





# Third-Party Web Tracking

## Technology, Policy, and Politics

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# Obligatory Disclaimers



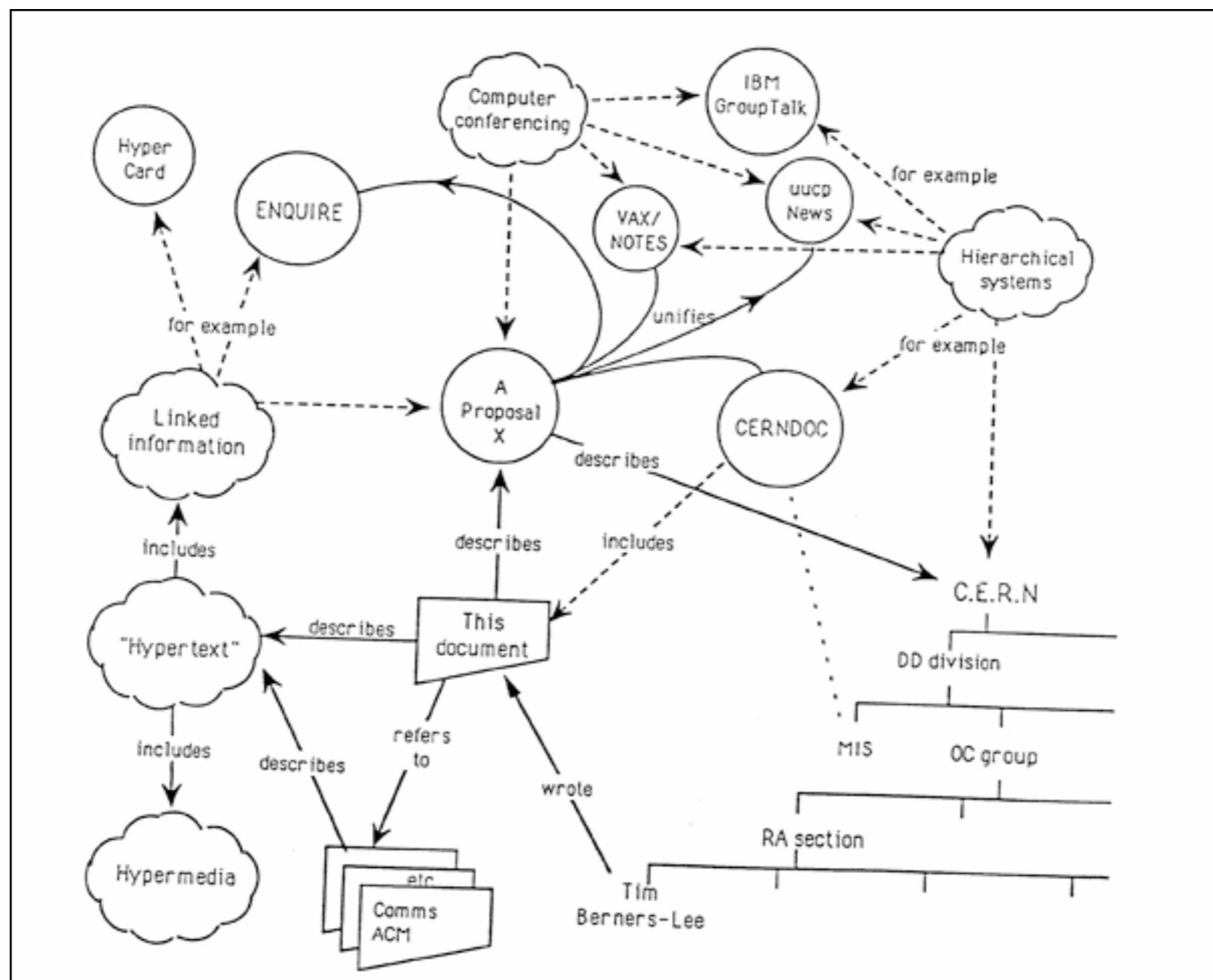
Stanford Security Laboratory

  
The Center for  
Internet and Society



**This is not legal advice.**

History and Status Quo  
Tracking Methods  
Signaling Mechanisms  
Technical Countermeasures  
Government Intervention  
Privacy-Preserving Advertising



# 1989

Source: W3C

# World Wide Web

The WorldWideWeb (W3) is a wide-area [hypermedia](#) information retrieval initiative aiming to give universal access to a large universe of documents.

Everything there is online about W3 is linked directly or indirectly to this document, including an [executive summary](#) of the project, [Mailing lists](#) , [Policy](#) , November's [W3 news](#) , [Frequently Asked Questions](#) .

## [What's out there?](#)

Pointers to the world's online information, [subjects](#) , [W3 servers](#), etc.

## [Help](#)

on the browser you are using

## [Software Products](#)

A list of W3 project components and their current state. (e.g. [Line Mode](#) ,[X11 Viola](#) , [NeXTStep](#) , [Servers](#) , [Tools](#) , [Mail robot](#) , [Library](#) )

## [Technical](#)

Details of protocols, formats, program internals etc

## [Bibliography](#)

Paper documentation on W3 and references.

## [People](#)

A list of some people involved in the project.

## [History](#)

A summary of the history of the project.

## [How can I help ?](#)

If you would like to support the web..

## [Getting code](#)

Getting the code by [anonymous FTP](#) , etc.

| 992

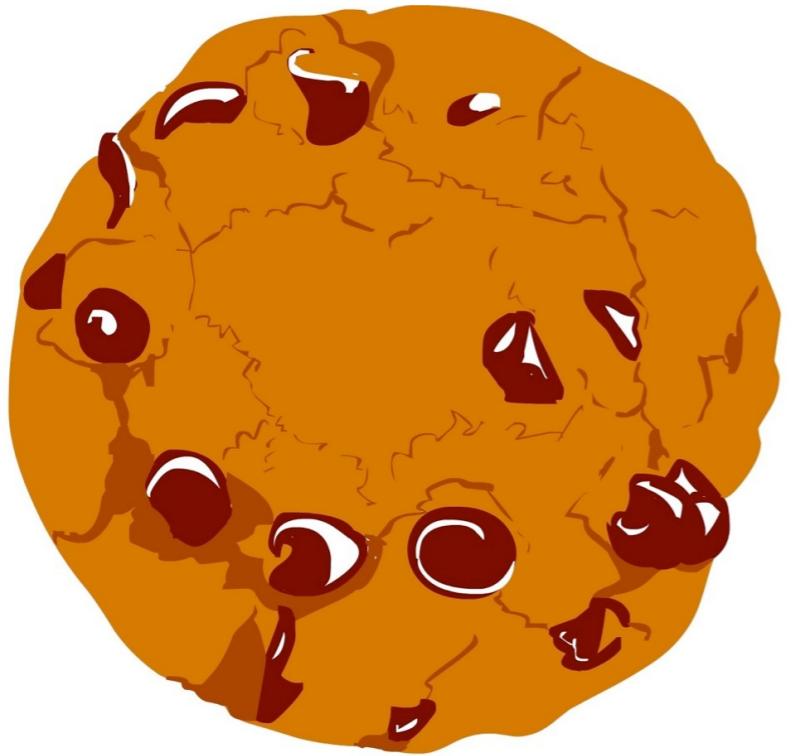
Source:W3C

<img>

<marquee>

<blink>

That didn't last long.



**Cookies**  
**1994**



**JavaScript**  
**1995**

**no**

“A user agent should make ~~every~~ attempt to prevent the sharing of session information between hosts that are in different domains.”

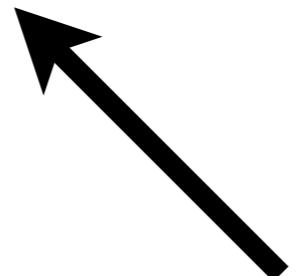
-IETF RFC 2109

| 997



1997

# Current Page



The New York Times - Breaking News, World News & Multimedia

http://www.nytimes.com/

Welcome to TimesPeople

TimesPeople recommended: Race to the Top of What? Obama On Education

8:11 PM | Recommend

HOME PAGE | TODAY'S PAPER | VIDEO | MOST POPULAR | TIMES TOPICS | Get Home Delivery-Bay Area | Log In | Register Now

SHOP MARCJACOBS.COM

MARC JACOBS

Tuesday, February 1, 2011 Last Update: 9:03 PM ET

Follow Us

**The New York Times**

Mubarak Won't Seek New Term  
Obama Says Orderly Transition 'Must Begin Now'

VIDEO: TIMESCAST PHOTOGRAPHS

Switch to Global Edition

JOBS  
REAL ESTATE  
AUTOS  
ALL CLASSIFIEDS

WORLD  
U.S.  
POLITICS  
NEW YORK  
BUSINESS  
DEALBOOK  
TECHNOLOGY  
SPORTS  
SCIENCE  
HEALTH  
OPINION  
ARTS  
Books  
Movies  
Music  
Television  
Theater  
STYLE  
Dining & Wine  
Fashion & Style  
Home & Garden  
Weddings/  
Celebrations  
TRAVEL  
All Blogs  
Cartoons  
Classifieds  
Corrections  
Crossword /  
Games  
Education  
First Look  
Learning Network  
Multimedia  
NYC Guide  
Obituaries

OPINION » EGYPT  
Kristof: The White House should support the protesters in Egypt.

VIDEO: Mubarak's concession followed one of the largest protests in recent memory.

Path to Change in Power Still Unclear  
By ANTHONY SHADID  
7 minutes ago

President Hosni Mubarak's vow to step down in the fall was not enough for the hundreds of thousands who poured into Tahrir Square.

King of Jordan Dismisses His Cabinet  
By RANYA KADRI and ETHAN BRONNER 50 minutes ago

A surprise move by King Abdullah II came in the face of a wave of protests sweeping the Arab world.

Obama Urges Quick Transition  
7:37 PM ET

Post a Comment | Read (332)

The Lede: Latest Updates, Day 8  
By ROBERT MACKIE Live  
Full video of President Obama's speech; a rebuttal to Mr. Mubarak's; video of protesters watching it in Cairo.

Antiquities Chief Says Sites Are Largely Secure  
By KATE TAYLOR 50 minutes ago

While Zahi Hawass, who was made a cabinet official on Monday, described two episodes of looting and said Egyptians had helped the army protect cultural sites.

MARKETS » At 8:50 PM ET

JAPAN Nikkei 10,478.97 +204.47 +1.99% CHINA Hang Seng 23,700.16 +217.21 +0.92%

Shanghai 2,798.96 +20.00 +0.92% Close for holiday Data delayed at least 15 minutes

GET QUOTES My Portfolios Stock, ETFs, Funds Go

1.30 % HIGH-YIELD SAVINGS ACCOUNT LEARN MORE TAKE CHARGE!

iMeet built a meeting room just for you.

REPLAY



# DISPLAY LUMAscape



<img>

<script>

<iframe>

GET http://advertising.com/ HTTP/1.1  
Referer: http://news.com/  
Cookie: id=12345

| User ID | Time               | URL                                      | Page Title                   |
|---------|--------------------|--|------------------------------|
| 12345   | 6/18/12<br>10:01am | <u>http://</u><br><u>foxnews.com/...</u> | Why Liberals<br>Hate America |
| 12345   | 6/18/12<br>10:02am | <u>http://</u><br><u>youtube.com/...</u> | Squirrels<br>Waterskiing?!   |

...

HELLO  
MY NAME IS

Browsing History

Health Information

Financial Information

Shopping History

...

**“it’s all anonymous”**

**actually, it's all pseudonymous**



**past**

**present**

**future**

- social network or other first party
- intentional leakage
- unintentional leakage
- security exploit
- deanonymization



- 1.Scorecard Research, 81 sites (44%)**
- 2.Google Analytics, 78 sites (42%)**
- 3.Quantcast, 63 sites (34%)**
- 4.Google Advertising, 62 sites (34%)**
- 5.Facebook, 45 sites (24%)**

**(signed up and interacted with 185 sites)**

Leland Stanford | Mitt Romney for President

Leland Stanford | Mitt Romney f... https://www.mittromney.com/users/lelandstanford Google Feedback

Leland Stanford | Logout

Learn About Mitt In Your Community News & Media Shop CONTRIBUTE

Americans deserve more jobs and more take-home pay. Read Mitt's Five Point Plan ▶

## MyMitt Member Account

 EDIT ACCOUNT

### Leland Stanford

TOTAL AMOUNT RAISED: \$0 PEOPLE WHO DONATED: 0 FUNDRAISING CAMPAIGNS: 0 POINTS: 5,000

Member for: 26 sec

CREATE A FUNDRAISER

INVITE A FRIEND ?  
Email Address \* SEND INVITE  
See your invites

GEAR UP  
Shop for official campaign gear.  
SHOP NOW

DONATE Make a contribution.

MAKE CALLS FOR MITT

Dashboard - Leland Stanford

Dashboard - Leland Stanford https://dashboard.barackobama.com/people/robber.baron Google Feedback

Days Hours Minutes

0 5 0 1 1 4

Leland S.

Help

# LELAND STANFORD

Supporter for Stanford Faculty for Obama



Your profile is not public.  
Update your sharing settings  
to share your page and the  
work you're doing to help  
re-elect the President.

Edit profile

Edit account

You're currently a supporter  
of Stanford Faculty for  
Obama.  
Want to get more involved?  
Talk to your team manager  
about becoming a Team  
Member.

Why I'm in edit

**tracking** |'trakiNG|  
noun  
1 the collection of a user's browsing history

- sensitive, identifiable information
- lack of transparency
- lack of usable, effective controls
- inadequate market incentives

History and Status Quo  
Tracking Methods  
Signaling Mechanisms  
Technical Countermeasures  
Government Intervention  
Privacy-Preserving Advertising

stateful tracking

tagging

stateless tracking

fingerprinting

HTTP cookies

HTTP authentication

HTTP ETags

content cache

IE userData

Flash Local Shared Objects

Silverlight Isolated Storage

TLS session ID & resume

browsing history

window.name

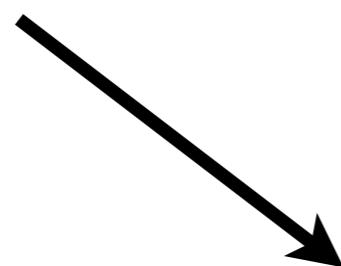
HTML5 protocol & content handlers

HTTP STS

HTML5 session/local/global/database storage

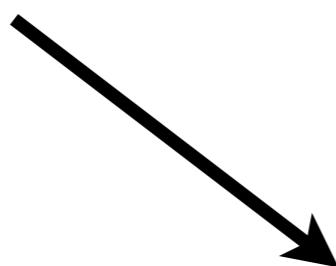
DNS cache

this is blue



link

this is purple



link

User-Agent

installed fonts

HTTP ACCEPT Headers

cookies enabled?

browser plug-ins

browser add-ons

MIME support

screen resolution

clock skew

the technologies that make the web awesome  
are the very technologies that enable tracking

Lots of empirical questions.

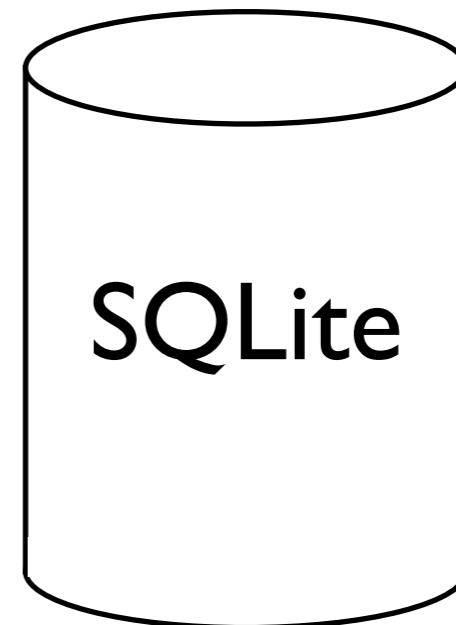
# Many Research Designs

1. build custom platform for experiment
2. run experiment
3. write paper
4. goto 1

# FourthParty Design

1. build one platform
2. collect as much data as possible
3. run many experiments
4. write many papers

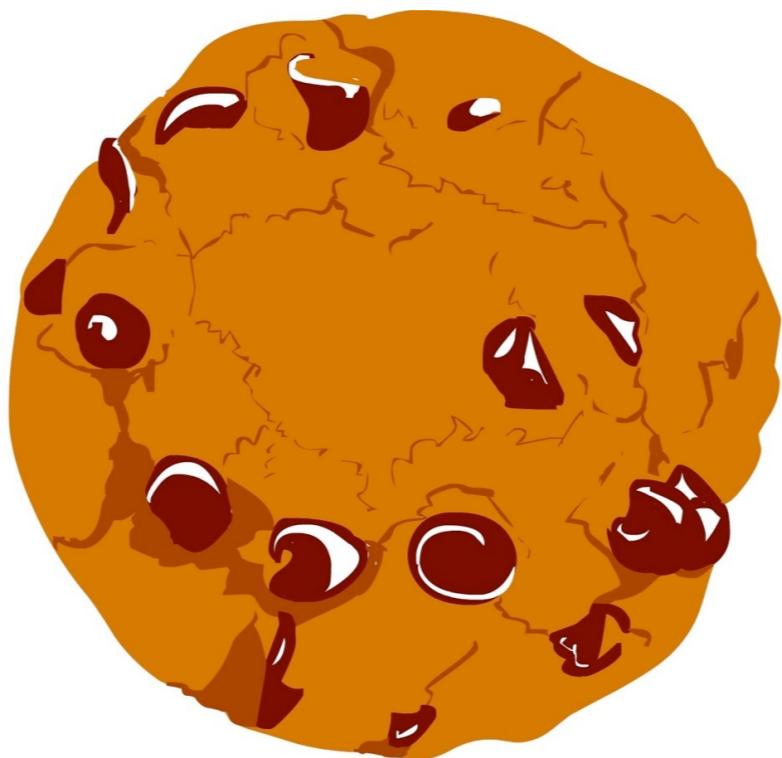
# FourthParty Architecture



- easy to use
- shared data, historical data
- works with existing extensions (crawling and more)
- multiplatform

History and Status Quo  
Tracking Methods  
**Signaling Mechanisms**  
Technical Countermeasures  
Government Intervention  
Privacy-Preserving Advertising

**opt out**

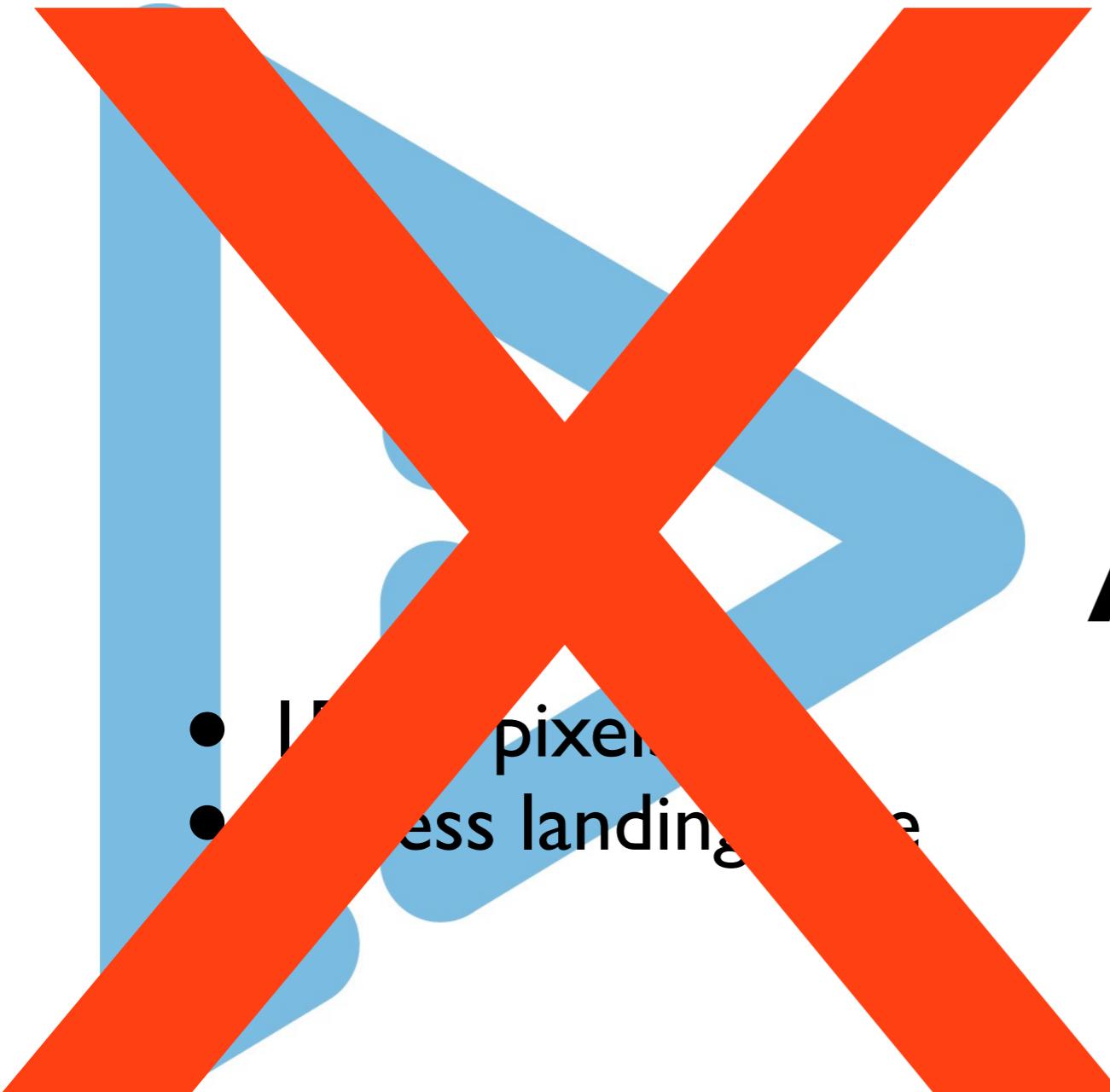




Network Advertising Initiative

$\approx$ 75 companies

- not comprehensive
  - not all third-party trackers offer
  - vast majority do not participate in NAI
- requires updating\*
- can accidentally clear\*

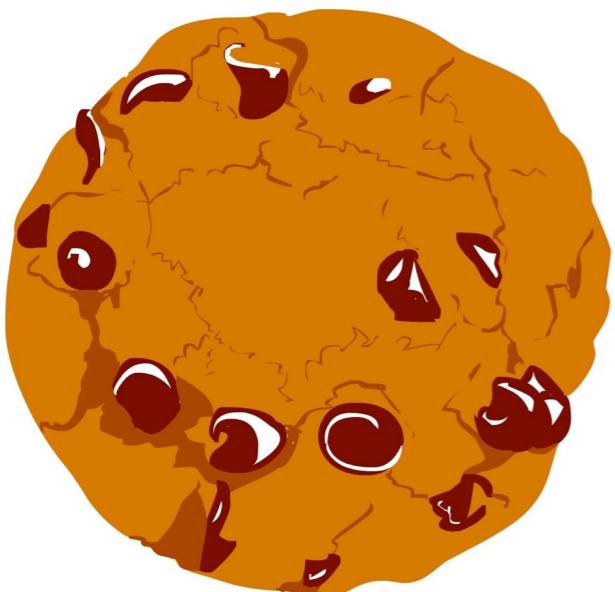


10% with icon  
**AdChoices**  
5% with icon + text

opt out

~~DECEPTIVE~~

= Do Not Target Ads



# Do Not Track

- universal
- no updating
- one click
- in the browser

# HTTP header

**DNT : 1**



4+



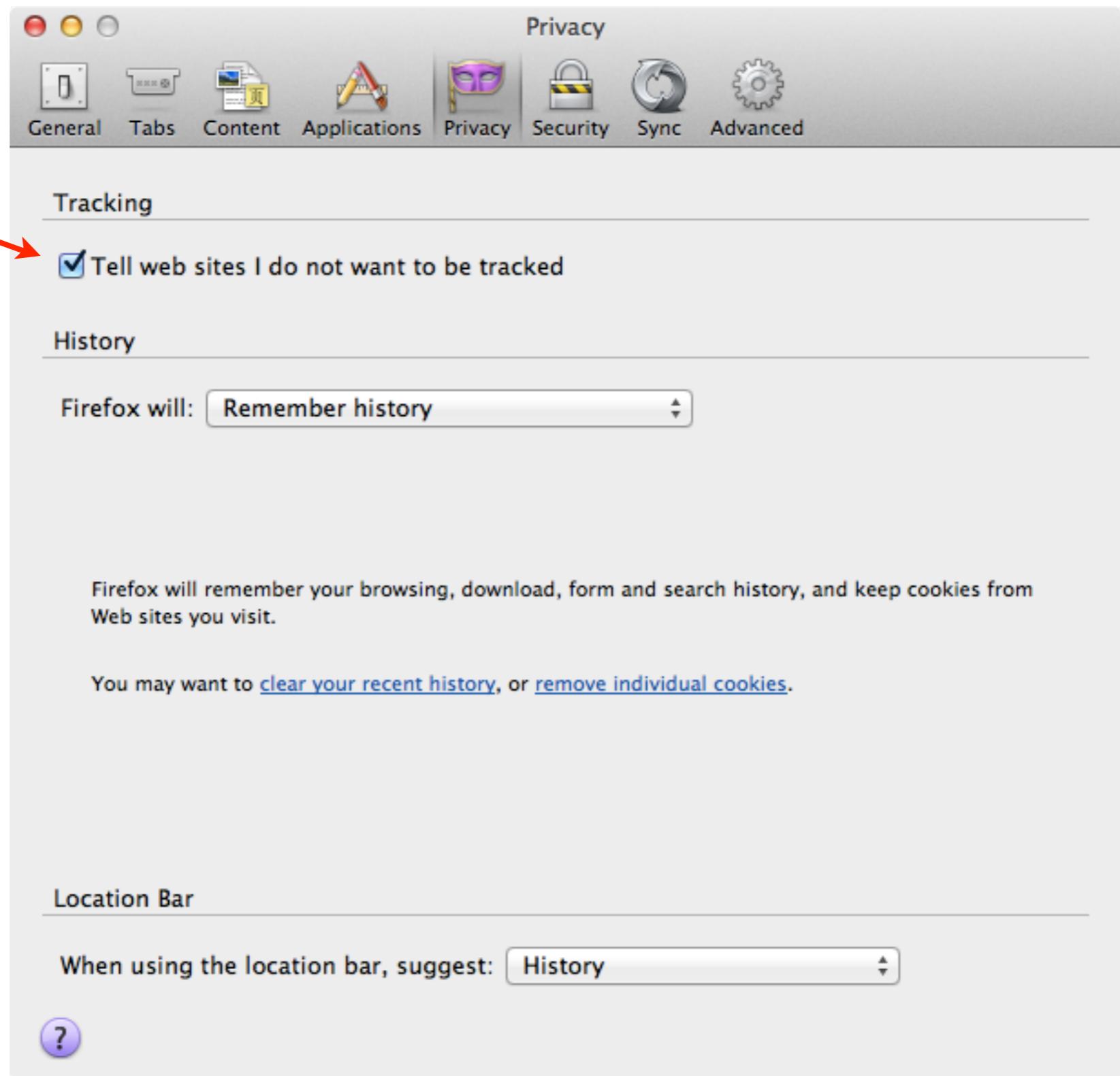
9+



5.1+



25+



 Privacy

General Bookmarks Tabs AutoFill Passwords Security Privacy Notifications Extensions Advanced

Cookies and other website data: [Remove All Website Data...](#)

Block cookies:  From third parties and advertisers  
 Always  
 Never

Limit website access to location services:  Prompt for each website once each day  
 Prompt for each website one time only  
 Deny without prompting

Website tracking:  Ask websites not to track me

Web search:  Prevent search engine from providing suggestions [?](#)

The screenshot shows the Google Chrome Settings page (`chrome://settings`) on a Mac OS X system. The left sidebar has tabs for Chrome, History, Extensions, Settings (which is selected), and Help. The main content area includes sections for On startup (with radio buttons for New Tab page, Continue where I left off, or Set pages), Appearance (with buttons for Get themes and Reset to default theme, and checkboxes for Show Home button and Always show the bookmarks bar), Search (with dropdown for search engine set to Google and a Manage search engines... button, and a checkbox for Instant search), Users (showing one user and buttons for Add new user..., Delete this user, and Import bookmarks and settings...), and Default browser (stating it's currently Google Chrome). A red arrow points to the "Show advanced settings..." link at the bottom of the Default browser section.

Settings

chrome://settings

Chrome      Settings

History      Extensions      Settings      Help

On startup

Open the New Tab page  
 Continue where I left off.  
 Open a specific page or set of pages. [Set pages](#)

Appearance

[Get themes](#) [Reset to default theme](#)

Show Home button  
 Always show the bookmarks bar

Search

Set which search engine is used when searching from the [omnibox](#).

[Google ▾](#) [Manage search engines...](#)

Enable Instant for faster searching (omnibox input may be [logged](#))

Users

You are currently the only Google Chrome user.

[Add new user...](#) [Delete this user](#) [Import bookmarks and settings...](#)

Default browser

The default browser is currently Google Chrome.

[Show advanced settings...](#)

The screenshot shows the Google Chrome settings page with a red arrow pointing to the "Send a 'Do Not Track' request with your browsing traffic" checkbox under the Privacy section.

**Chrome**      **Settings**      [Create user...](#)      [Delete this user...](#)      [Import bookmarks and settings...](#)      [Search settings](#)

History      **Default browser**  
The default browser is currently Google Chrome.

Extensions      **Privacy**

Settings      Help

[Content settings...](#)      [Clear browsing data...](#)

Google Chrome may use web services to improve your browsing experience. You may optionally disable these services. [Learn more](#)

Use a web service to help resolve navigation errors  
 Use a prediction service to help complete searches and URLs typed in the address bar  
 Predict network actions to improve page load performance  
 Enable phishing and malware protection  
 Use a web service to help resolve spelling errors  
 Automatically send usage statistics and crash reports to Google  
 Send a 'Do Not Track' request with your browsing traffic

**Passwords and forms**

Enable Autofill to fill out web forms in a single click. [Manage Autofill settings](#)  
 Offer to save passwords I enter on the web. [Manage saved passwords](#)

**Web content**

Font size: [Medium](#) ▾      [Customize fonts...](#)  
Page zoom: [100%](#) ▾

Pressing Tab on a webpage highlights links, as well as form fields

Settings – Do Not Track x

← → C chrome://settings

Chrome Settings Search settings

History Default browser

Extensions The default browser is currently Google Chrome.

Settings Privacy

Help Content settings... Clear browsing data...

Google Chrome may use web services to improve your browsing experience. You may optionally disable these services. [Learn more](#)

Use a web s

Use a predi

Predict netw

Enable phis

Use a web s

Automatica

Send a 'Do

**Do Not Track**

Enabling 'Do Not Track' means that a request will be included with your browsing traffic. Any effect depends on whether a website responds to the request, and how the request is interpreted. For example, some websites may respond to this request by showing you ads that aren't based on other websites you've visited. Many websites will still collect and use your browsing data – for example to improve security, to provide content, services, ads and recommendations on their websites, and to generate reporting statistics. [Learn more](#)

OK Cancel

Passwords and forms

Enable Autofill to fill out web forms in a single click. [Manage Autofill settings](#)

Offer to save passwords I enter on the web. [Manage saved passwords](#)

Web content

Font size: Medium  [Customize fonts...](#)

Page zoom: 100%

Pressing Tab on a webpage highlights links, as well as form fields



# Settings

## Express settings

You can customize the following settings or choose express settings. If you choose express settings, your PC will occasionally send info to Microsoft and will:

- 
- Automatically install important and recommended updates.
  - Help protect your PC from unsafe files and websites.
  - Turn on Do Not Track in Internet Explorer.
  - Help improve Microsoft software, services, and location services by sending us info.
  - Check online for solutions to problems.
  - Let apps give you personalized content based on your PC's location, name, and account picture.
  - Turn on sharing and connect to devices on this network.

[Learn more about express settings](#)

[Privacy statement](#)

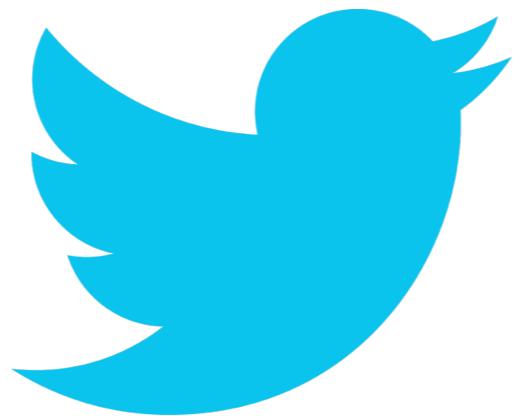


[Use express settings](#)

[Customize](#)

**tens of millions of users**

**≈25 third parties honor DNT**



**Advertising industry White House pledge:  
Implement by end of 2012**



Negotiations for 2+ years, no agreement.

# Enforcing a Signaling Mechanism



- observe suspicious behavior
- monitor ad distributions

History and Status Quo  
Tracking Methods  
Signaling Mechanisms  
**Technical Countermeasures**  
Government Intervention  
Privacy-Preserving Advertising

**old view: privacy  $\approx$  security**

anti-tracking technology

blocking



Internet Explorer 9



forbes.com^\*/track.  
fresh.techdirt.com^  
frstatic.net^\*/tracking.js  
ft.com^\*/ft-tracking.js  
ft.com^\*/fttrack2.js  
ft.com^\*/si-tracking.js  
g.msn.com^  
gamerevolution.com^\*/gn\_analytics.min.js  
gamesradar.com^\*/clacking.js  
gametrailers.com/neo/stats/  
gamezone.com/?act=  
gamezone.com/site/linktracker.js  
geo.perezhilton.com^  
geo.yahoo.com^  
geoip.mlive.com^  
geoip.nola.com^  
geoiplookup.wikimedia.org^  
ghostery.com^\*/clicky.js  
go.com/stat/  
goauto.com.au^\*/ecblank.gif?  
godaddy.com/image.aspx?  
google.\*/gwt/x/ts?  
google.\*/stats?ev=  
google.com/lh/ajaxlog?  
google.com/uds/stats?  
greatschools.org/res/js/trackit.js  
guim.co.uk^\*/sophusthree-tracking.js  
harrisbank.com^\*/zig.js  
heraldm.com/tracker.tsp?  
hitcount.heraldm.com^  
holiday-rentals.co.uk/thirdparty/tag  
holiday-rentals.co.uk^\*/hrtrackjs.gif?  
hostels.com/includes/lb.php?  
hostels.com/includes/thing.php?  
hostels.com/includes/vtracker.php?

- not comprehensive
- requires updating
- breaks stuff
- requires user knowledge about providers

**“blocks many . . . technologies that can track and profile you as you browse the Web . . . updated weekly”**

-Abine TPL

**“completely removes all forms of tracking from the internet”**

-EasyPrivacy ABP Subscription

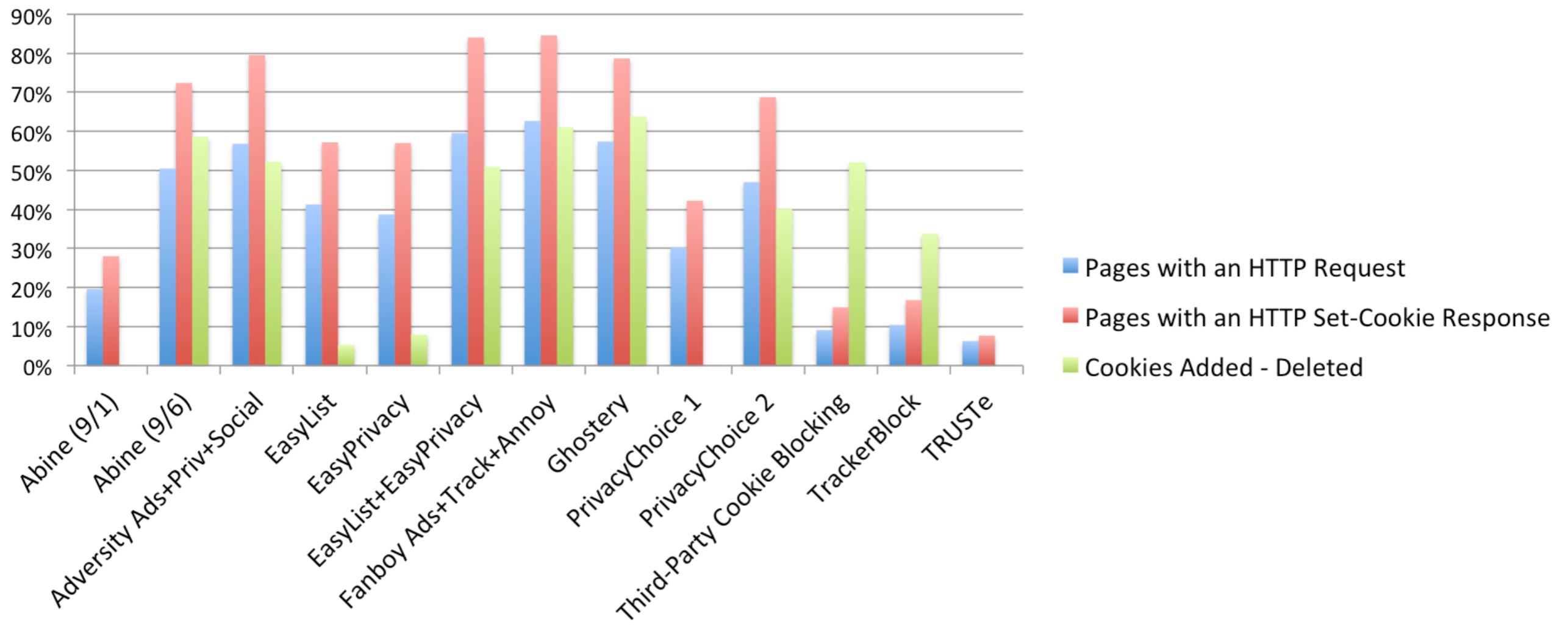
**“complete control over online tracking”**

-PrivacyChoice TrackerBlock

**“helps users get good ads, without compromising personal privacy”**

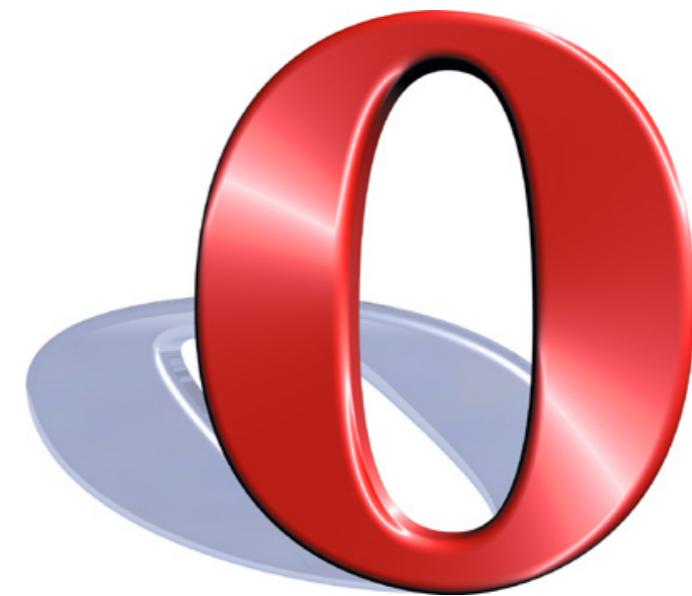
-TRUSTe TPL

## Average Decrease in Tracking

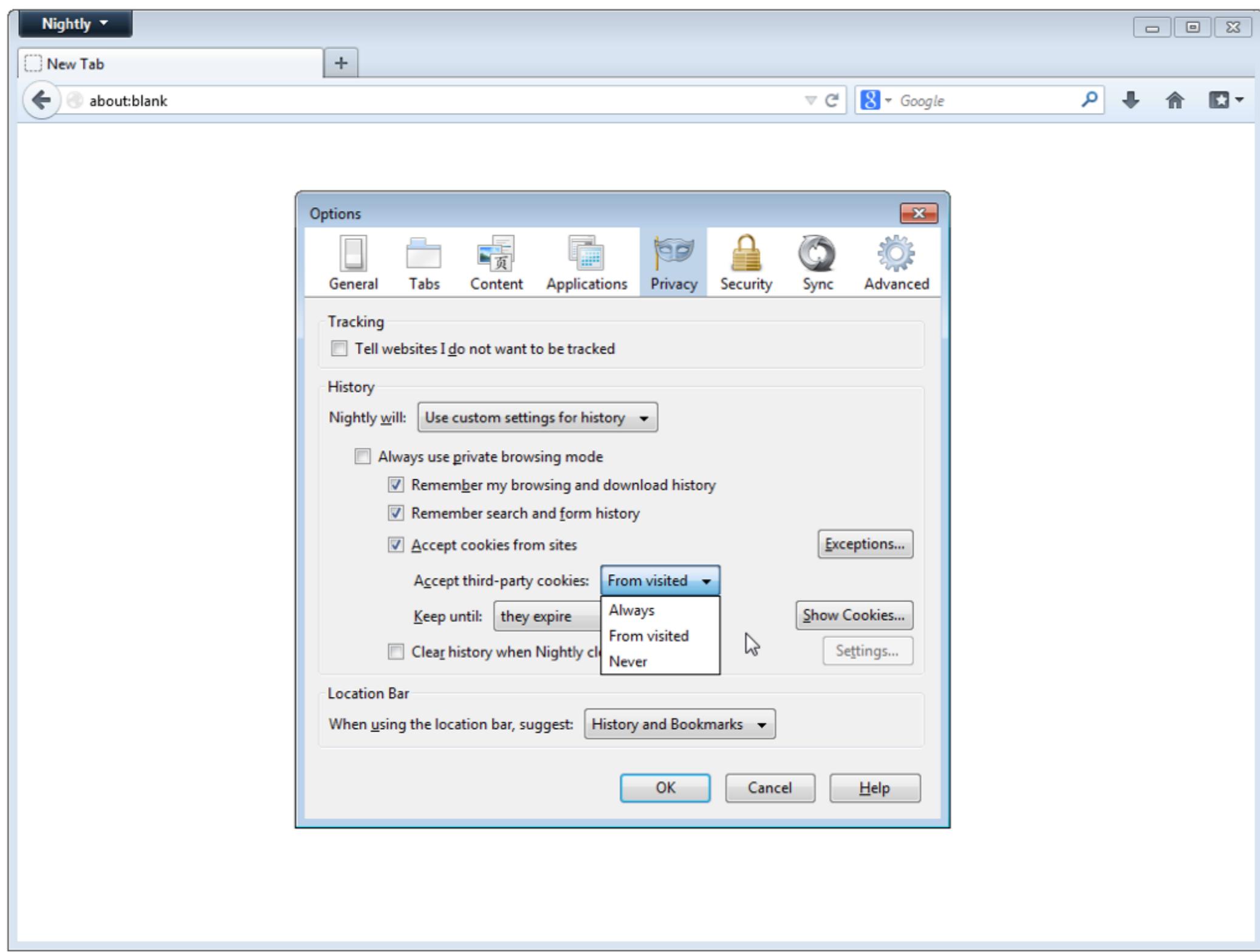


**(we can't reasonably expect the average user to sort this out)**

**new view: privacy ≠ security**



**relaxed third-party cookie blocking**



**study: measuring browsers**

Mozilla Firefox

file:///Users/j...easurement.html

Go to a Website

Google

STANFORD UNIVERSITY

Stanford Center for Professional Development

LAND STANFORD  
DIE LUFT DER  
FREIHEIT WEHT  
UNIVERSITÄT

Adapt to new opportunities.

Online Engineering Courses, Certificates, and Degrees from Stanford University

Participate in Stanford courses, seminars, and webinars **online** and be part of the Stanford University spirit of innovation and openness. Our online engineering courses reflect the exciting research and world-class teaching of Stanford faculty from the School of Engineering.

Engineering Courses Leadership & Management Courses Why Stanford? Free Content

**Earn world-class credentials.**

Through the Stanford Center for Professional Development, you may take online individual graduate and professional courses in engineering and related fields. Graduate courses may also be audited. Earn a graduate or professional certificate or a master of science degree in engineering part-time, at a pace that works for you. Listed here are some areas in which you may take online courses and earn a certificate or an engineering degree:

**Computer Science and Information Technology**

- Computer Science MS Degree
- Advanced Computer Security Professional Certificate
- Advanced Software Systems Graduate Certificate
- Artificial Intelligence Graduate Certificate

**Request Information**

First Name

Last Name

Email

SUBMIT

f t in You G+

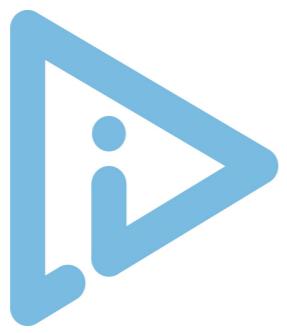
**Student Spotlight**



"The coursework and lessons learned at Stanford have enabled me to work more closely with customers and be on the forefront of product development."

60k impressions  
| 3 countries

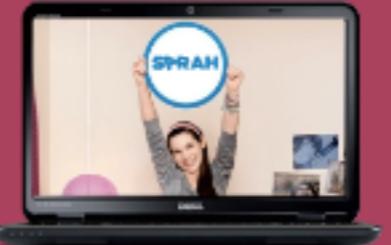
# **Result I:Advertising Opt Out Usage (U.S.)**



**AdChoices**

**Inspiron™ 15R**

It helps me email, study, chat, flirt, and focus all at once



**DELL**

**intel inside®**  
**CORE™ i7**

Select Dell systems are available with 2nd generation Intel® Core™ i7 processors

[Shop Now >](#)



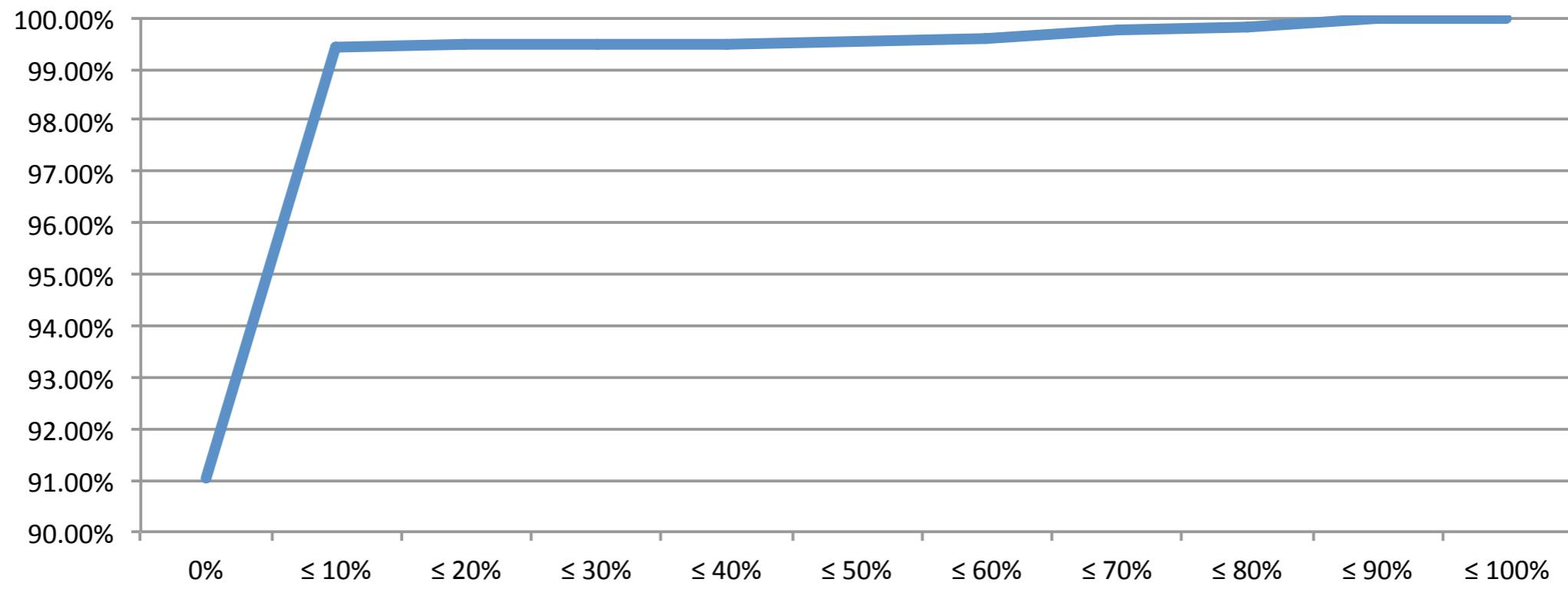
The screenshot shows a web browser window with the title "Opt Out From Online Behavioral Advertising By Participating Companies (BETA)". The URL in the address bar is "www.aboutads.info/choices/#completed". The page content includes a navigation menu with links like Home, The Principles, For Consumers, For Companies, List of Participants, Resources, News, Enforcement, and Contact. A main text area welcomes users to the consumer opt-out page for the Self-Regulatory Program for Online Behavioral Advertising. It explains that ads are customized based on interests from visits across sites and that this is achieved through browser cookies. It also mentions that advertising helps support free content and products online. Below this, a section titled "Using the tools on this page, you can opt out from receiving interest-based advertising from some or all of our participating companies." provides a list of steps:

- Find out which participating companies have currently enabled customized ads for your browser;
- See all the participating companies on this site and learn more about their advertising and privacy practices;
- Check whether you've already opted out from participating companies;
- Opt out of browser-enabled interest-based advertising by some or all participating companies, using [opt-out cookies](#) to store your preferences in your browser; or
- Use the "Choose All Companies" feature to opt out from all currently participating companies in one step. [GO](#)

On the left, a yellow callout box highlights "All Participating Companies (114)". On the right, there are four links: "Help with the Opt Out Page", "How Interest-based Ads Work", "Feedback on This Site", and "Protect My Choices". At the bottom, there are three sections: "All Participating Companies (114)", "Companies Customizing Ads For Your Browser (23)", and "Existing Opt Outs (0)". The "All Participating Companies" section lists company names: 24/7 Media and 33Across.

Queried ≈ 175 advertising status mechanisms

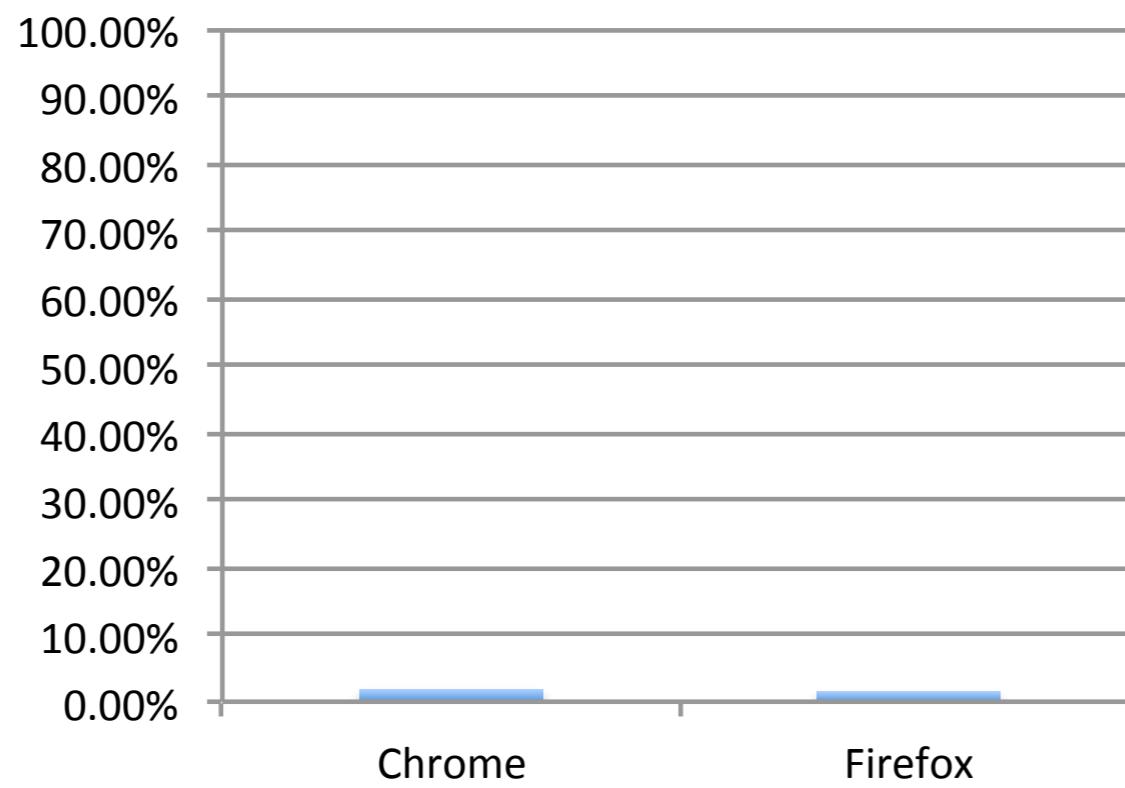
## Cumulative Share of Browsers by Proportion of Opt Outs



**Q: revealed preference or usability?**

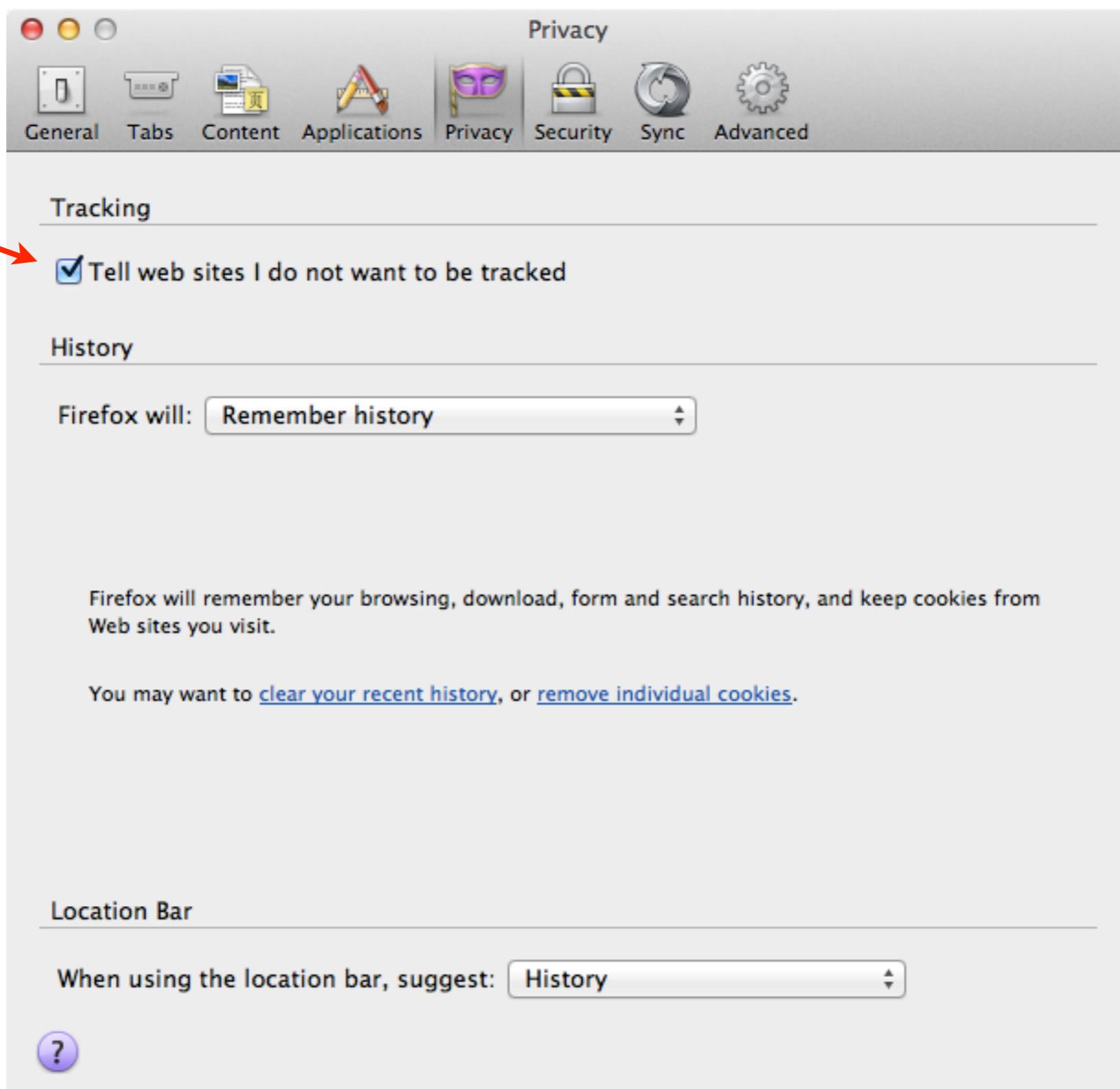
## **Result 2: Third-Party Cookie Blocking (U.S.)**

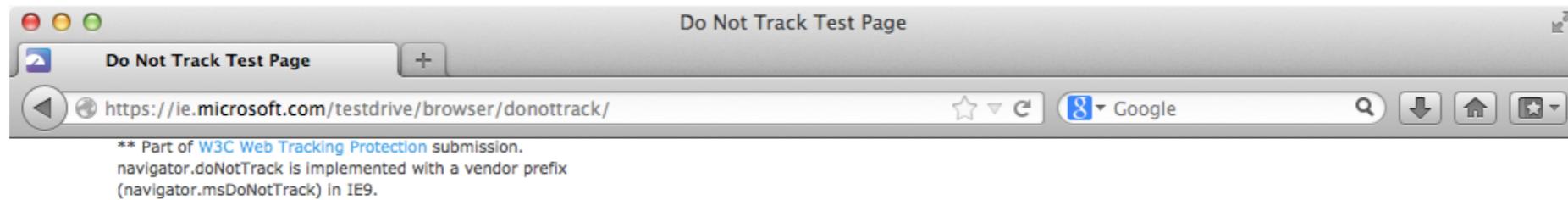
## Third-Party Cookie Blocking



Supports the usability hypothesis

## **Result 3: Do Not Track (U.S.)**





## Technical Details

The DOM properties and methods below can be tested from Javascript, for example:

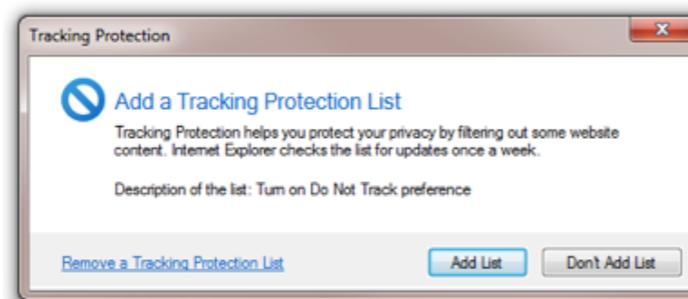
```
var tpEnabled = window.external.msTrackingProtectionEnabled();
```

The DNT HTTP header requires a small bit of server code in order to be accessible from script:

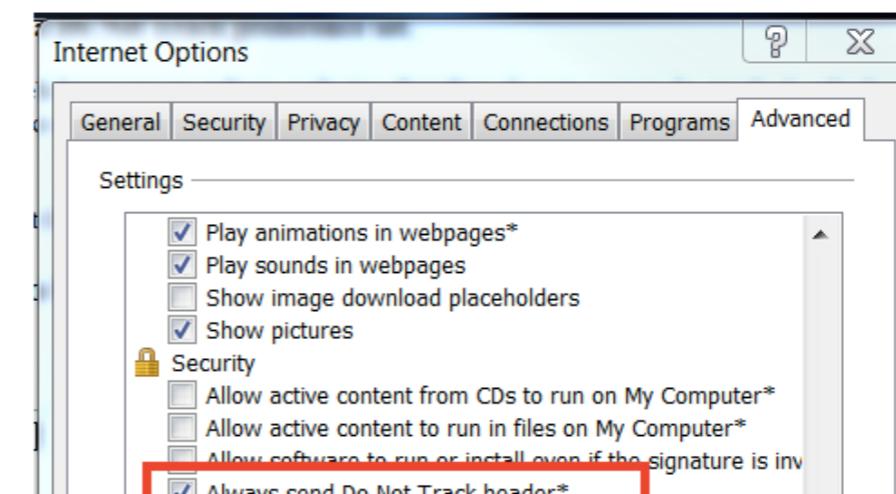
```
var dntValue = "<%= Request.ServerVariables["HTTP_DNT"] %>";
```

**To express your preference not to be tracked in IE9** **To express your preference not to be tracked in IE10** **To**  
**For**

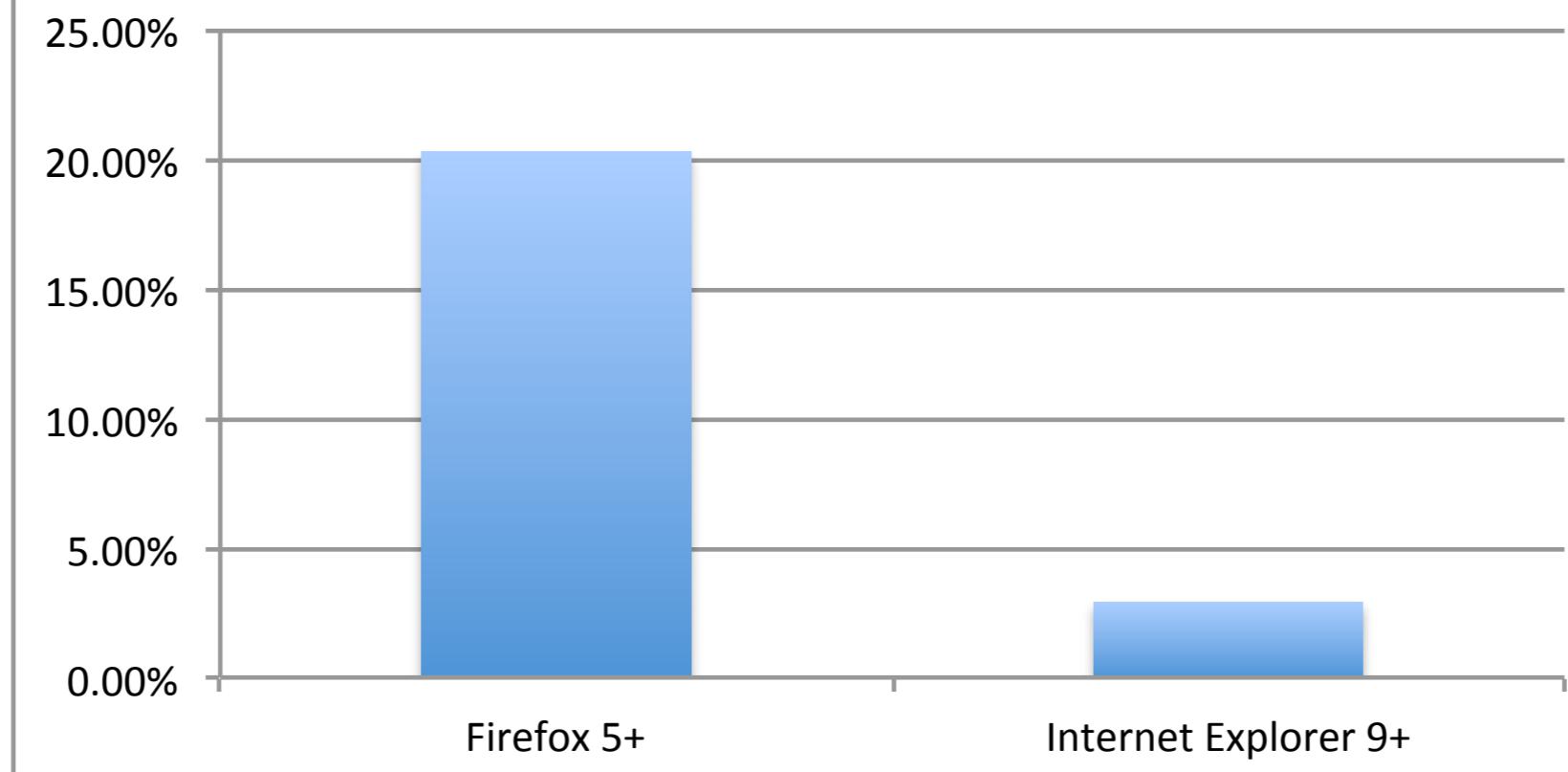
1. [Click here to add an empty Tracking Protection list](#)
2. When prompted, click the "Add List" button:

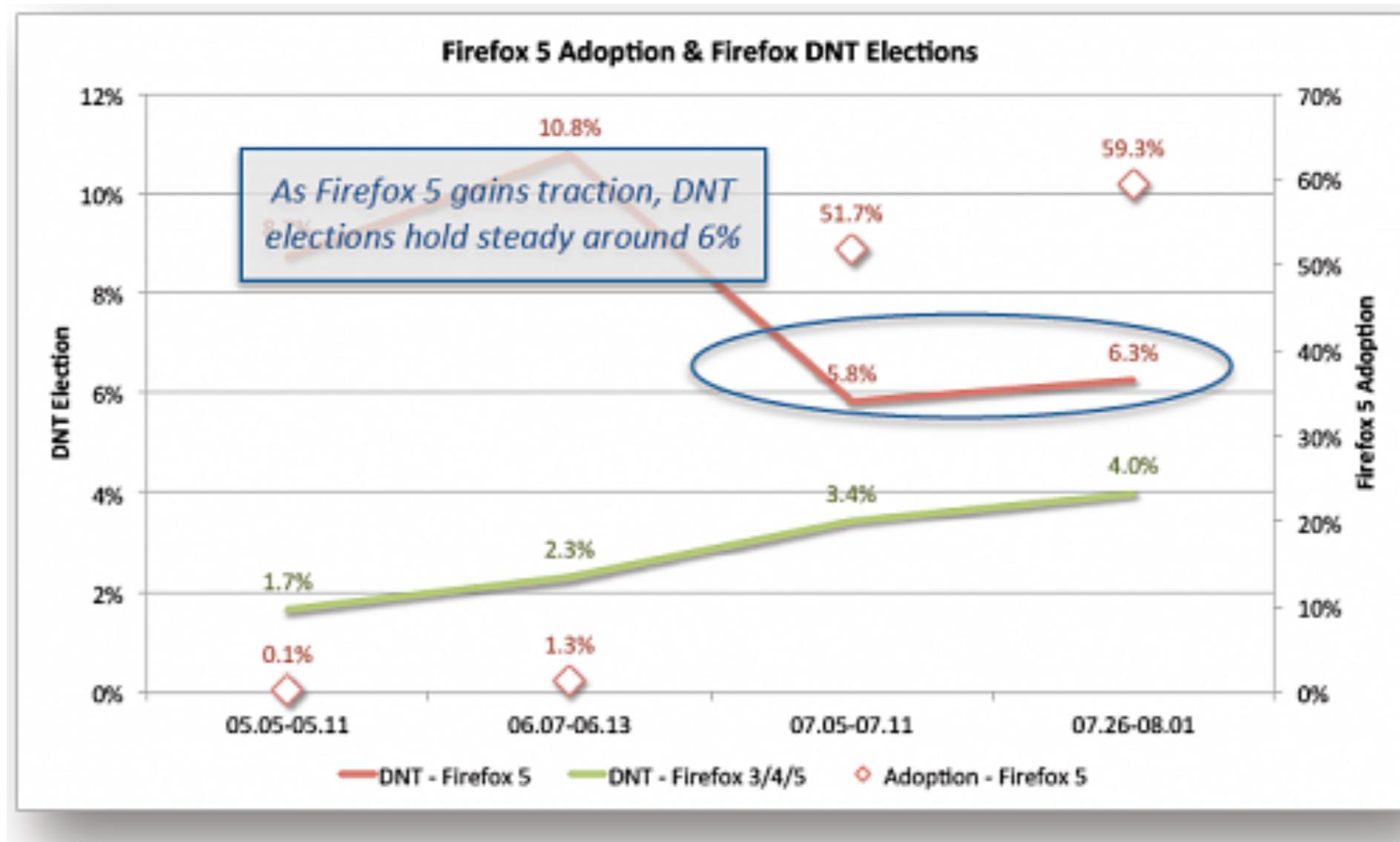


1. This preference is set by default for you in IE10
2. You can check by going to the Advanced tab under Internet Options and making sure the "Always send Do Not Track header" option is set



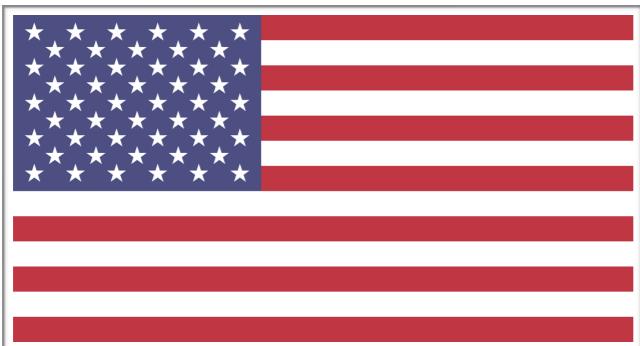
## Do Not Track





Supports the usability hypothesis

History and Status Quo  
Tracking Methods  
Signaling Mechanisms  
Technical Countermeasures  
**Government Intervention**  
Privacy-Preserving Advertising



- FTC enforcement
- FTC proposal
- White House proposal
- Pending legislation



- Draft legislation

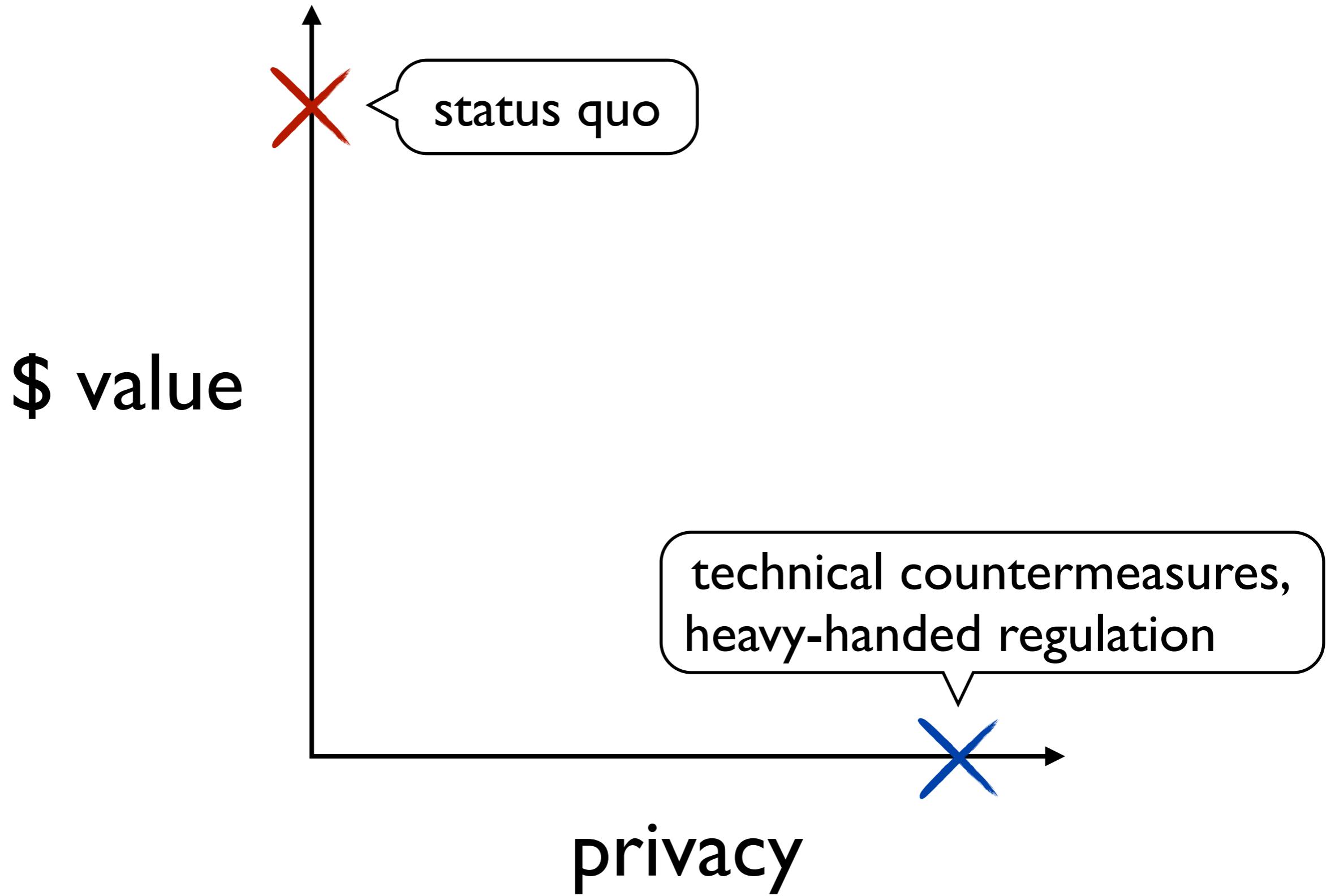


- ePrivacy Directive
- Article 29 Working Party opinions
- Pending legislation

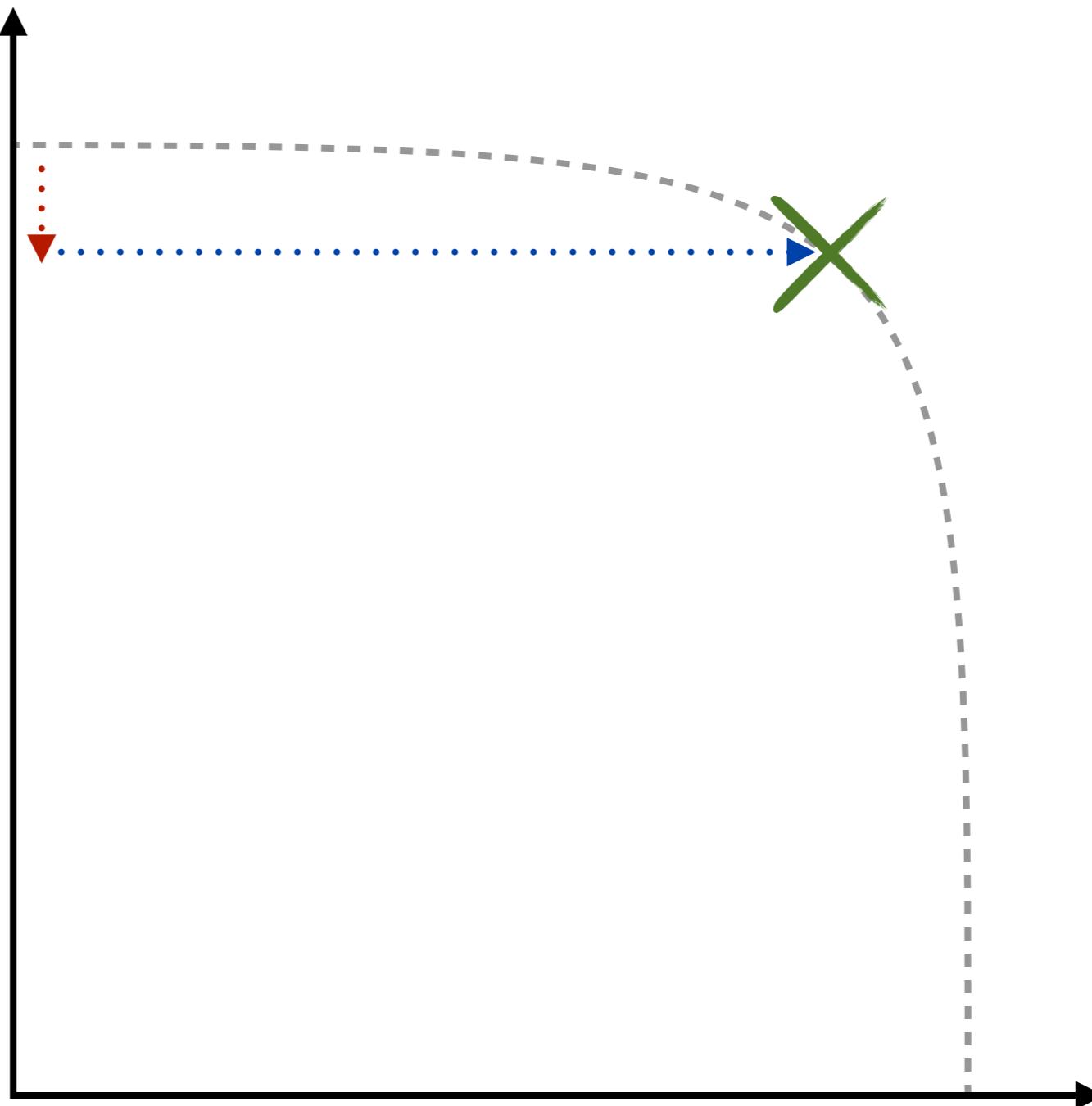


- PIPEDA

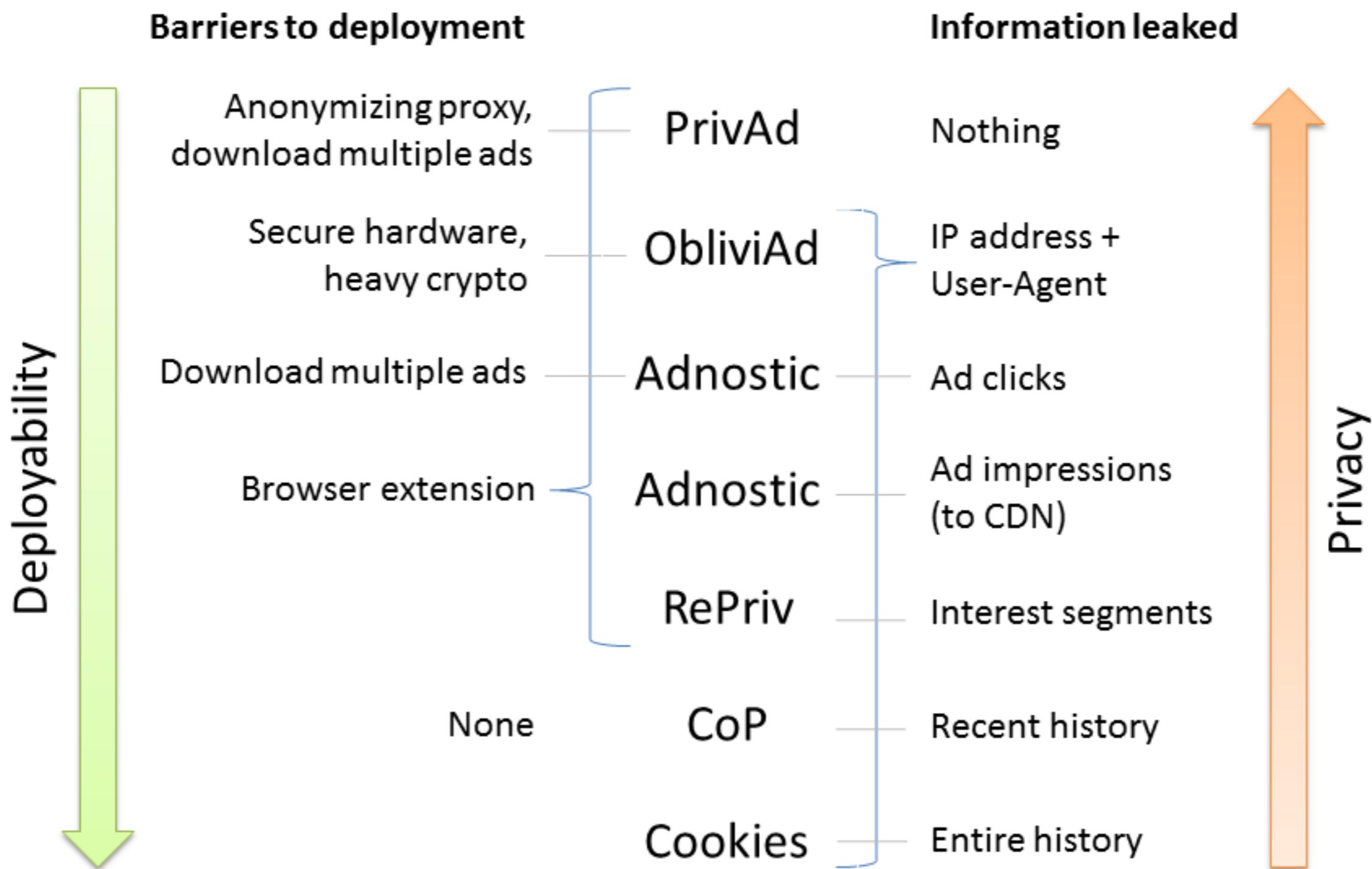
History and Status Quo  
Tracking Methods  
Signaling Mechanisms  
Technical Countermeasures  
Government Intervention  
**Privacy-Preserving Advertising**



\$ value



privacy



engineering conventions

information asymmetries

implementation and switching costs

diminished private utility

inability to internalize

competition barriers

**regulatory responses?**

History and Status Quo  
Signaling Mechanisms  
Technical Countermeasures  
Government Intervention  
Privacy-Preserving Advertising

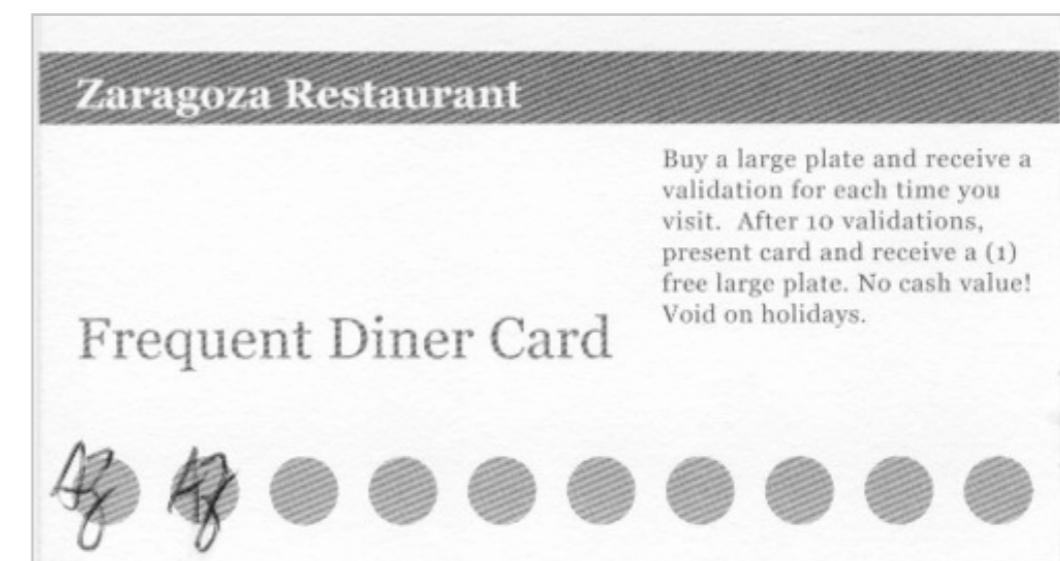
# Questions?

[jmayer@stanford.edu](mailto:jmayer@stanford.edu)  
[stanford.edu/~jmayer](http://stanford.edu/~jmayer)



# Tracking Not Required

## Privacy-Preserving Third-Party Web Services



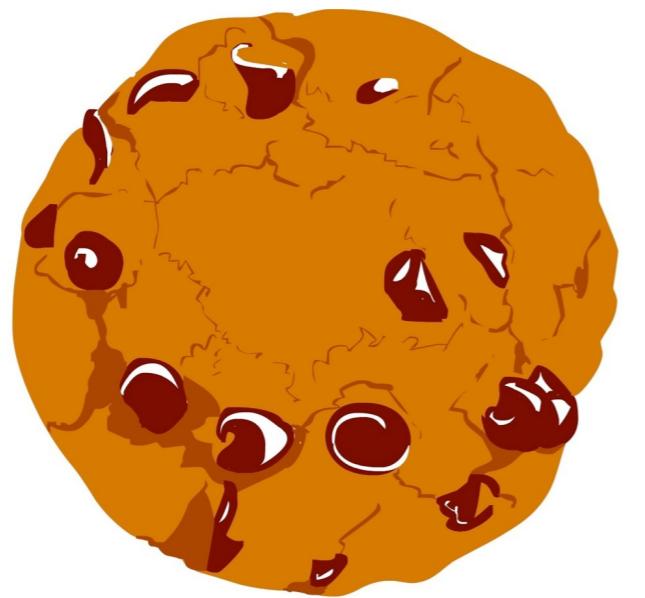


**Tell me about yourself...**



**Do you come here often?**

# I. client-side storage

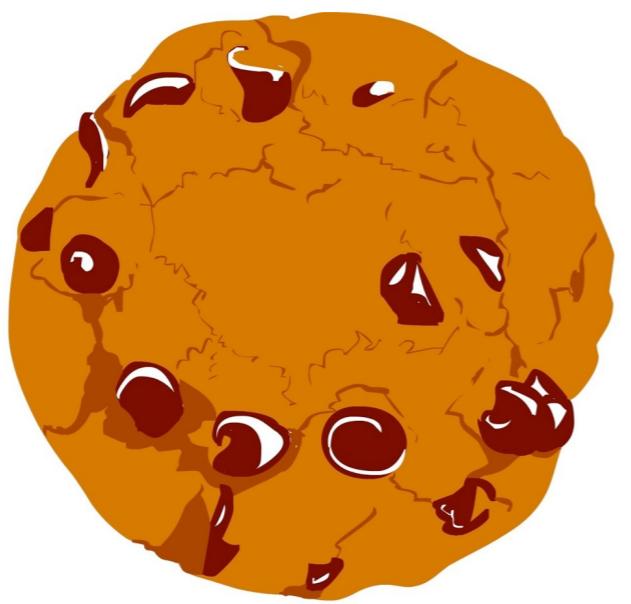


$\approx$  4 KB

**HTML**

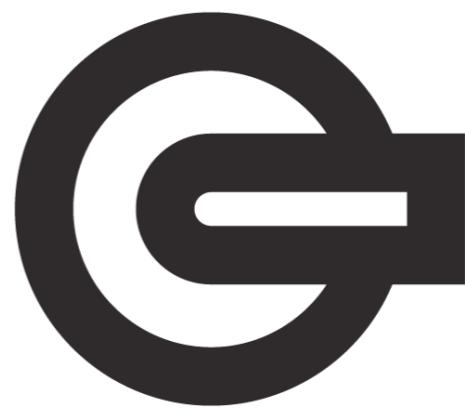


> 5 MB



**(but domains, paths)**

**HTML**



## 2. client-side logic

# JavaScript

# 3. server-side preprocessing

any web platform

**example:  
advertisement frequency capping**

**today: ID cookies**

**step I: client-side storage**

| <u>Campaign</u>      | <u>Count</u> | <u>Last</u> |
|----------------------|--------------|-------------|
| CarCo                | 1            | today       |
| Toothpaste Unlimited | 4            | yesterday   |
| ...                  | ...          | ...         |

“tell me everything”

(gets unique very quickly)

**step 2: client-side secrecy**

| <u>Campaign</u>      | <u>Count</u> | <u>Last</u> |
|----------------------|--------------|-------------|
| CarCo                | 1            | today       |
| Toothpaste Unlimited | 4            | yesterday   |
| ...                  | ...          | ...         |

“tell me about impressions”

**step 3: server-side preprocessing**

| <u>Campaign</u>      | <u>Count</u> | <u>Last</u> |
|----------------------|--------------|-------------|
| CarCo                | 1            | today       |
| Toothpaste Unlimited | 4            | yesterday   |
| ...                  | ...          | ...         |

“tell me about impressions for these ads”

**step 4: client-side logic**

Campaign

CarCo

Toothpaste Unlimited

Cap

|

5

+

Campaign

CarCo

Toothpaste Unlimited

Count

|

4

Last

today

yesterday

...

...

...

=

Campaign

CarCo

Toothpaste Unlimited

Capped

yes

no

**“tell me whether these ads are capped”**

**step 5: client-side logic**

| <u>Campaign</u>      | <u>Cap</u> | <u>Preference</u> |
|----------------------|------------|-------------------|
| CarCo                | 1          | 1                 |
| Toothpaste Unlimited | 5          | 2                 |

+

| <u>Campaign</u>      | <u>Count</u> | <u>Last</u> |
|----------------------|--------------|-------------|
| CarCo                | 1            | today       |
| Toothpaste Unlimited | 4            | yesterday   |
| ...                  | ...          | ...         |

=

| <u>Campaign</u>      |
|----------------------|
| Toothpaste Unlimited |

**“tell me my most preferred uncapped ad”**

**state space = # of candidate campaigns**

## Website

- list of preference-ranked ads
- arbitrary data

## Browser

arbitrary computation

- list of ads to display

- frequency capping
- frequency targeting
- behavioral targeting
- retargeting

**example:  
advertising conversion measurement**

Campaign

Origin

Time

CarCo

news.com

this week

Toothpaste Unlimited

sports.com

last week

...

...

...

**social sharing widget personalization**

URL

[http://gothamnews.com/batman\\_strikes\\_again](http://gothamnews.com/batman_strikes_again)

Friend

Bruce

...

...

+

Friend

Alfred

Photo



Bruce



...