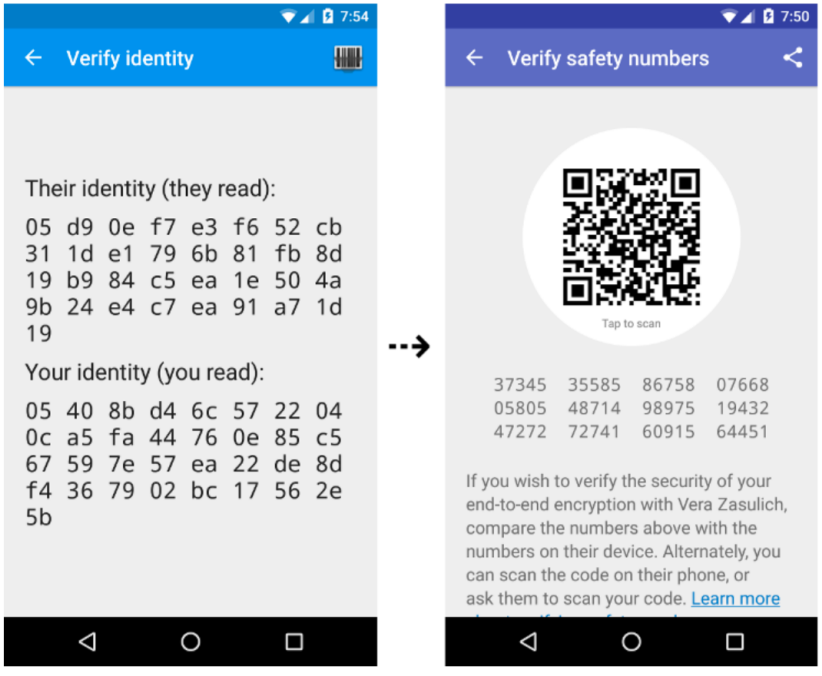
- Fingerprint verification
  - Verify a cryptographic hash of a public key through a separate channel, or “trust on first use” (TOFU).
  - This is used by SSH for host keys.

```
nadiah$ ssh portal.cs.princeton.edu
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@       WARNING: POSSIBLE DNS SPOOFING DETECTED!          @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
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.
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
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
SHA256:9yBBea9ZOER6asvvtNf6fRXVra6LOQ3OVZLtYKVpNc8.
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



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

Public Key Infrastructure: Establishing Trust in Keys

Ways to establish trust in keys:

- Certificate Authorities
  - A CA is a kind of commercial/non-profit trusted intermediary.
  - Certificate Authorities verify public keys and sign them.

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Ways to establish trust in keys:

- Certificate Authorities
  - A CA is a kind of commercial/non-profit trusted intermediary.
  - Certificate Authorities verify public keys and sign them.
  - If you trust the CA, you transitively trust the keys it signs.
  - This is used for TLS, software signing keys.

Public Key Infrastructure: Establishing Trust in Keys

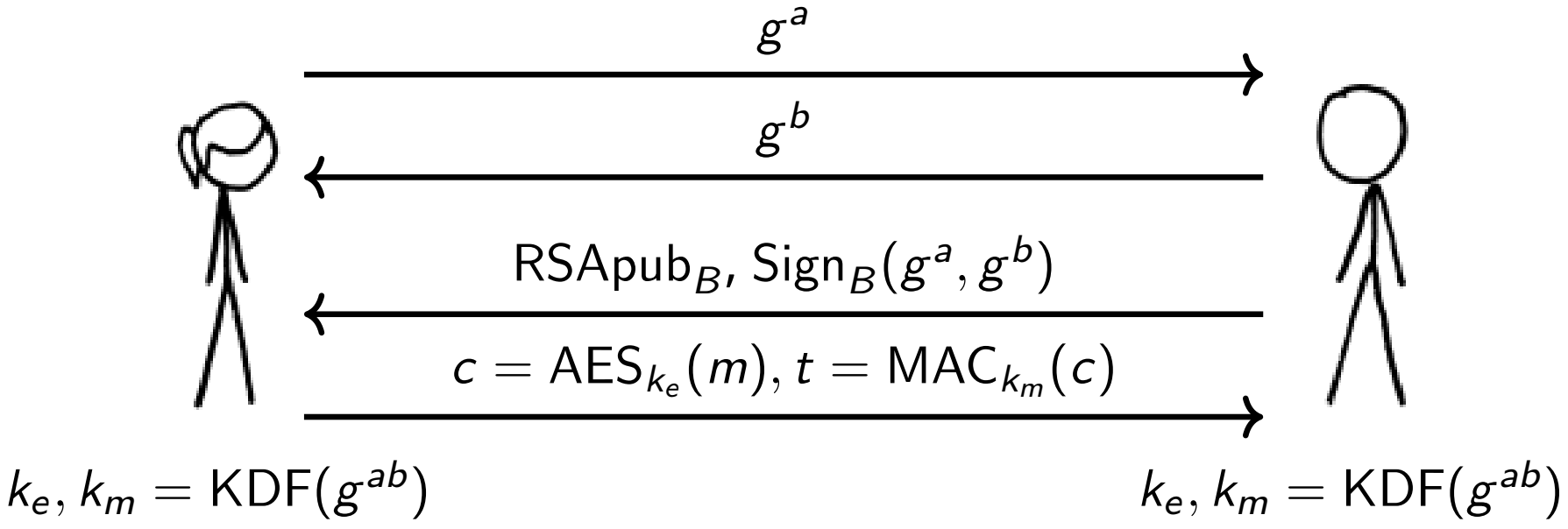
Ways to establish trust in keys:

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

```
nadiah$ 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?
```

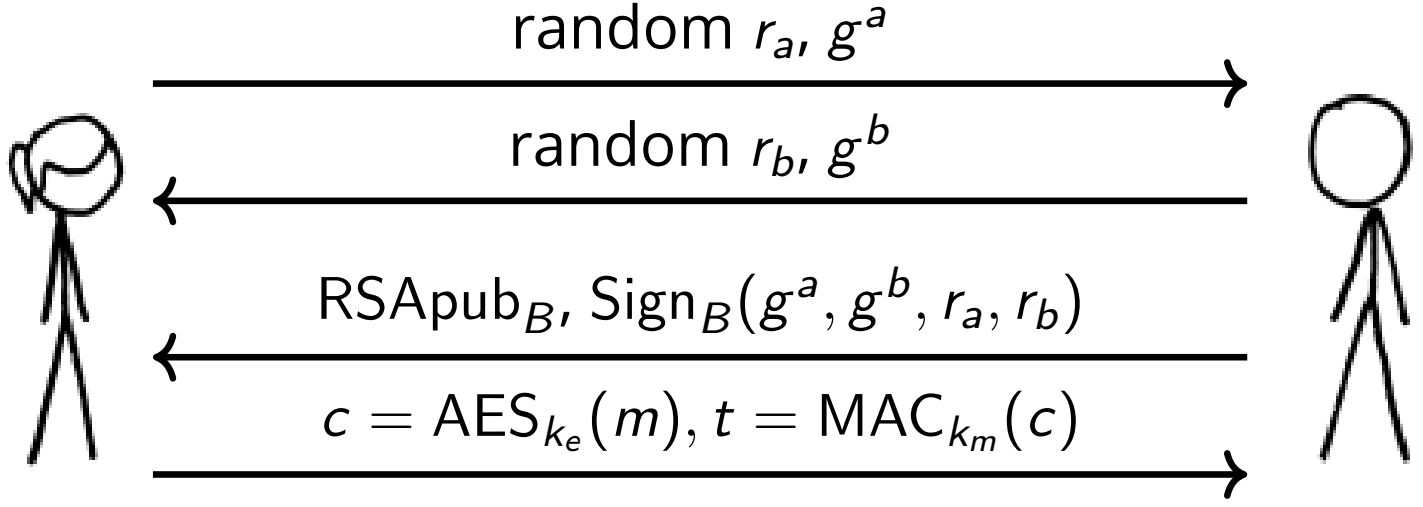
Constructing a secure encrypted channel

- To ensure confidentiality and integrity: Encrypt and MAC data
- To negotiate shared symmetric keys: DH key exchange
- To ensure authenticity of endpoints: Digital Signatures



Constructing a secure encrypted channel

- To ensure confidentiality and integrity: Encrypt and MAC data
- To negotiate shared symmetric keys: DH 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")



$k_e, k_m = \text{KDF}(g^{ab})$ $k_e, k_m = \text{KDF}(g^{ab})$

This is not exactly what TLS looks like, but it's similar.

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.

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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.

client hello: client random

[list of cipher suites]

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

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[list of cipher suites]

Cipher suites: list of options like:
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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.

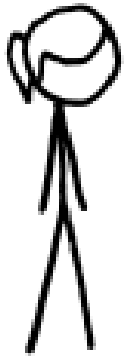
TLS 1.2 with Diffie-Hellman Key Exchange

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

client hello: client random

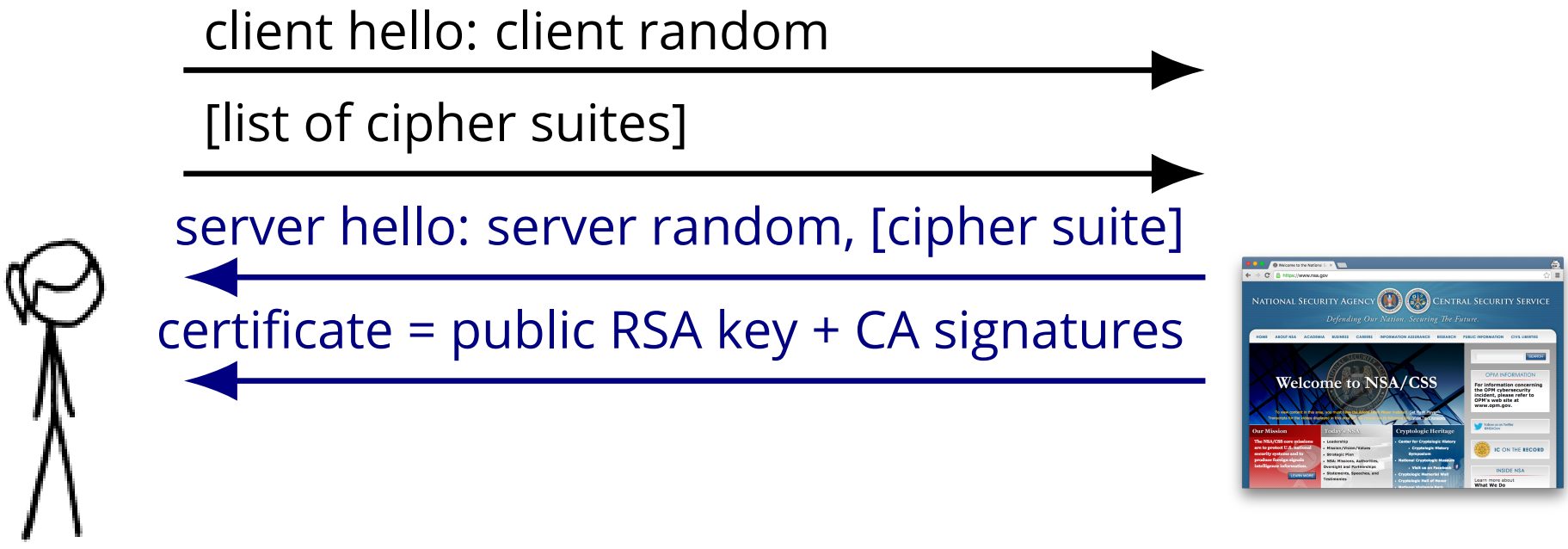
[list of cipher suites]

server hello: server random, [cipher suite]



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.



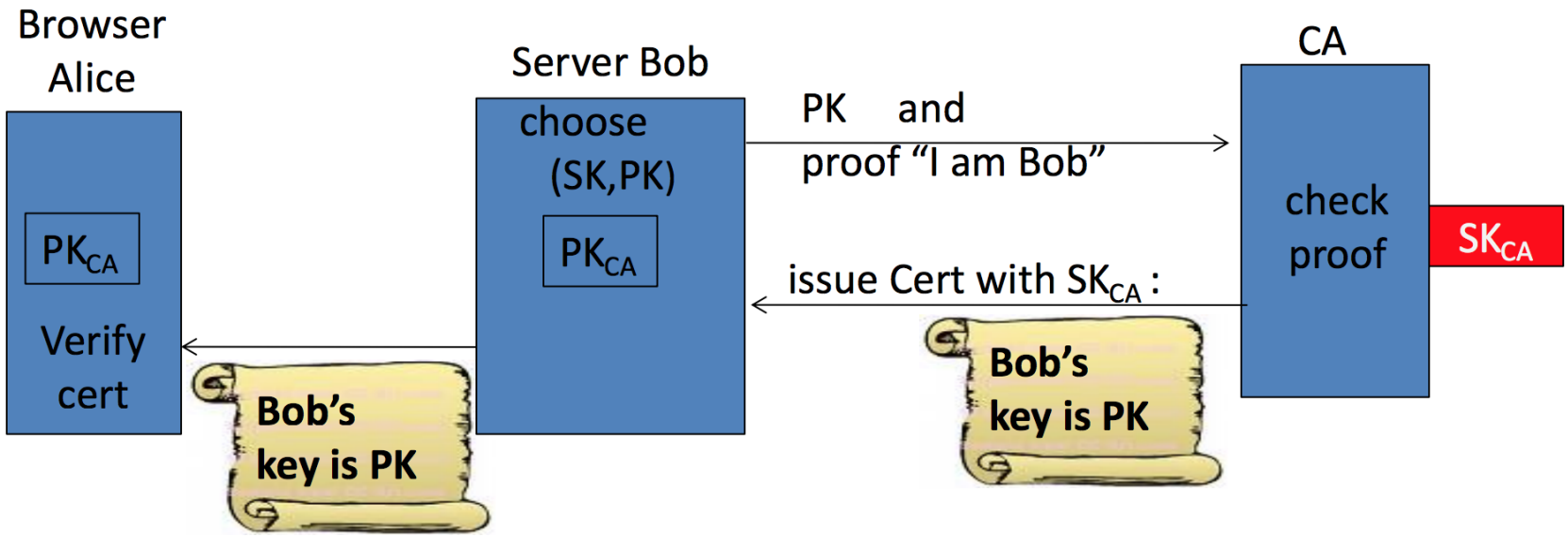
Certificates and Certificate Authorities in TLS

Website public keys are encoded into certificates.

Certificates signed by CAs.

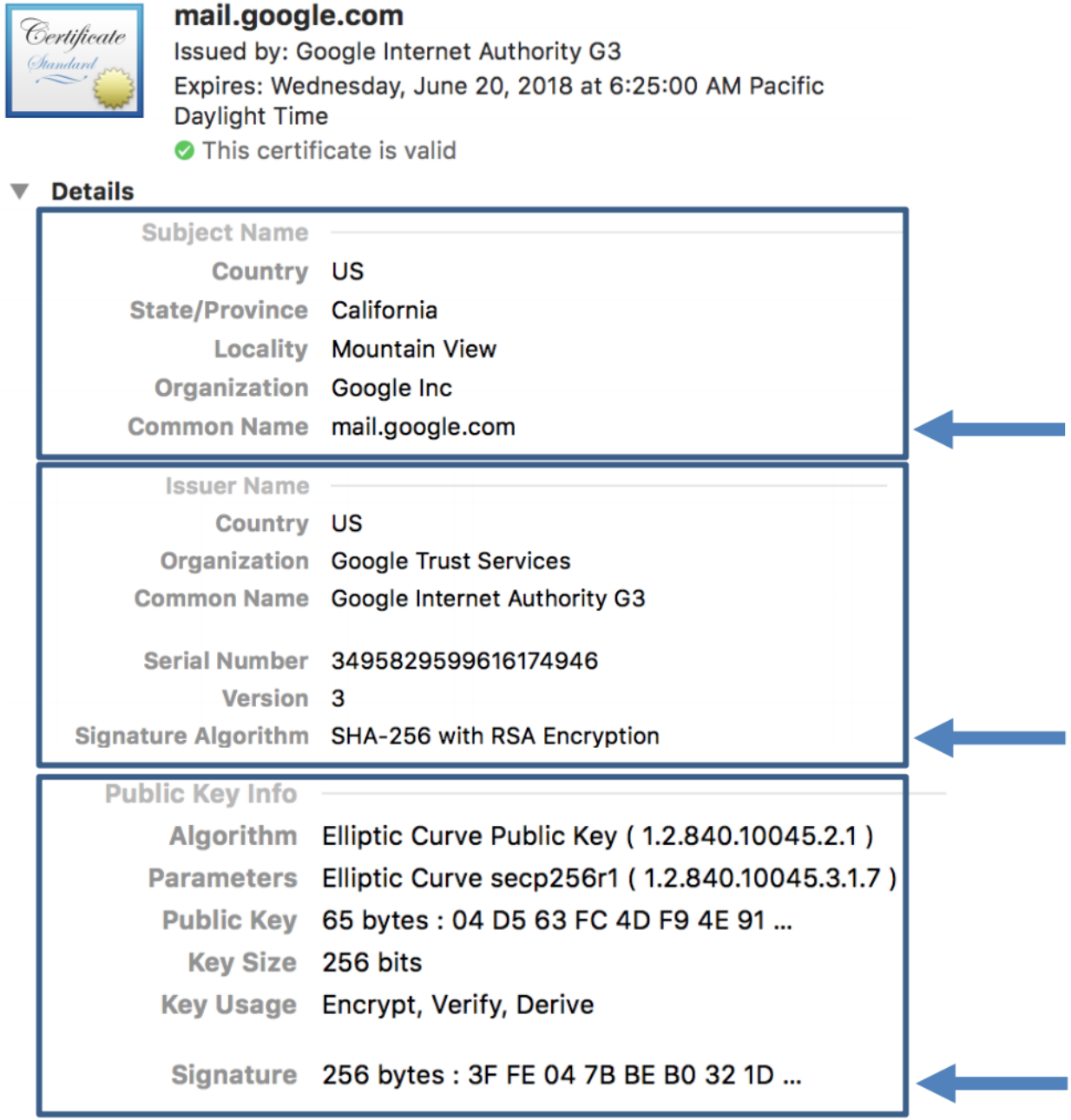
Browsers come with set of trusted CAs.

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



cse.ucsd.edu

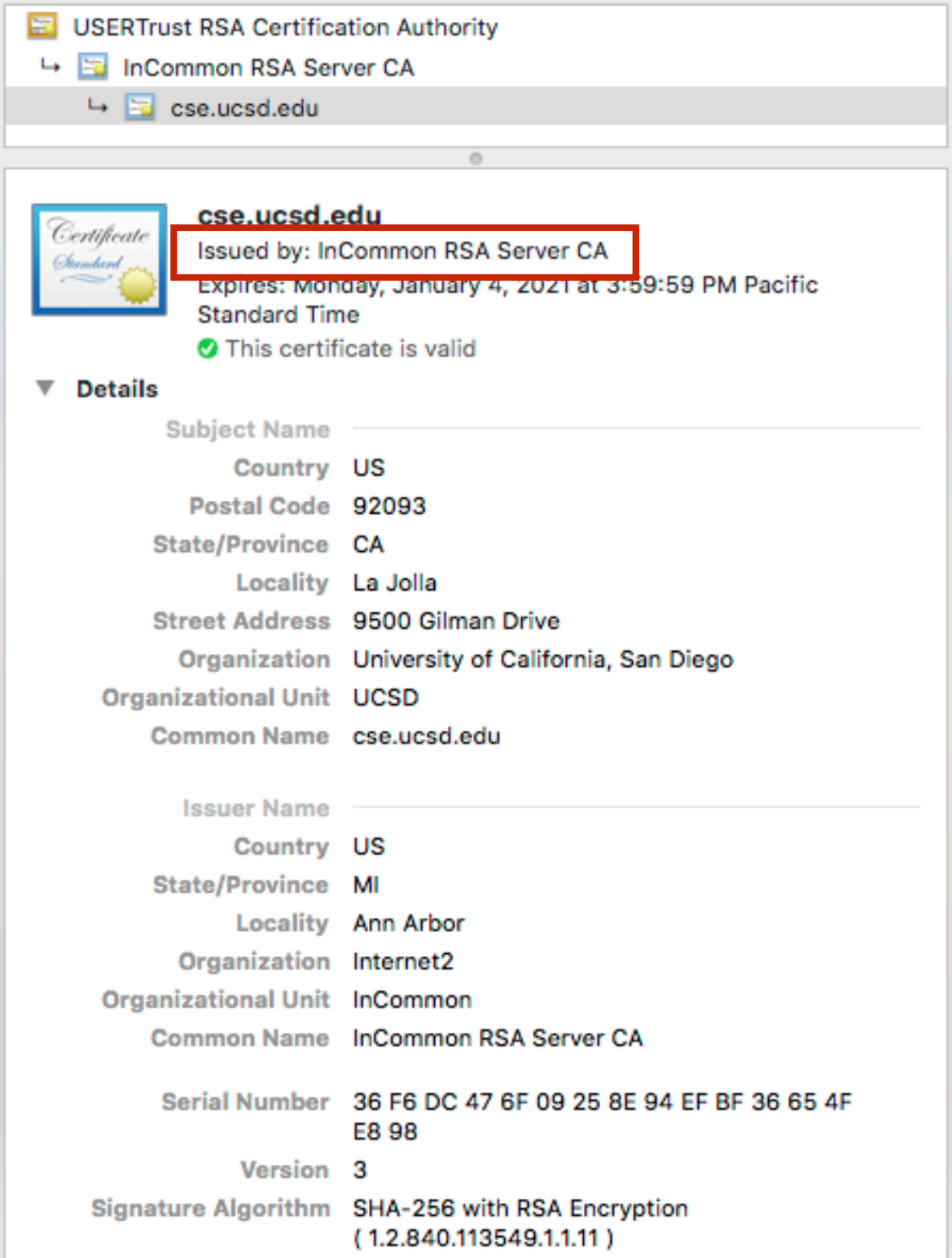
Issued by: InCommon RSA Server CA

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

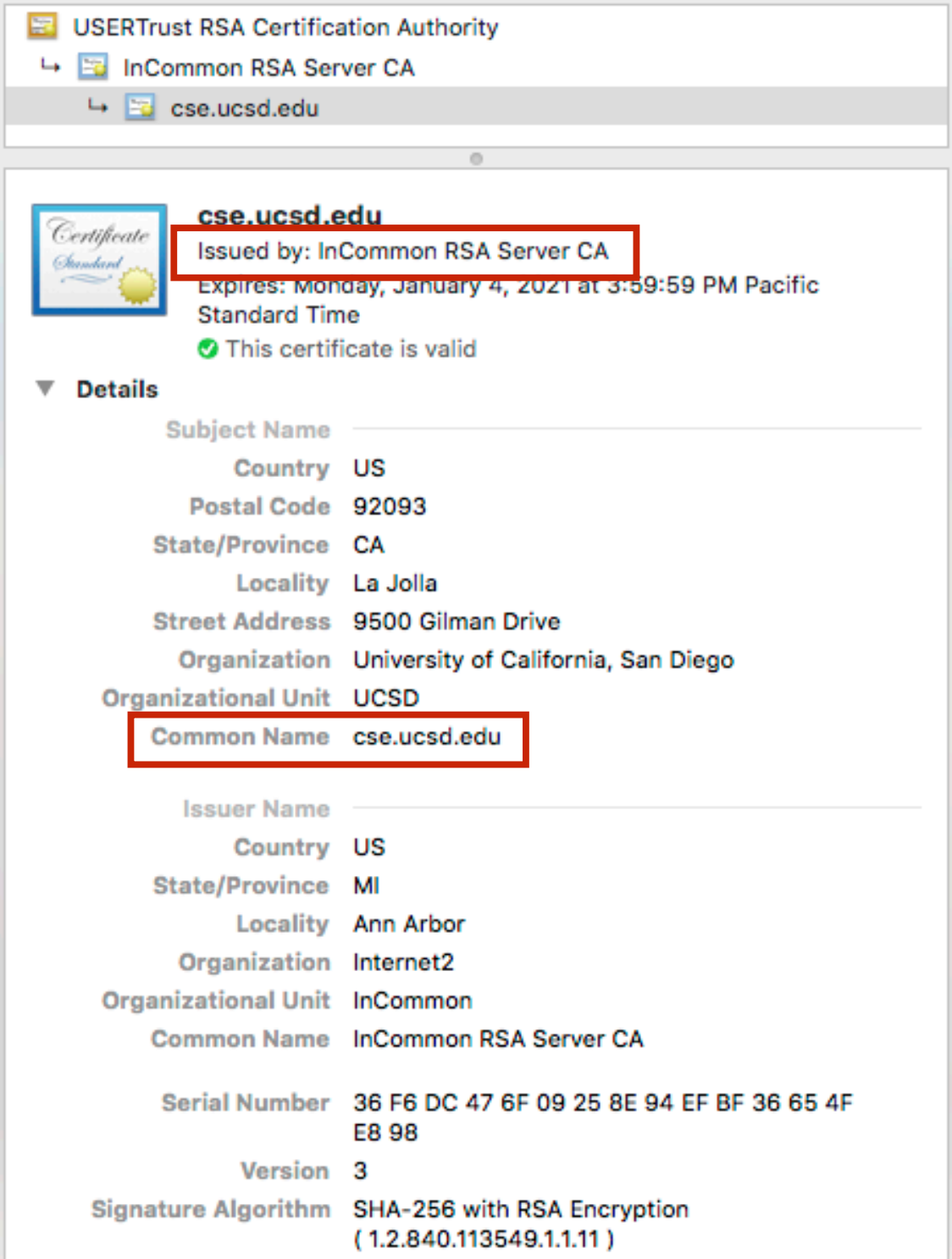
This certificate is valid

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)



Who are we trusting?



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
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
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
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URI	http://ocsp.usertrust.com

Who is this cert for?

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)
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
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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
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DNS Name	www-cs.ucsd.edu
DNS Name	www-cse.ucsd.edu
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Extension	Certificate Policies (2.5.29.32)
Critical	NO
Policy ID #1	(1.3.6.1.4.1.5923.1.4.3.1.1)
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CPS URI	https://www.incommon.org/cert/repository/cps_ssl.pdf
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Extension	CRL Distribution Points (2.5.29.31)
Critical	NO
URI	http://crl.incommon-rsa.org/InCommonRSAServerCA.crl
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URI	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

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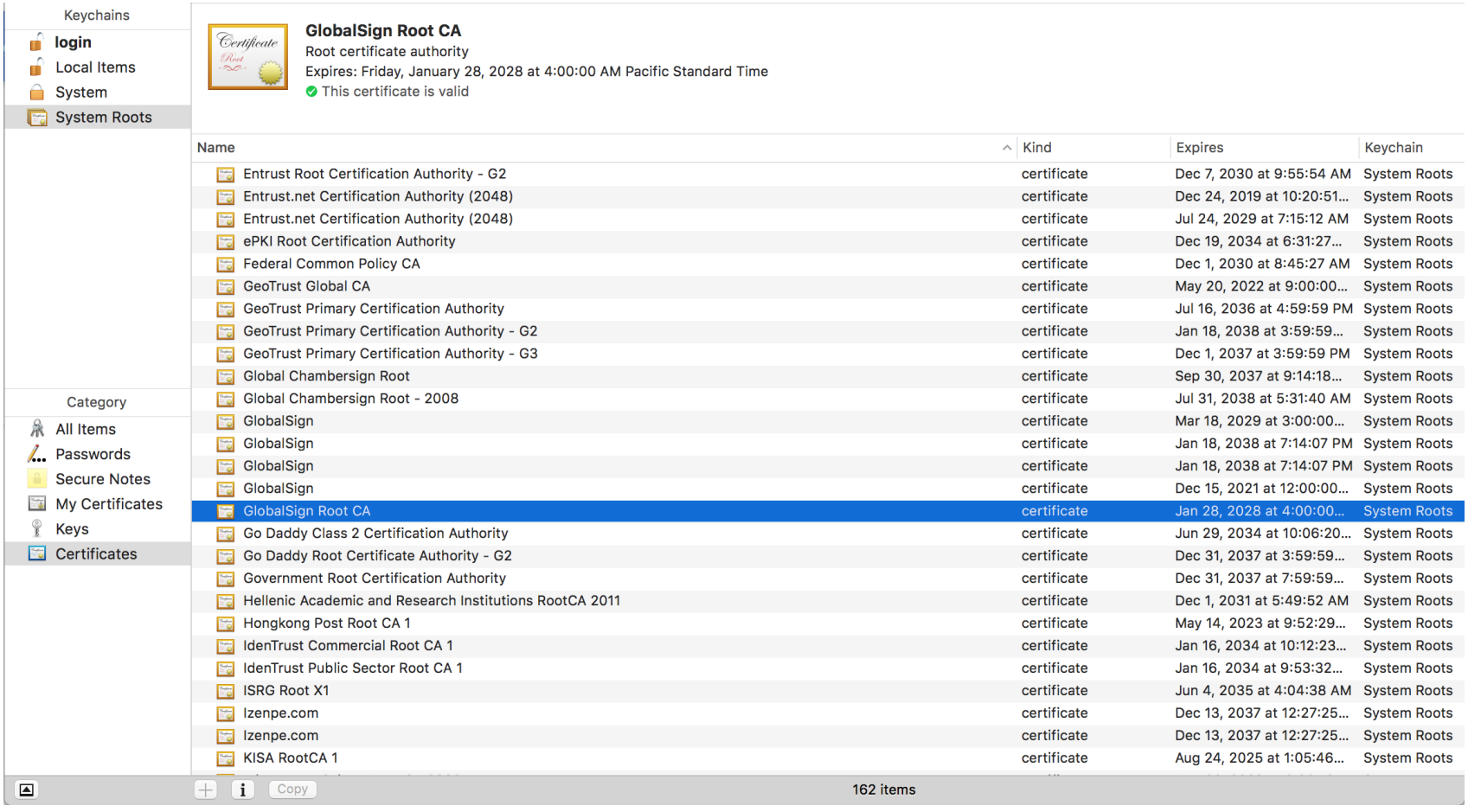
Where we should check for revocation information

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



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.

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Mitigations:

- Certificate pinning.
  - Hard code certificates for some sites in browser.

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.

client hello: client random

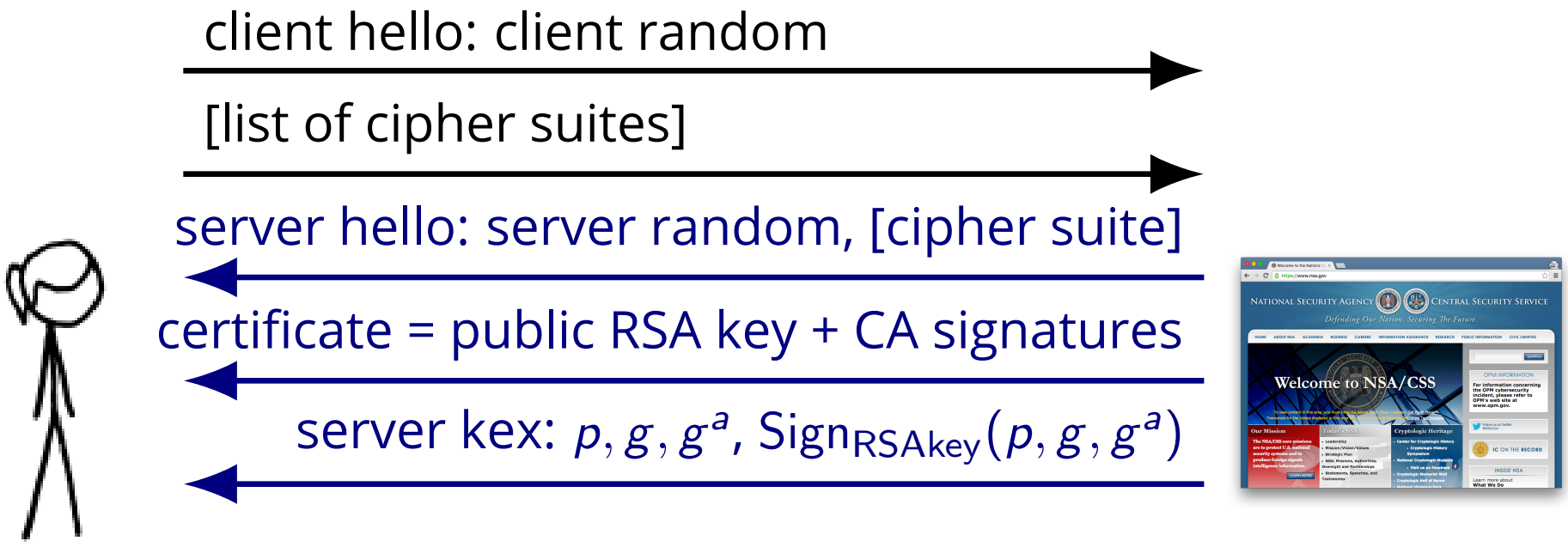
[list of cipher suites]

server hello: server random, [cipher suite]

certificate = public RSA key + CA signatures

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.

client hello: client random

[list of cipher suites]

server hello: server random, [cipher suite]

certificate = public RSA key + CA signatures

server kex: $p, g, \mathbf{g^a}$, $\text{Sign}_{\text{RSAkey}}(p, g, g^a)$

client kex: $\mathbf{g^b}$

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.

client hello: client random

[list of cipher suites]

server hello: server random, [cipher suite]

certificate = public RSA key + CA signatures

server kex: $p, g, \mathbf{g^a}$, $\text{Sign}_{\text{RSAkey}}(p, g, g^a)$

client kex: $\mathbf{g^b}$

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

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.

client hello: client random

[list of cipher suites]

server hello: server random, [cipher suite]

certificate = public RSA key + CA signatures

server kex: $p, g, \mathbf{g^a}$, $\text{Sign}_{\text{RSAkey}}(p, g, g^a)$

client kex: $\mathbf{g^b}$

client finished: $\text{MAC}_{k_{m_c}}$(dialog)

server finished: $\text{MAC}_{k_{m_s}}$(dialog)

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

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

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.

client hello: client random

[list of cipher suites]

server hello: server random, [cipher suite]

certificate = public RSA key + CA signatures

server kex: $p, g, \mathbf{g^a}$, $\text{Sign}_{\text{RSAkey}}(p, g, g^a)$

client kex: $\mathbf{g^b}$

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

client finished: $\text{MAC}_{k_{m_c}}$(dialog)

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

server finished: $\text{MAC}_{k_{m_s}}$(dialog)

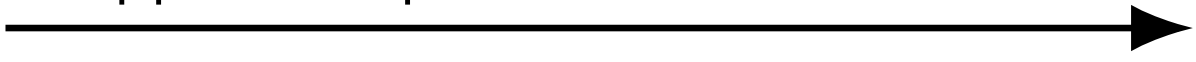
Enc_{k_e}(request)

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

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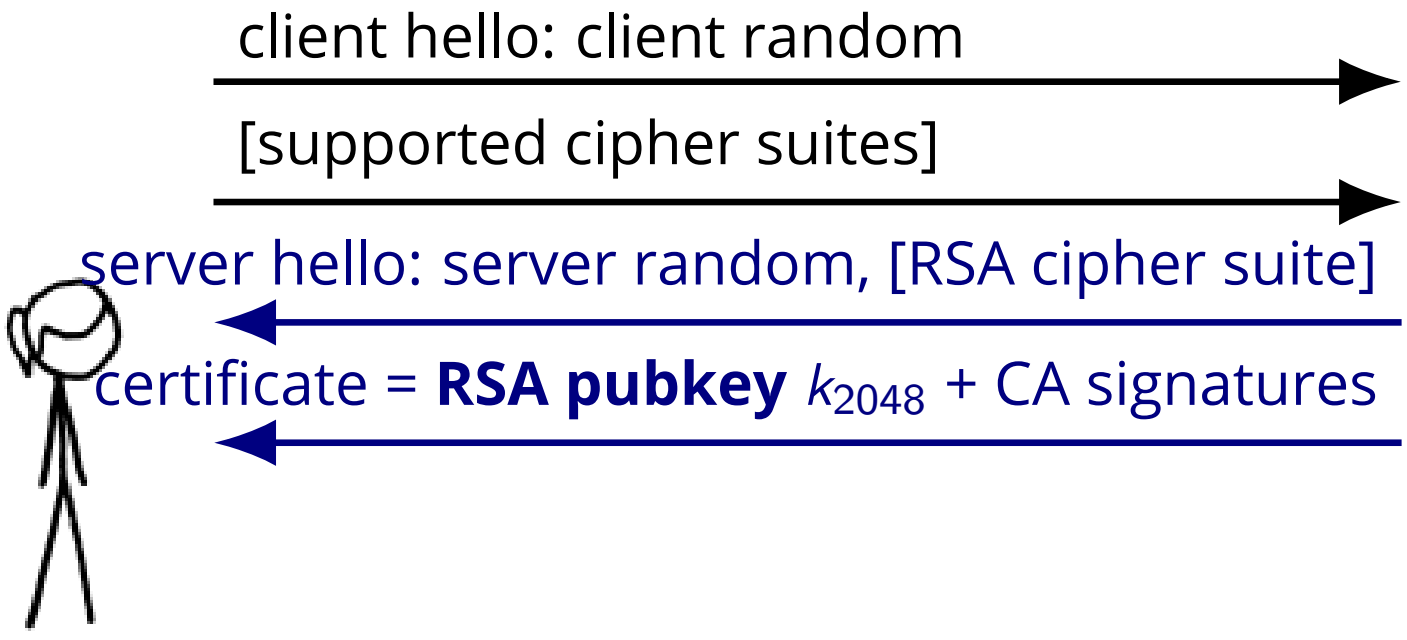

TLS 1.2 with RSA Key Exchange

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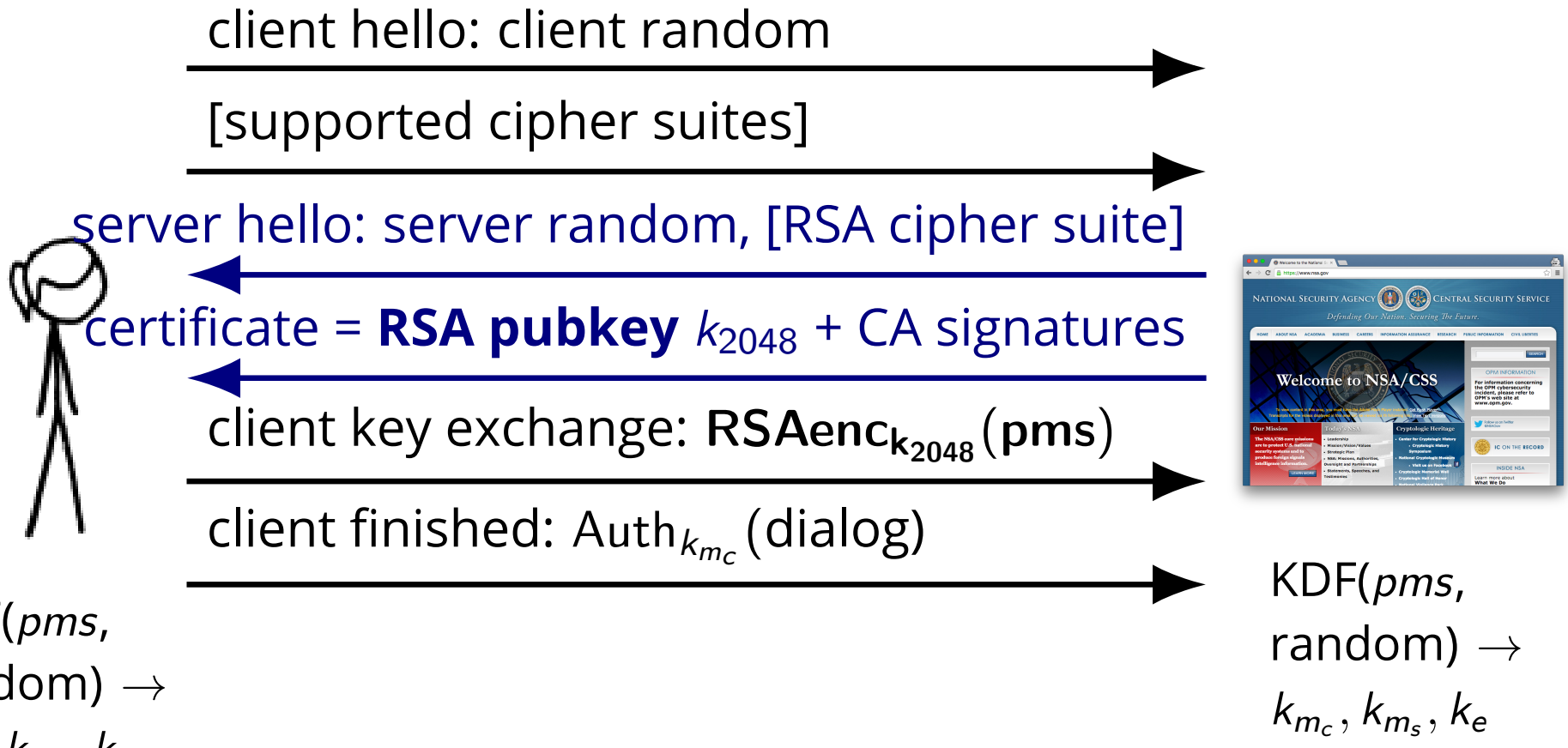

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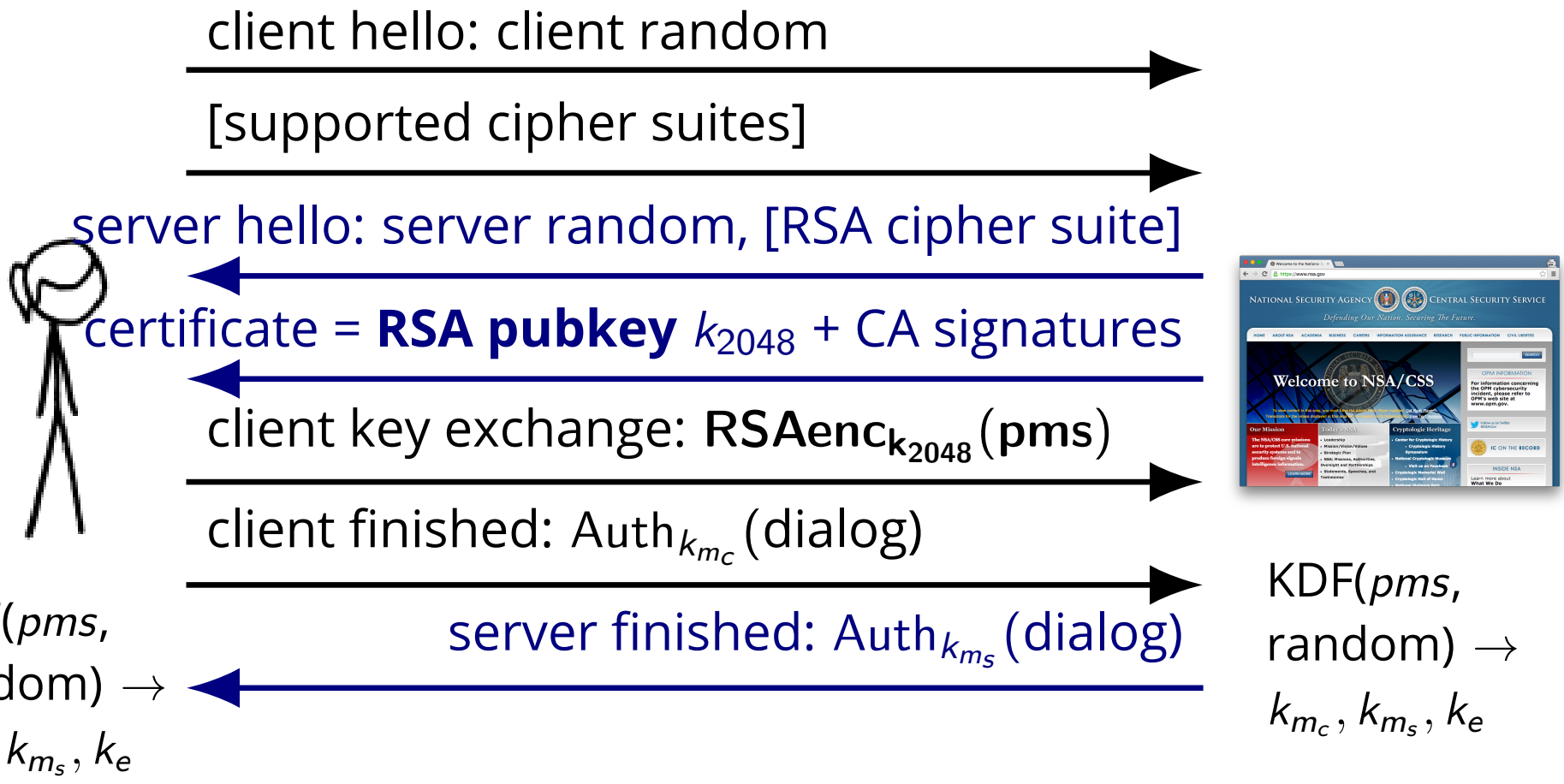

TLS 1.2 with RSA Key Exchange

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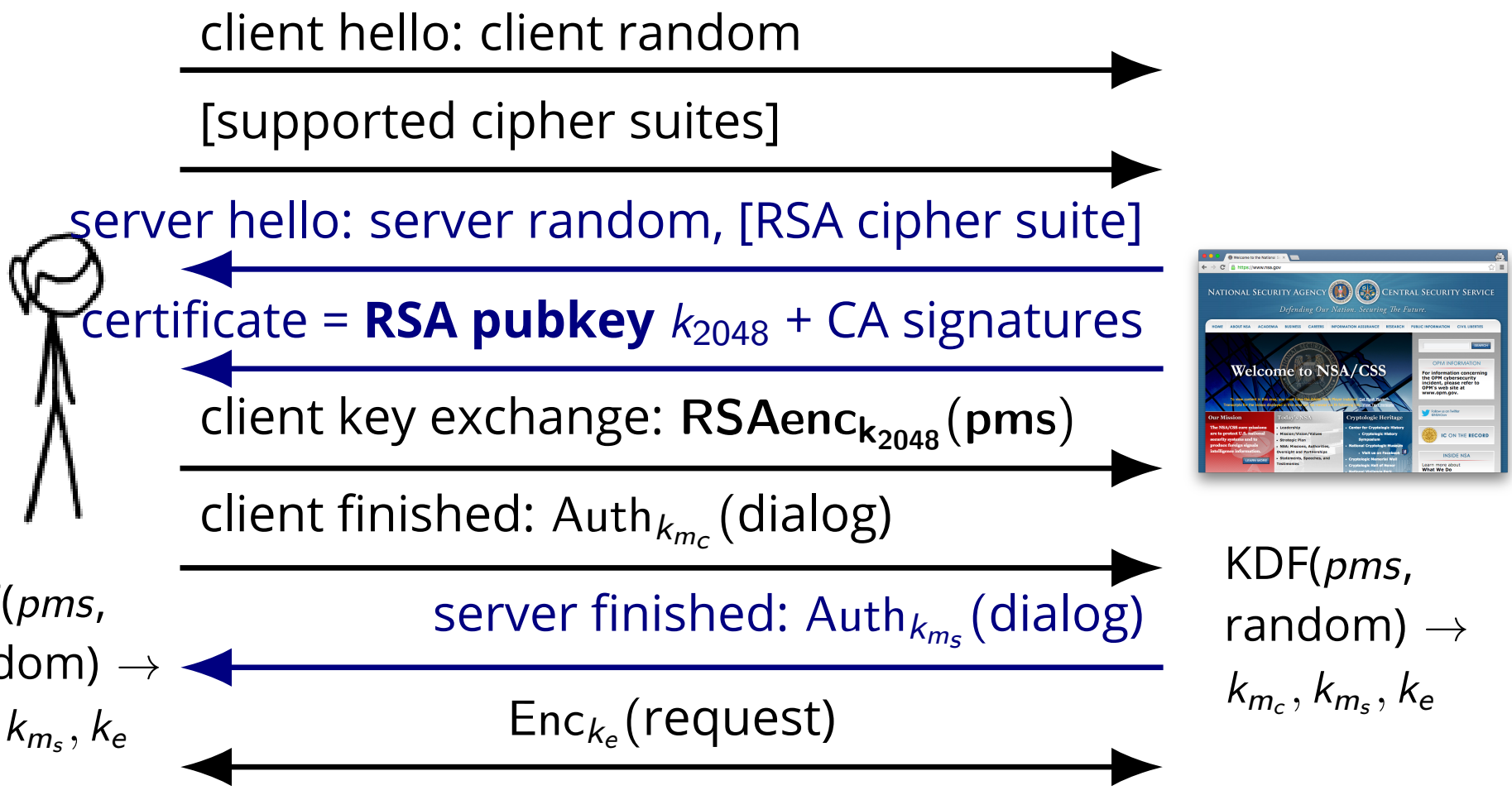


What if a private key gets stolen or compromised?

If an adversary obtains a server certificate private key:

- With Diffie-Hellman key exchange, the adversary can:

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.

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:

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 tesify 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

[redacted]

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

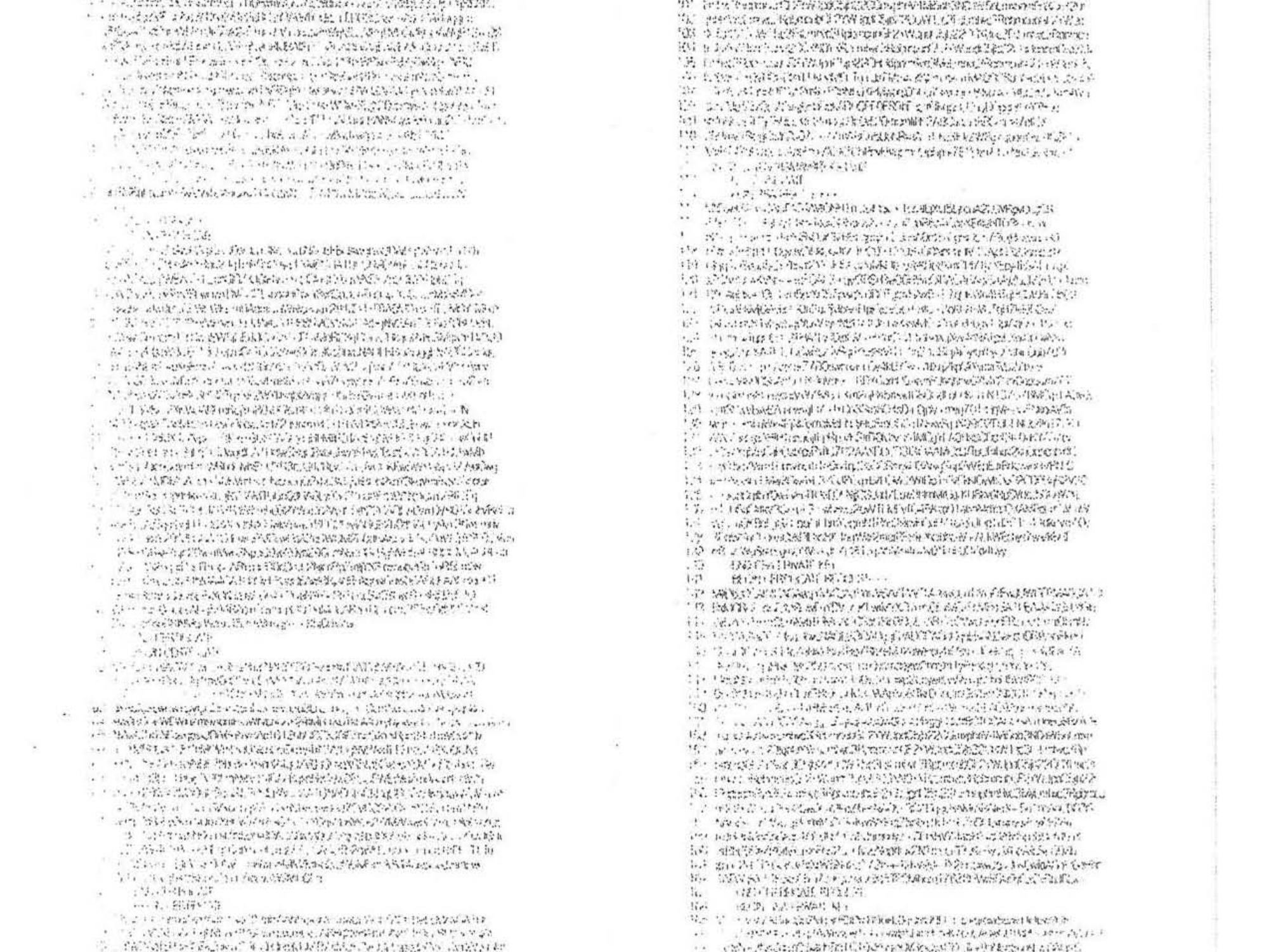
I. Information to be disclosed by Lavabit, LLC (the "Provider")

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:

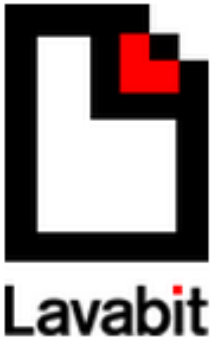
a. All information necessary to decrypt communications sent to or from the Lavabit e-mail account [redacted] including encryption keys and SSL keys;

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.



August 2013



My Fellow Users,

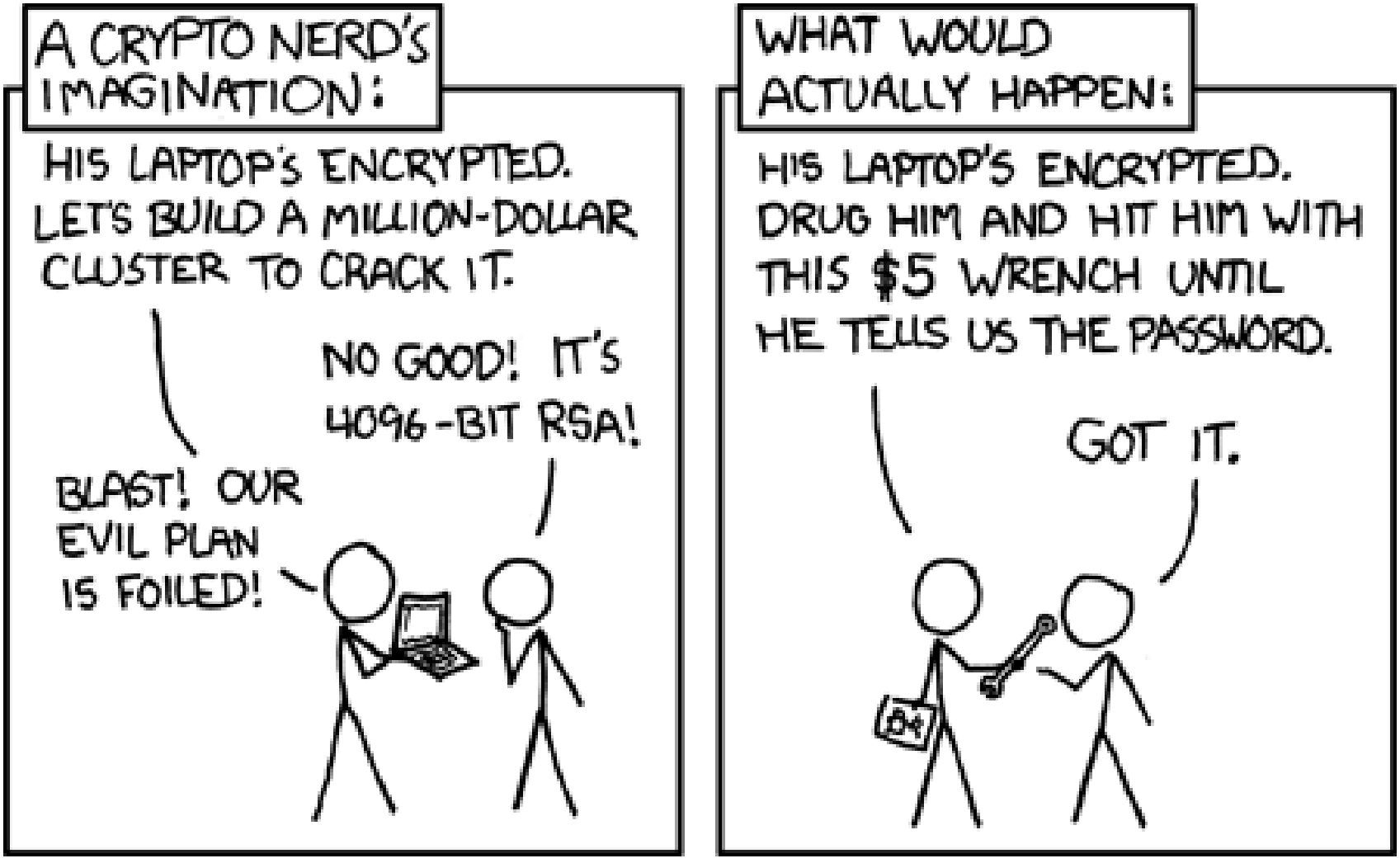
I have been forced to make a difficult decision: to become complicit in crimes against the American people or walk away from nearly ten years of hard work by shutting down Lavabit. After significant soul searching, I have decided to suspend operations. I wish that I could legally share with you the events 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.

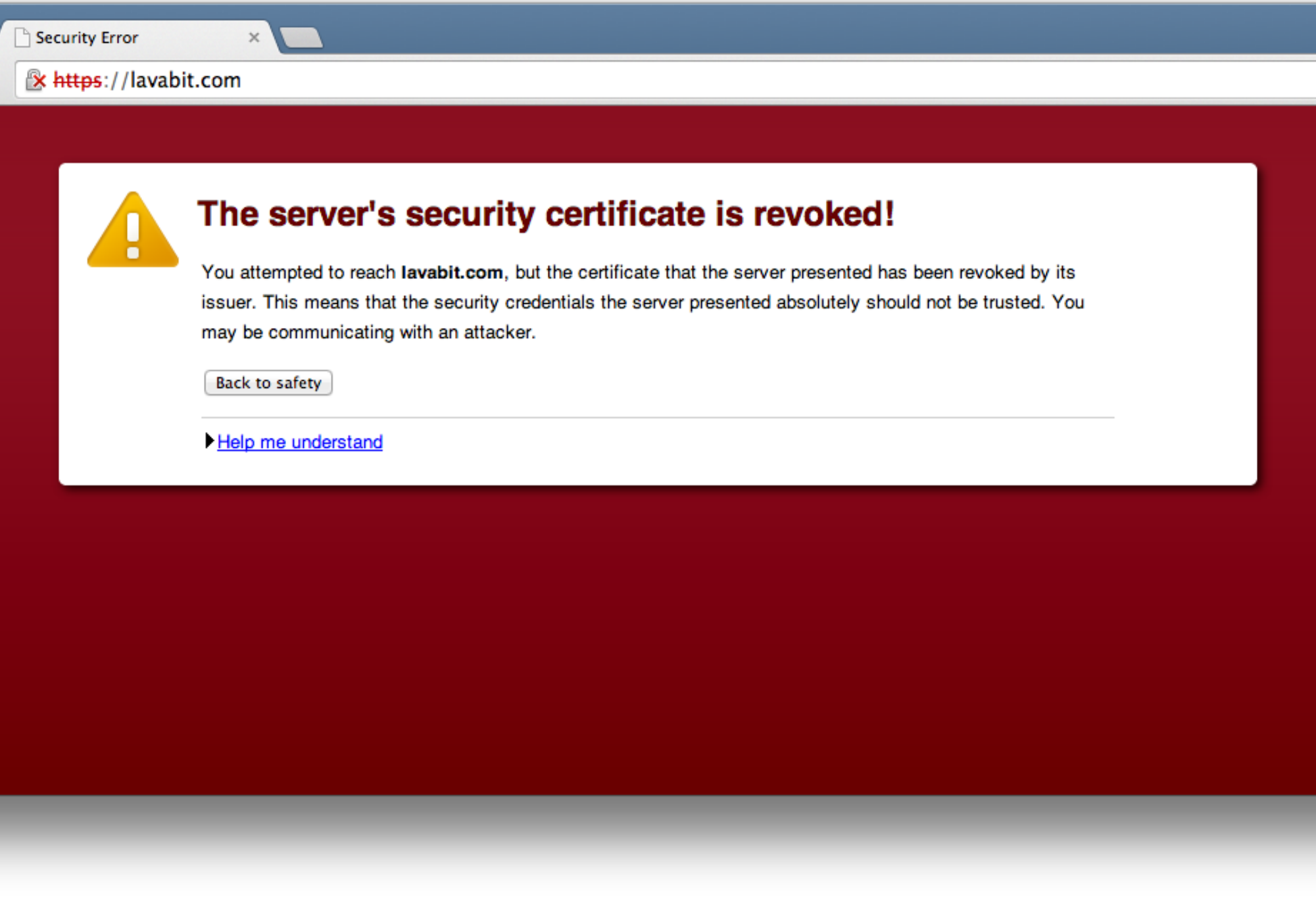
Sincerely,
Ladar Levison
Owner and Operator, Lavabit LLC

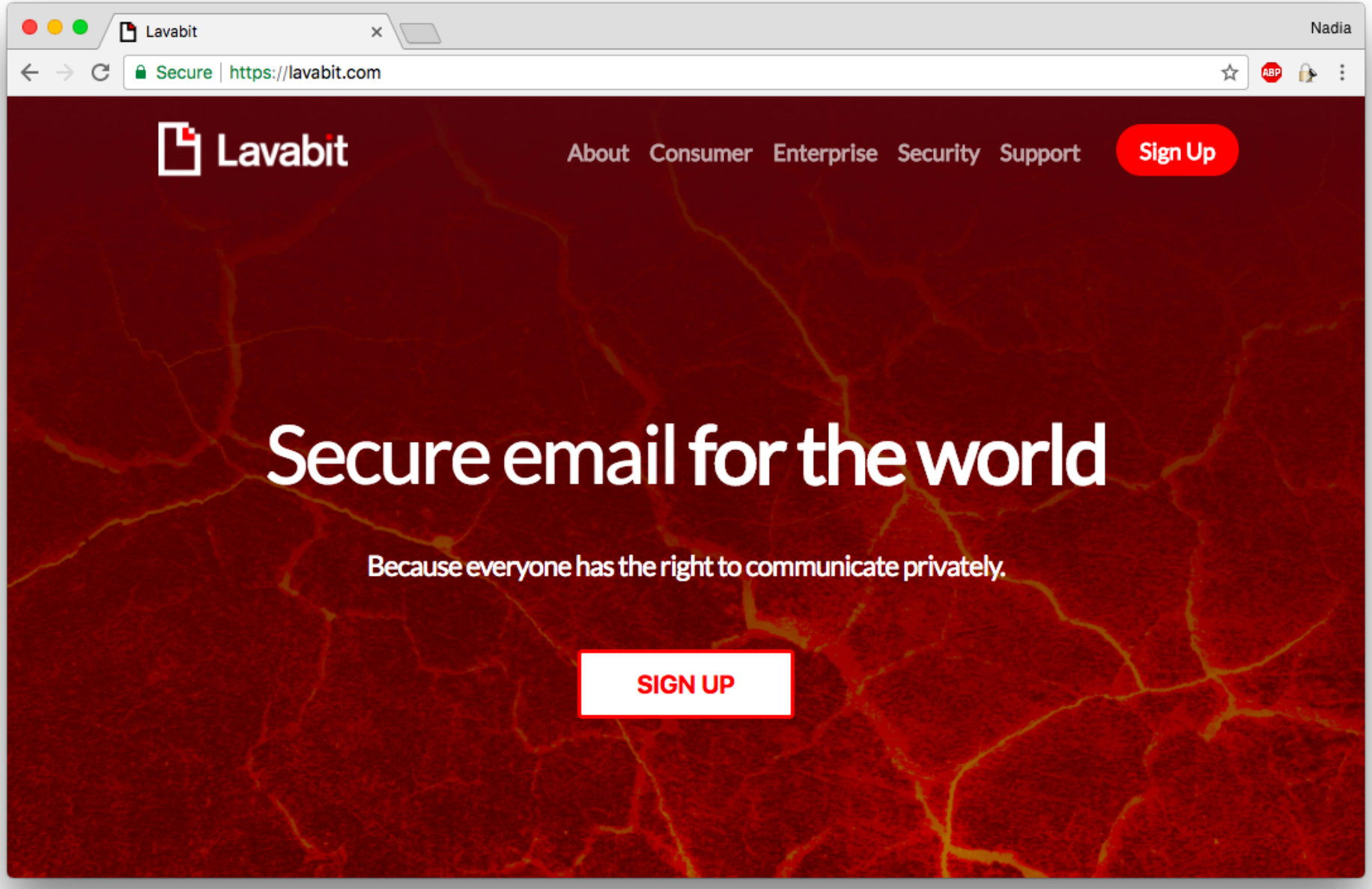
We reiterate that our review is circumscribed by the arguments that Lavabit raised below and in this Court. We take this narrow course because an appellate court is not a freestanding open forum for the discussion of esoteric hypothetical questions. See Swann v. Charlotte-Mecklenburg Bd.



https://xkcd.com/538/

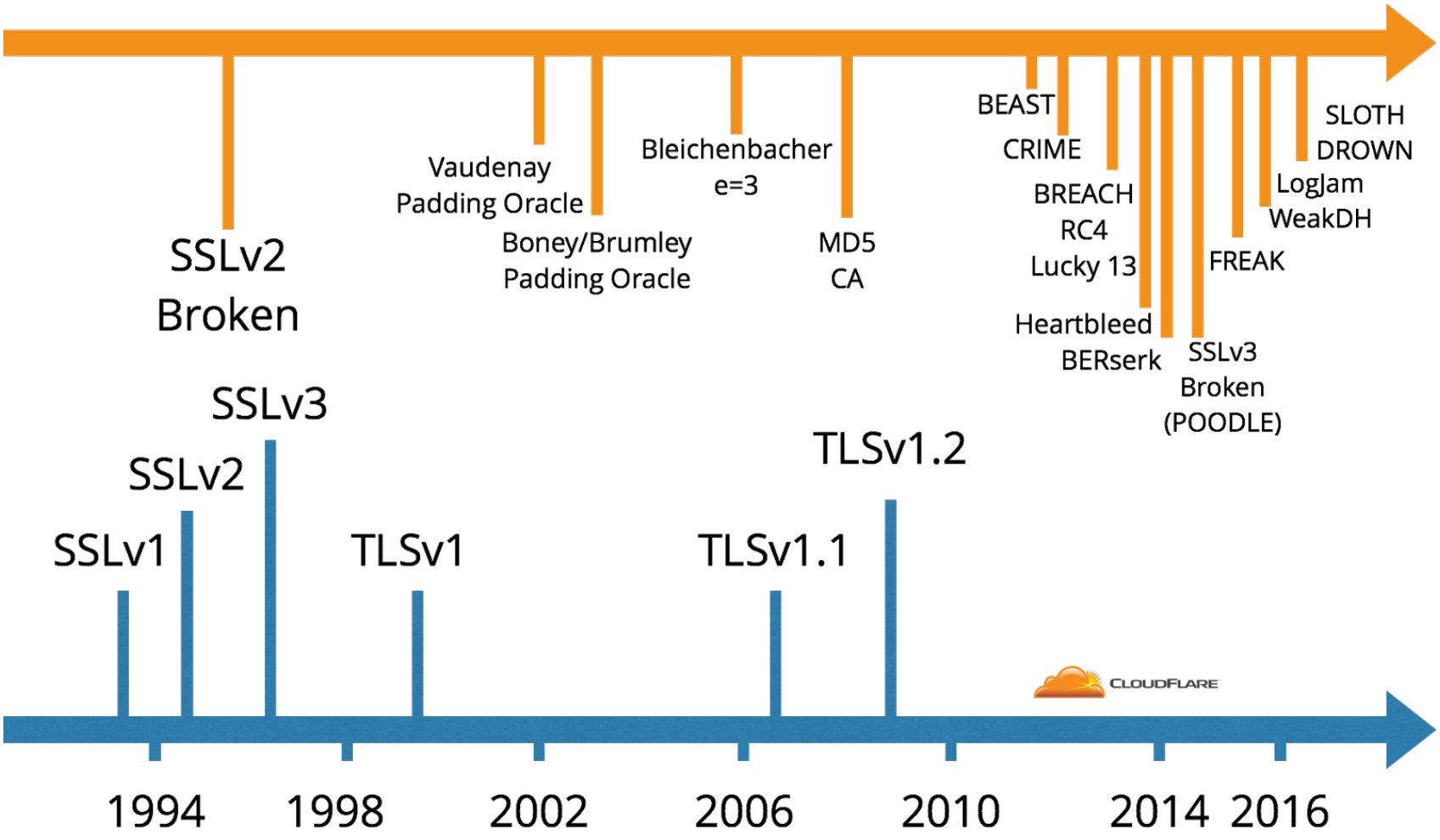
"Actual actual reality: nobody cares about his secrets. Also, I would be hard-pressed to find that wrench for $5."


Security Error
https://lavabit.com
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


Lavabit
Nadia
Secure | https://lavabit.com
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 Z/pZ); 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." — 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.” — Obama, March 2016

“To think that Apple won’t allow us to get into her cellphone? Who do they think they are?” — 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.