# An Observatory for the SSLiverse

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# Quick overview

- Electronic Frontier Foundation, funded by NL Net
  - – with volunteer help from iSEC Partners
- Collected x.509 Certificates used for HTTPS on the internet
- Looked for odd behavior, checking up on CAs
- Identified “trusted” intermediaries – foreign, security agencies, companies
- Weird, wonderful and suspicious certificates found
- Noted interesting behaviors of servers & clients
- Will be opening data for further review

# Agenda

- Why we need an HTTPS Observatory
- Data Collection Technique
- Results Summary
- Interesting Questions
- Vulnerabilities
- Conclusions
- Future work

# Why We Need an Observatory

# Why We Need an HTTPS Observatory

HTTPS is a rather important protocol!

“Certificate **Authority**”

The words cry out for accountability & transparency

Several recent exploits based on CA mistakes

- Trust model: 1 of *N* CAs (*N* is large)
- Just how large is *N*, exactly?
- Who are these CAs we trust & what’s going on?

# How do we get an HTTPS Observatory

Let's download all the SSL certificates and build a dataset that everyone can study.

(ideally, on an ongoing basis)

# Data Collection Techniques

# Observatory Infrastructure

- Collection:
  - Three low end Linux servers with only 2GB ram
  - Good, shared 100Mbs network connection
  - NMap with poor timings, some python
  - 2-3 months worth of patience
- Analysis:
  - 1 year old i920 server with a new fast disk and 12G ram
  - 2 little laptops
  - Lots of crazy scripts, OpenSSL and a database
  - OpenSSL
- Currently vaporware:
  - Distribution (coming soon)
  - Some web query forms
  - Full datasets (via BitTorrent)

# 1. Observe the SSLiverse

- NMAP Internet for hosts listening on tcp 443
  - Distribute, resume, chaotically permute
  - Work units of the form 157.*.*.15
  - Remember who replies

- Python Client
  - Connect with custom client, send SSL Hello
  - Collect whole certificate chain from server
  - Drops connection pre-key exchange
  - And the other random garbage they say

# 2. Extract the certificates

Custom client used python and Construct

Based on the RFCs definitions

- Still needed to be tuned with Wireshark & test cases

Only need parts of TLS:

- Handshake type, Protocol Version, HelloRequest, ServerHello, Certificate, ASNCert, Handshake, ContentType, TLSRecord, Random, CompressionMethod, a funny unsigned 24 bit big-endian length

Result: lots of X.509 Certificates

# X.509 Aside

- Designed in 1980s
- By: International Telecommunications Union
- Advantages: extremely flexible & general
- Disadvantages: extremely flexible & general

  extremely ugly

- Also: so many security features that the interactions between them are hard to understand

# 3. Parsing X.509 certificates

How do you parse an X.509 certificate?

- No right way to do it
  - Might want quirky side effects, nulls, charset conversions

Effective, wrong ways are easily identified:

- Parse the output of **openssl x509 -text** prettyprinter
- Yup… gross but it gives you useful data quickly

Other interesting ways

- Use Java's certificate parser
- Use openssl's many obscure parsing facilities
- Custom library

# 4. Analysis

- Stick all the data into MySQL tables
- Build new ones for things like domain <-> cert
- Interesting questions become fancy SQL queries
- Handles the complexity of X.509

Validity

- Crucial concept
- Not easy to measure
- More on this later

# Results Summary

16.2M IPs were listening on port 443

10.8M started an SSL handshake

4.3+M used valid cert chains

1.3+M *distinct* valid leaves

# Crash X.509 Certificate Course

Key usage says your SSL cert != a CAs

Certs need to chain back to trust roots,

- Issuer == Subject
- If AKID or SKID in either cert AKID == SKID
- Valid dates
- Key usage is right
- No 'critical' properties we don't understand

# Valid vs Invalid certs

There is all sorts of crazy stuff in the set of invalid certs

- People pretending to be Microsoft, Google, *, etc…
- Some telcos with wildcard certs for their WAP gateways
- You name it, it's there

Unless otherwise noted, this talk is about the valid certs…

# Interesting Questions

How many CAs are there?

Who are they?

What do they sign?

Server impersonation attacks?

# Number of Trusted CAs

How many does your browser trust?

Mozilla: 124 trust root s (~60 organizations)

Microsoft: lists only 19 trust roots in Windows 7

- Silent on-demand updating!
- Can make this 300+ certs
- 100+ from controlling organisations

# Number of trusted certificate signers?

We observed:

1,482 CA Certificates trustable by Windows or Firefox

1,167 distinct issuer strings

651 organizations

but ownerships & jurisdictions overlap

If a CA can sign for one domain, it can sign for any domain

# CAs

Recorded 1,377,067* unique, valid leaf certs

300,224 – signed by one GoDaddy cert

FD:AC:61:32:93:6C:45:D6:E2:EE:85:5F:9A:BA:E7:76:99:68:CC:E7

244,185 – signed by one Equifax cert

48:E6:68:F9:2B:D2:B2:95:D7:47:D8:23:20:10:4F:33:98:90:9F:D4

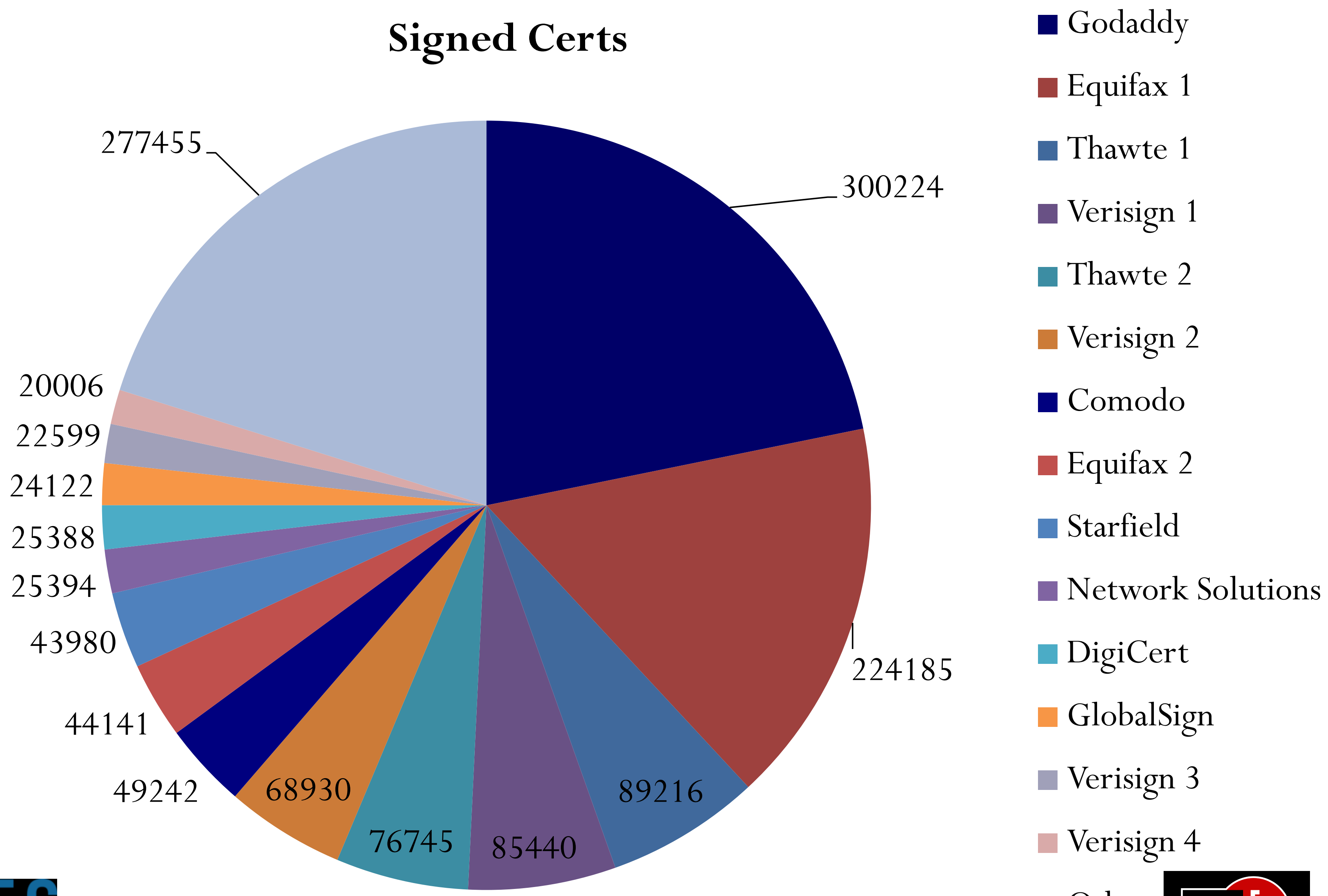
89,216 – signed by Thawte's skid free cert

85,440 – signed USERTRUST's 4 certs w/ skid

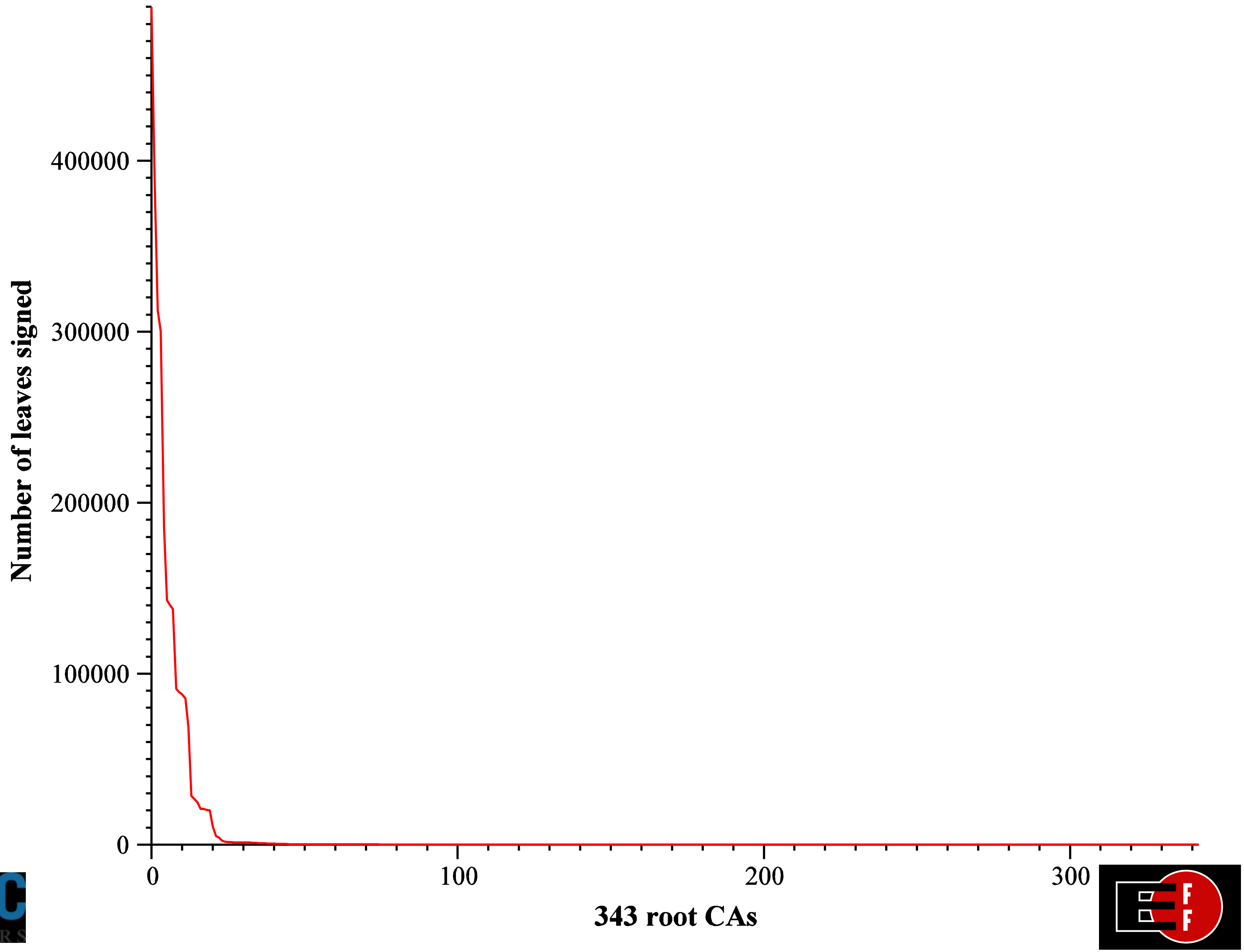
A1:72:5F:26:1B:28:98:43:95:5D:07:37:D5:85:96:9D:4B:D2:C3:45

- Valid based on OpenSSL 0.9.8k with Firefox **or** all XP i.e. trust roots…

# CA Certificate use frequency



# # Leaves validated per Root CA



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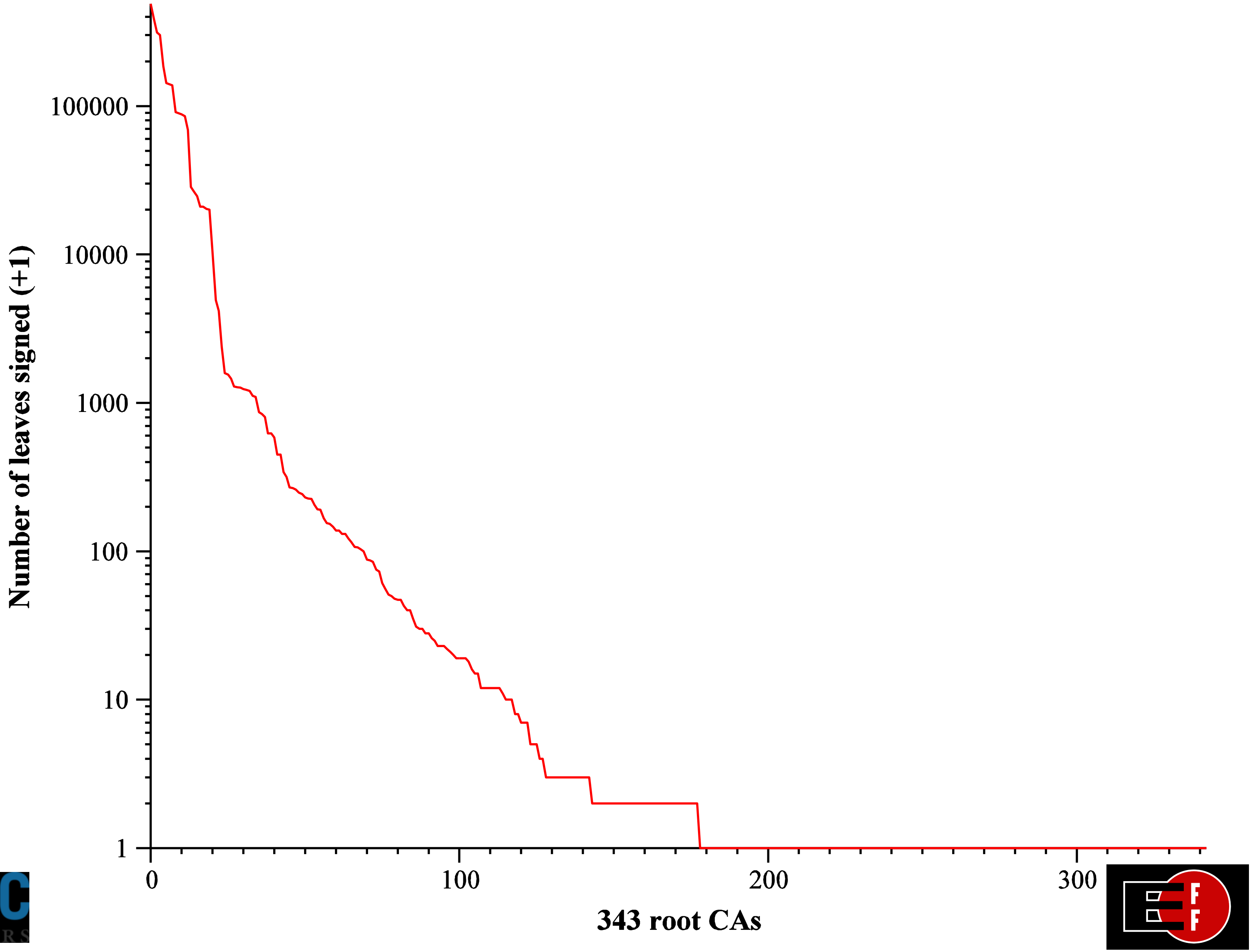


# CA Usage

When might a root be legitimately unused?

- New, more secure cert being pushed out
  - Needs to be accepted widely before it can be used
  - Obviously legitimate, and improves overall security
- Backup root – maybe if a root needed revoking?!?

When might a subordinate CA be legitimately unused?

- Hard to imagine hey
  - If you want a more secure one, make it
  - If you get compromised revoke and make a new one
  - Maybe some argument around how long that takes?

# Valid CA Certs Sharing Keys

Many signing certificates share keys!

Identified 80 distinct keys used in multiple CA Certs

Most widely reused, valid Public RSA key:

- Verisign, 2006 2048-bit key
- Certs share subject, lack subject or authority ids
- 4 expire simultaneously in 2021, 1 expires in 2036

# Valid CA Certs Sharing Keys

Some keys are shared between organizations

mergers or acquisitions?

Certificate 1, a 2048-bit RSA, CA signing certificate

American Optimum SSL CA

```
E0:E6:09:81:CF:00:78:0D:13:FE:61:6B:01:DC:0C:A5:17:61:F8:EF
```

Certificate 2

UK Comodo CA, CN=OptimumSSL CA

```
60:87:D7:16:62:34:11:75:62:CE:62:A0:F7:F6:2E:A5:C1:4F:C5:45
```

Simultaneous expiration 2020-05-30 10:48:38

Different start dates, same SKID, AKID & key usage

# Valid CA Certs Sharing Keys

Certificate 1, a 2048-bit RSA, CA signing certificate

UK Comodo CA Limited, CN=PositiveSSL CA

```
DD:C5:8C:53:DF:2E:F2:B2:66:20:BF:1C:A7:D4:15:FF:98:CD:B4:84
```

Certificate 2 Issuer same as 1: US USERTRUST

US Positive Software Corporation, CN=LiteSSL CA

```
93:D7:BC:5C:CC:3A:B6:DB:09:CA:49:6F:25:81:AA:65:7F:16:96:20
```

Certificate 3 – No AKID, Issuer: Swedish AddTrust

US Positive Software Corporation, CN=LiteSSL CA

```
A8:99:38:62:1C:B3:76:17:80:FD:33:7E:E8:85:90:64:2B:37:26:2A
```

1 & 2 expire 2020-05-30 10:48:38, 3 expires 10 months earlier

2&3 share start dates, same SKID key usage

Over 44K certs using this key ID

# CA Certs Sharing Keys to delay expiration

Certificate 1, a 1024-bit RSA, CA signing certificate

Israeli ComSign Ltd.

```
62:E7:8E:92:BF:CA:C0:CD:FA:90:34:1B:F6:27:F7:36:1D:D7:AA:F2
```

Certificate 2, basically identical aside from dates

Israeli ComSign Ltd.

```
29:F4:B6:CC:16:5E:EB:60:CF:DC:95:C9:81:DC:E6:7E:71:28:15:10
```

1 expires 2014-06-14 14:56:31, 2 expire 2020-12-31 21:05:25

41 valid certs with this issuer, **none** expire after 2014-5-29!?

same SKID, AKID, & key usage

Trick adds 2392 days to this key's 6000+ day life.

# CAs signing RFC 1918 (Reserved) IPs

Would the **authentic** 192.168.1.2 please step forward:

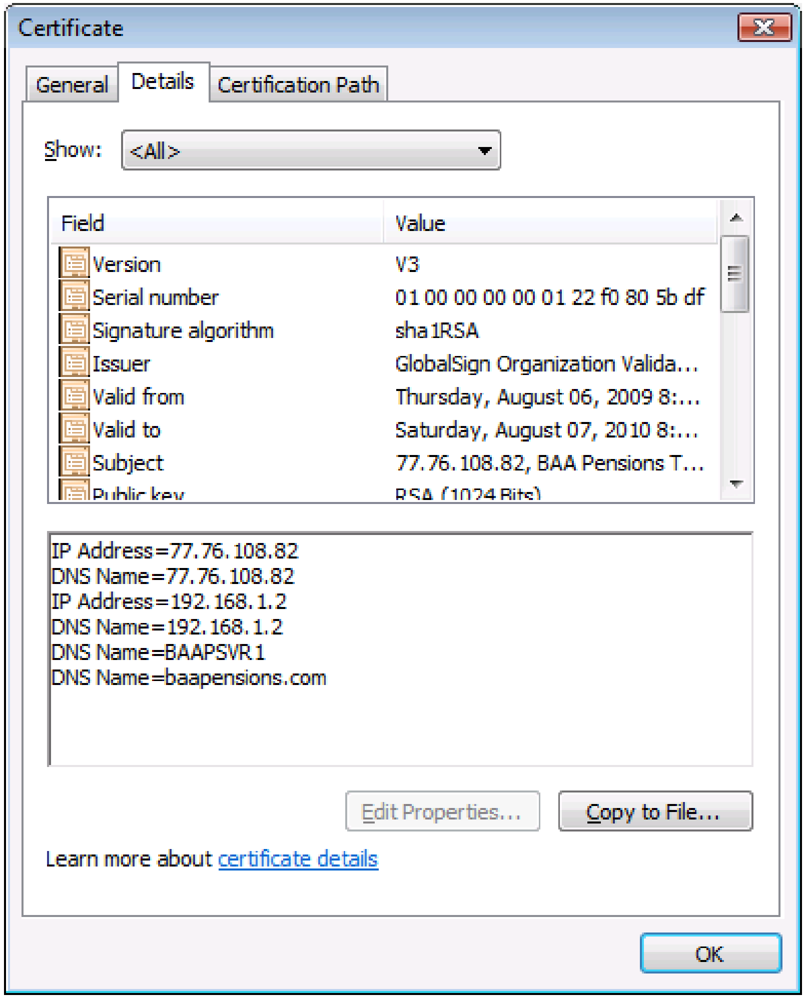
US Equifax asserts it is in Texas

Belgian GlobalSign puts it in:

the US, the UK, Switzerland,

Belgium and cutely also as

77.76.108.82



| Field | Value |
|---|---|
| Version | V3 |
| Serial number | 01 00 00 00 00 01 22 f0 80 5b df |
| Signature algorithm | sha1RSA |
| Issuer | GlobalSign Organization Valida... |
| Valid from | Thursday, August 06, 2009 8:... |
| Valid to | Saturday, August 07, 2010 8:... |
| Subject | 77.76.108.82, BAA Pensions T... |
| Public key | RSA (1024 Bits) |

```
IP Address=77.76.108.82
DNS Name=77.76.108.82
IP Address=192.168.1.2
DNS Name=192.168.1.2
DNS Name=BAAPSVR1
DNS Name=baapensions.com
```

# CAs signing unqualified names

It would be meaningless to assert ownership of such a name

Yet… we saw over 6 thousand unique valid "localhost" certs

From different issuers like:

Comodo , Go Daddy, GlobalSign, Starfield, Equifax, Digicert, Entrust, Cybertrust, Microsoft, and Verisign

Some CAs only signed one "Localhost" name:

Cybertrust, Entrust, Equifax, Microsoft & Verisign

Maybe they have a process to track what they assert?

# Countries use of CAs

Some countries are not using their CAs

Macao – has its own 2048 bit CA in XP

- Isn’t used on the Internet*
- Doesn’t use Chinese or Portuguese CA either
- Signs government websites with commercial certificates from US and UK CAs

* As far as we saw…

# Weak Certs

Two leaf certs

- 508 bit RSA keys – think 512, starting with a 0
- Signed by Equifax and Thawte
- Valid under Mozilla and Microsoft’s trust roots

Fingerprints:

B4:21:9E:89:24:29:41…

7B:BB:1B:CF:FD:6A:1A…

# Vulnerabilities

Yes, a few things pop out when you look.

# Vulnerabilities

Remember the Debian OpenSSL bug?

- Affected keys generated from 2006-2008
- Private keys have only 15-17 bits of entropy
  (i.e. not private)

```
select subject from certs join blacklist on
    sha1(certs.rsa_modulus) = blacklist.hash
```

~ 28K vulnerable certs seen

- Fortunately only 500 are valid
- 12K are private CA certs

# About those vulnerable certificates

530 Validate, 73 of these are revoked

CAs that revoked a lot of vulnerable certs:

- ✓ Starfield (5/5)
- ✓ Comodo (29/30)
- ✓ USERTRUST (24/25)

Some CAs that didn't:

- ✗ Equifax (0/140)
- ✗ ipsca (0/24)
- ✗ Cybertrust (4/125)
- ✗ Thawte (4/35)
- ✗ VeriSign (2/9)
- ✗ Unizeto (0/6)
- ✗ FNMT (0/6)

# Certificates that should not exist

```
select `X509v3 Basic Constraints:CA`, subject
          `X509v3 Key Usage`, from valid_certs
where
 (locate("Certificate Sign", `X509v3 Key Usage`)!=0)
   !=  (locate("TRUE", `X509v3 Basic Constraints:CA`
  ) !=0);
```

**CA:** FALSE

**Key Usage:**Digital Signature, Non Repudiation, Key Encipherment,Data Encipherment, Key Agreement, *Certificate Sign*

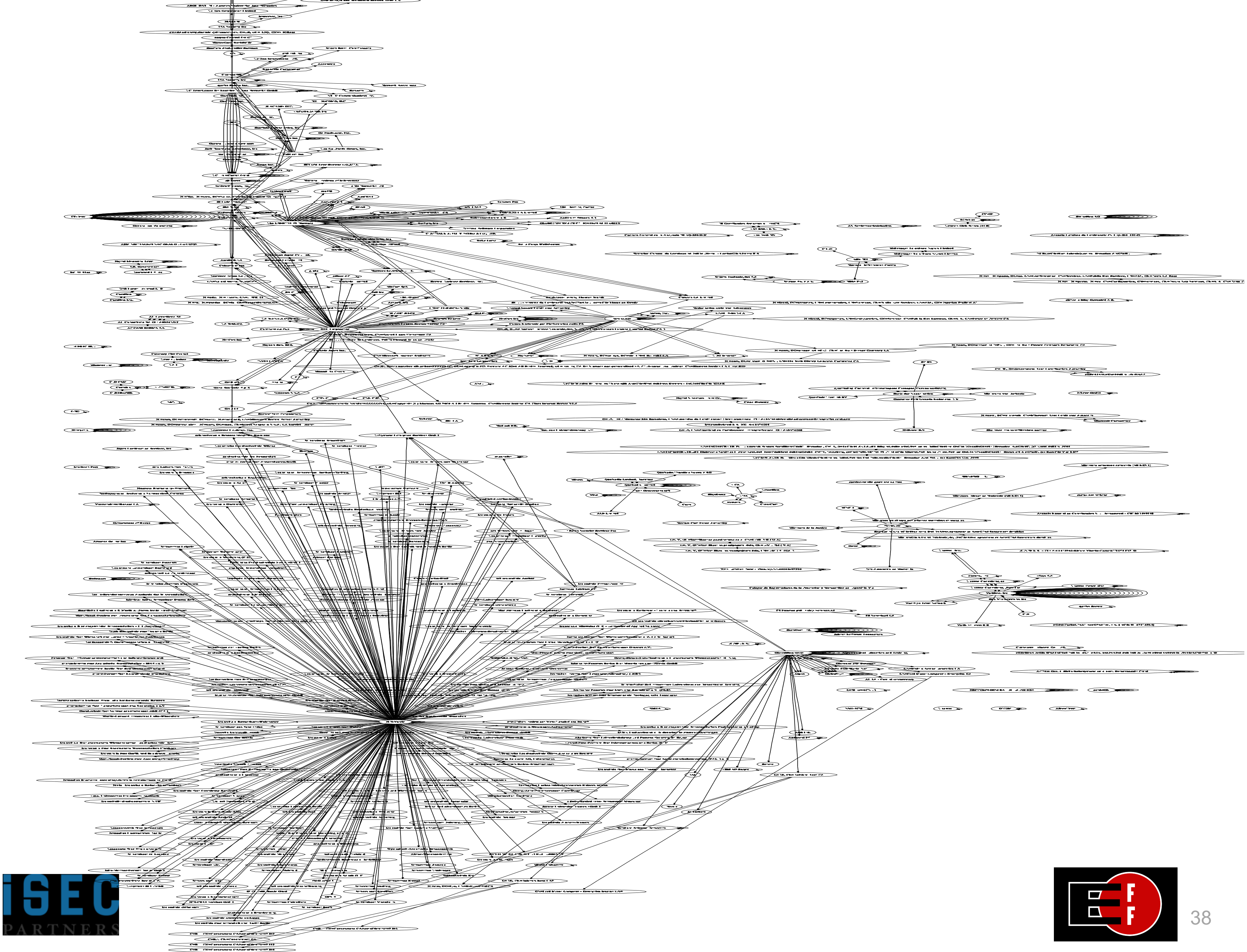
**Issuer:** C=BM, O=QuoVadis Limited,
OU=www.quovadisglobal.com,
CN=QuoVadis Global SSL ICA

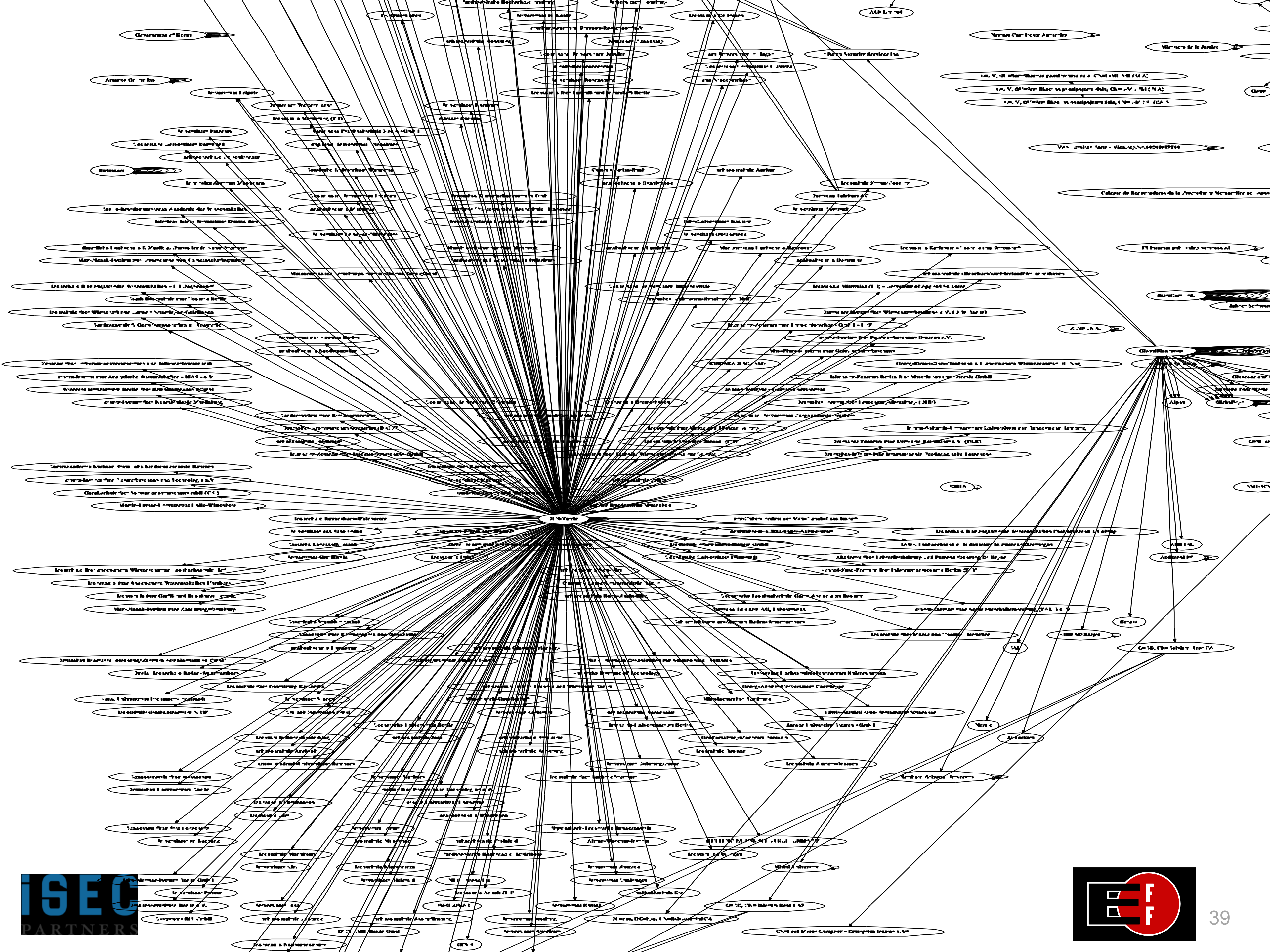
# Pretty Pictures

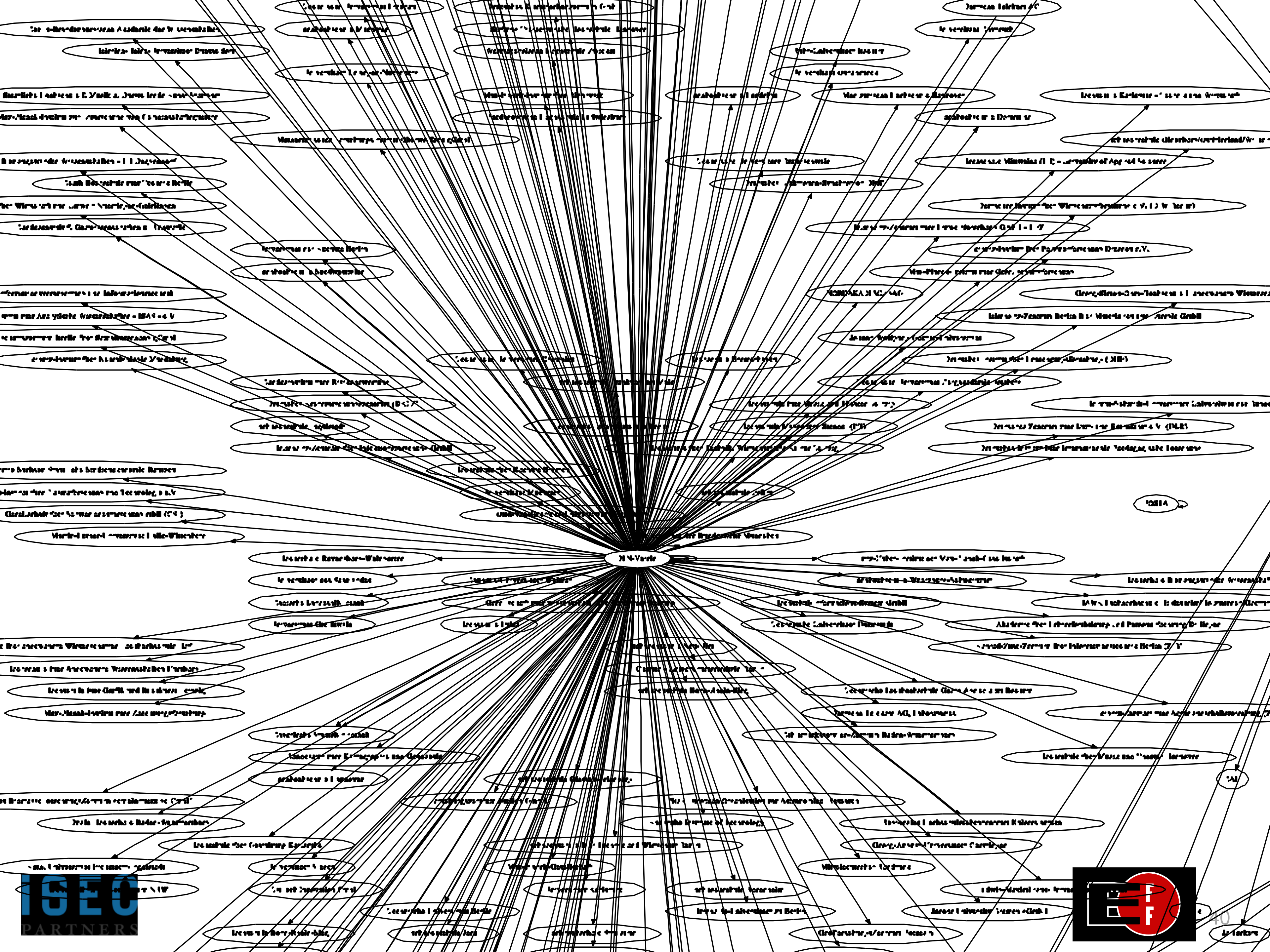
Roots create subordinates

Subordinates create subordinates

A zillion leaves are no good



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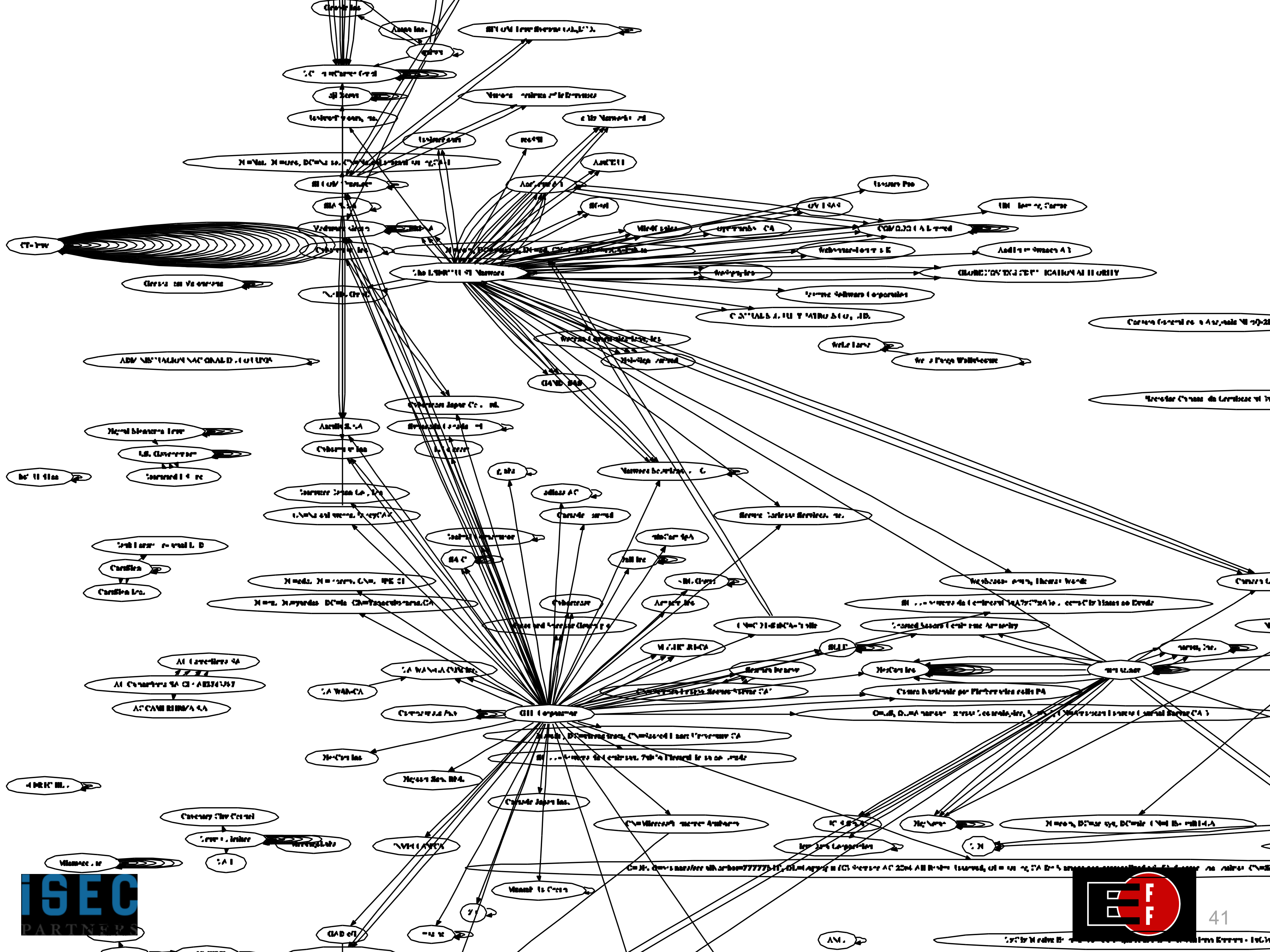
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Centro Nazionale per l'Informatica nella PA
Entrust Software Corporation
AddTrust AB
Deutsche Telekom AG
Digital Signature Trust
Secure Business Services, Inc.
CT-Trust
ENTRUST
Network Solutions
GANDI SAS
GlobalSign Interactive Communications, Inc
AOL

# Subordinate CAs

Interesting Subordinate CAs:

- Department of Homeland Security
- CNNIC from 2007, removing that root helps you how?
- Etisalat
- Booz Allen Hamilton
- Gemini Observatory – Can I have a CA?
- Companies: Dell, Ford, Google, Marks and Spencer, Vodaphone…
- Hundreds more….

# Subordinate CAs

Countries with valid CAs: 46

- USA, South Africa, The UK, Belgium, Japan, Germany, The Netherlands and Israel

lots more

Countries without CAs but with Subordinate CAs:

- United Arab Emirates, Iceland, Luxembourg, Macedonia, Malaysia, Russian Federation,

* 64 roots didn’t include a country – probably US based

# Unwashed Self-Signed Masses

Argument for persistence of key, TOFU, or ssh model.

- Trusted introducer is nice, but some want to skip it
- Reduced complexity, cost
- More security if CAs sign – say random subordinates

X509 isn't simple however:

- What name is a self-signed cert valid for?

IE, Firefox and Chrome track the site a self-signed cert is for

Firefox lets you track permanent assumptions about these.

Substituting trust-chained different cert allowed

# Conclusions & Discussion

Is the CA model fundamentally broken?

Can we do any better?

Are we observing middleperson / server impersonation attacks?

# Future Work

Release our data

Detecting private attacks and non-public addresses

Consider an analysis of CA importance

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- Eray Ozkan – provided MS roots

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