Introduction

CS-576 Systems Security

Instructor: Georgios Portokalidis

Fall 2018

Overview

A (very short) introduction to systems security

General information

Overview

A (very short) introduction to systems security

General information

Systems Security

Systems

A system is a set of connecting things or parts forming a complex whole

- Definition from the *New Oxford American Dictionary*

Unnaturally occurring systems:

Computer system

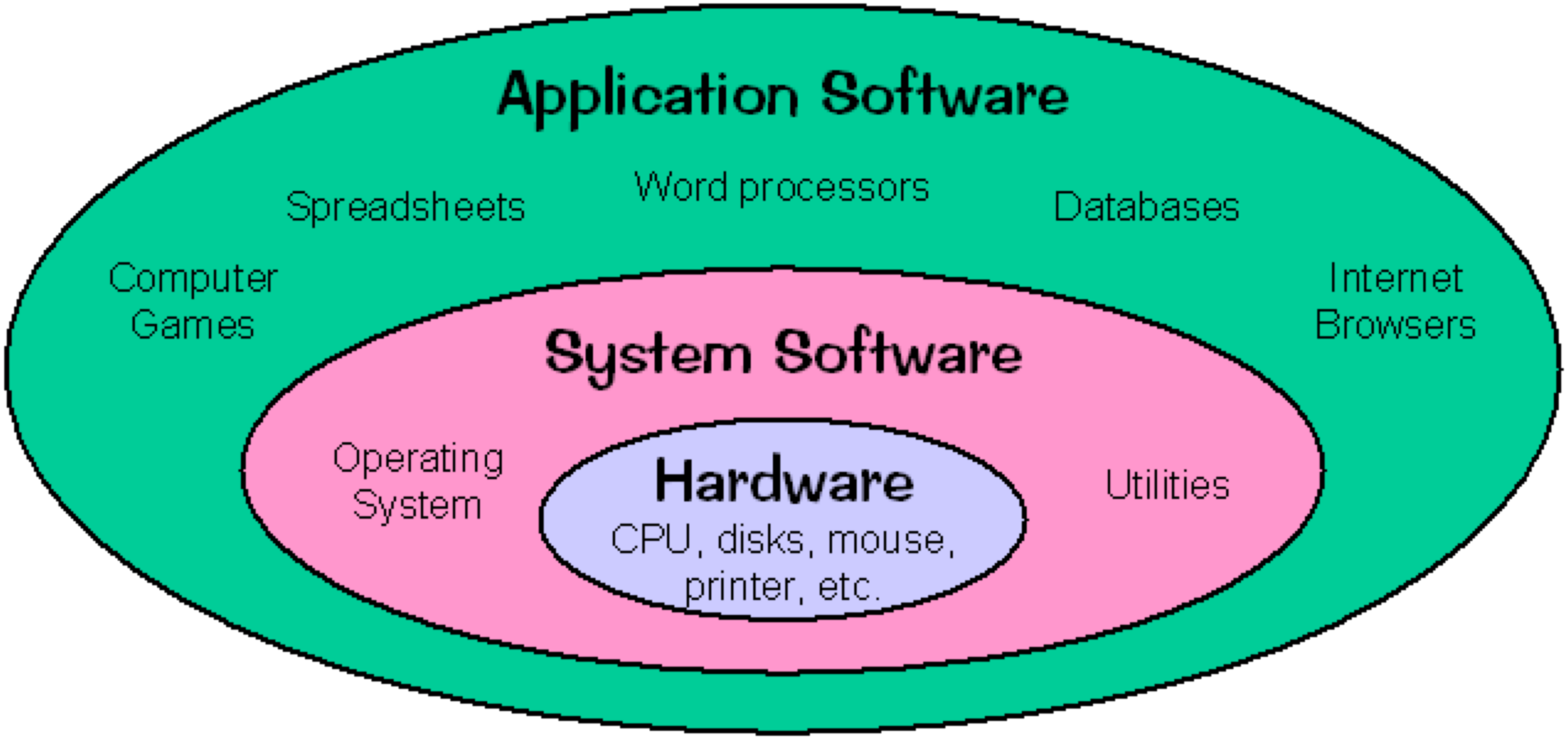
- The complete computer made up of the CPU, memory and related electronics (main cabinet), all the peripheral devices connected to it and its operating system

Operating system

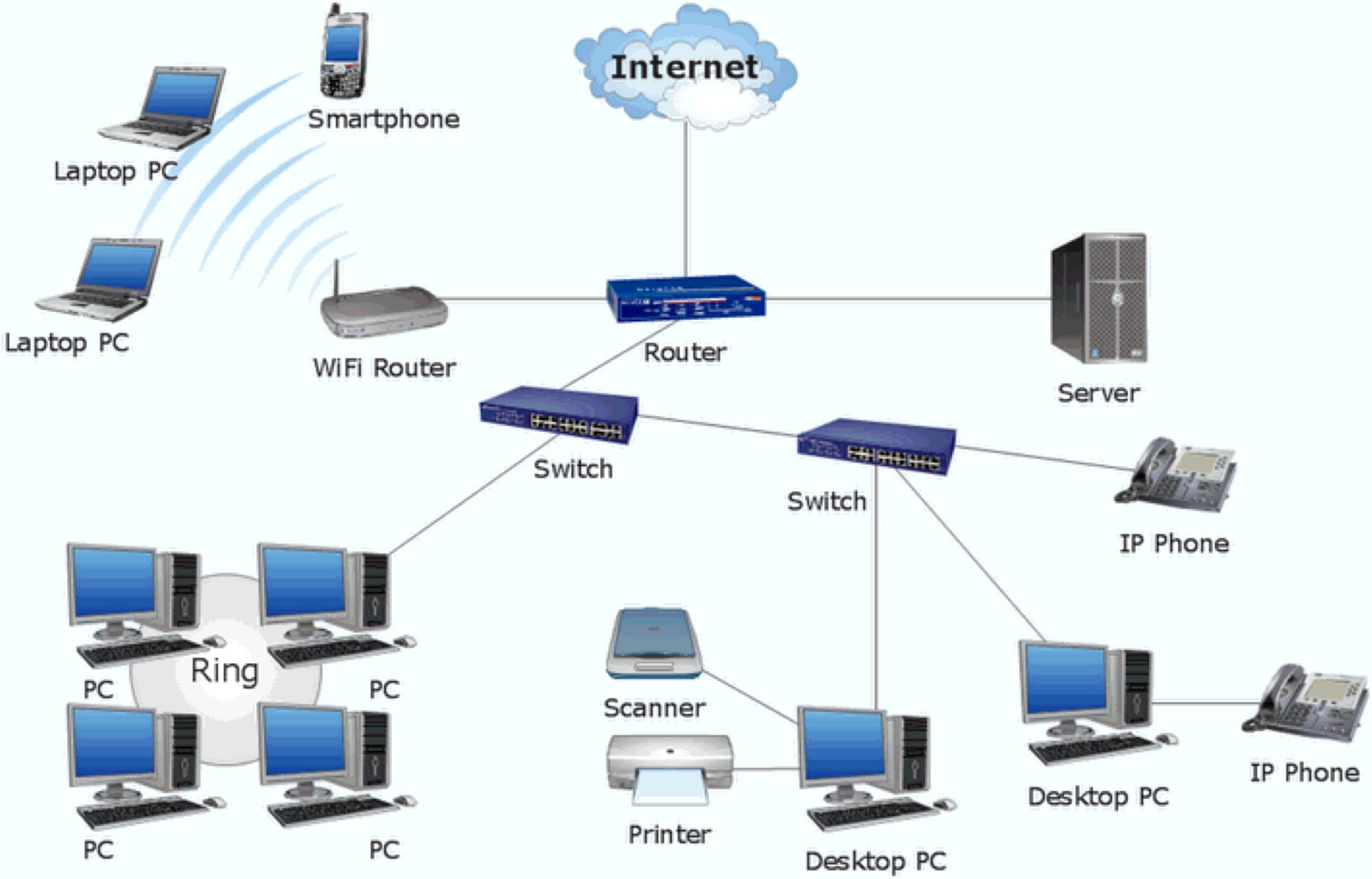
- A software system that manages computer hardware and software resources and provides common services for computer programs

Distributed system

- A software system in which components located on networked computers communicate and coordinate their actions by passing messages



Computer Systems



(Inter-)Networked Systems

Security -- The CIA Triad

Confidentiality

- Data confidentiality
- Privacy

Integrity

- Data integrity
- System integrity

Availability

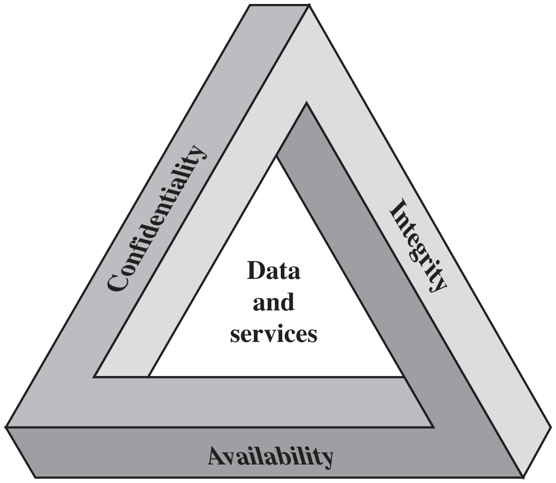


Figure 1.1 The Security Requirements Triad

Building Secure Systems

What are the right principles to design and develop **secure** systems

Building Secure Systems

What are the right principles to design and develop **secure** systems

- Economy of Mechanism
- Open Design Open Design
- Principle of Least Privilege
- Separation of Privilege
- Failsafe Defaults
- Psychological Acceptability
- Additional principles
  - Diversity of Mechanism
  - Multiple Lines of Defense

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- Additional principles
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  - Multiple Lines of Defense

Not the focus of this course!

Focus on Existing Systems

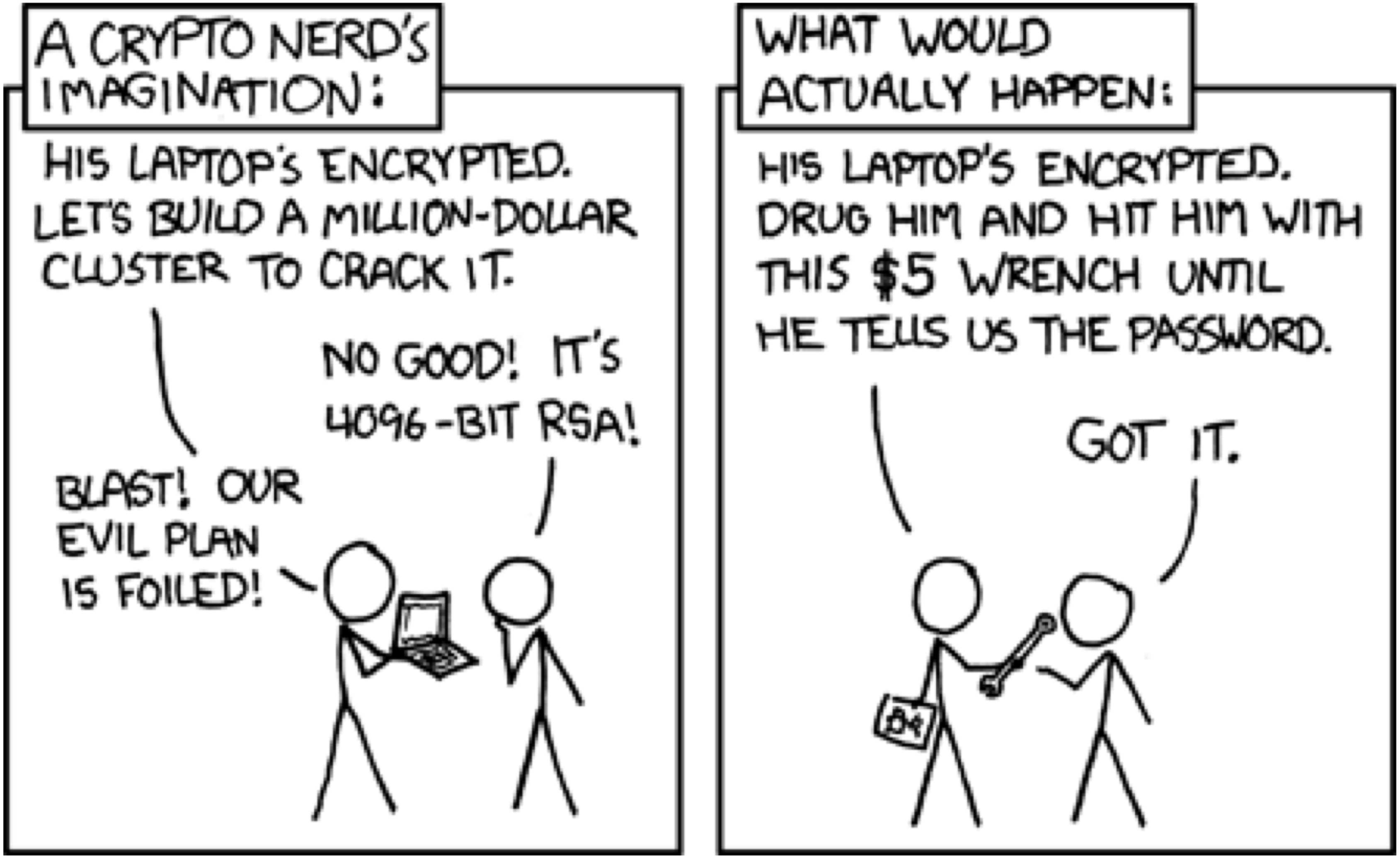
It is important to understand how a system works

- What is the execution environment
- What are the programming languages used
- How do applications interact with the OS
- How does the OS interact with the HW
- How do applications interact with the HW
- How do applications interact with other applications
  - Locally
  - Over the network

What are the security threats facing a system?

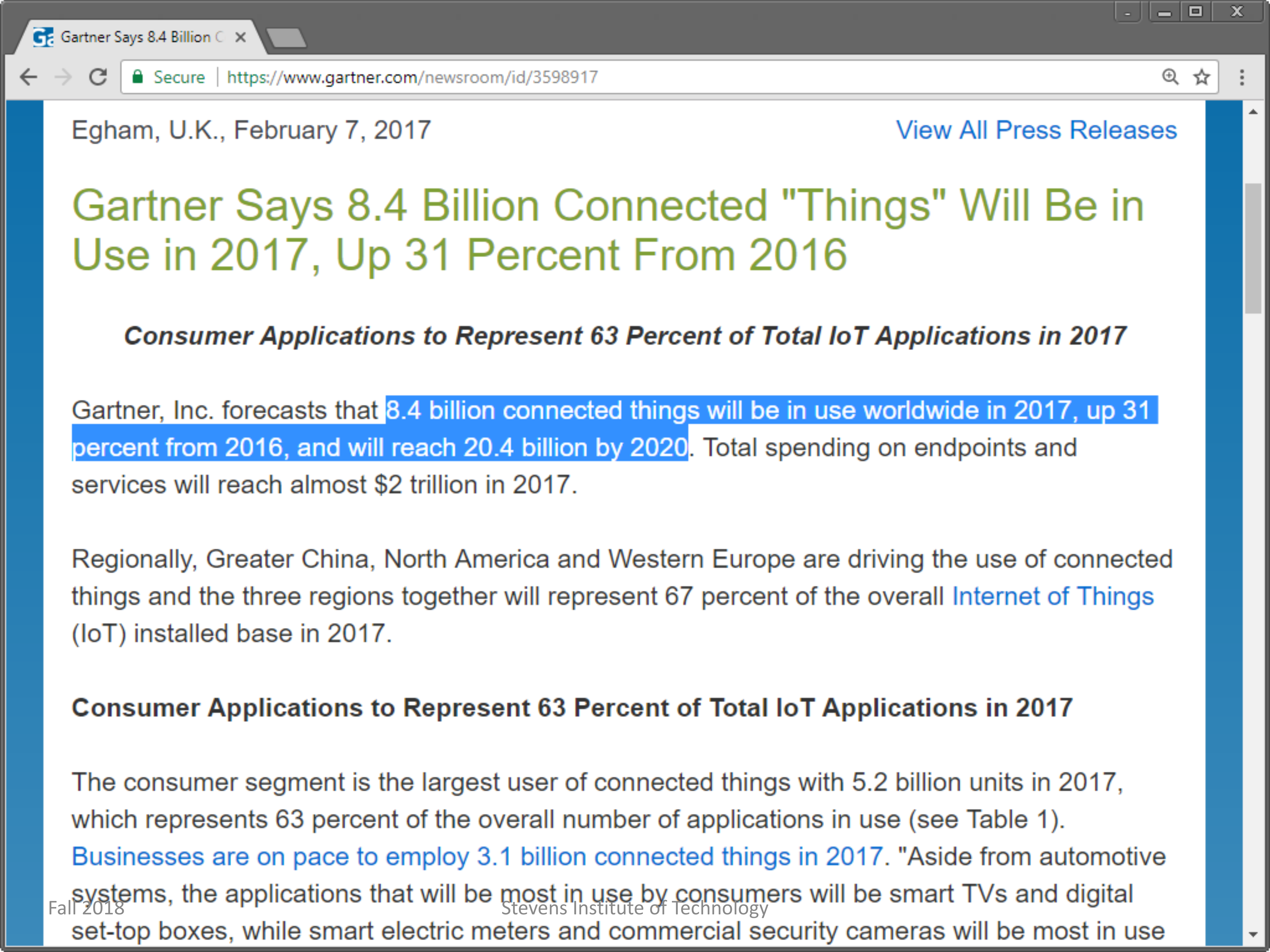
- How can they be mitigated?

Not just understanding abstractions, but also **mechanisms** https://xkcd.com/538/


A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.

Different approach from crypto

Is it important?


Gartner Says 8.4 Billion C
Secure
https://www.gartner.com/newsroom/id/3598917

Egham, U.K., February 7, 2017

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Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016

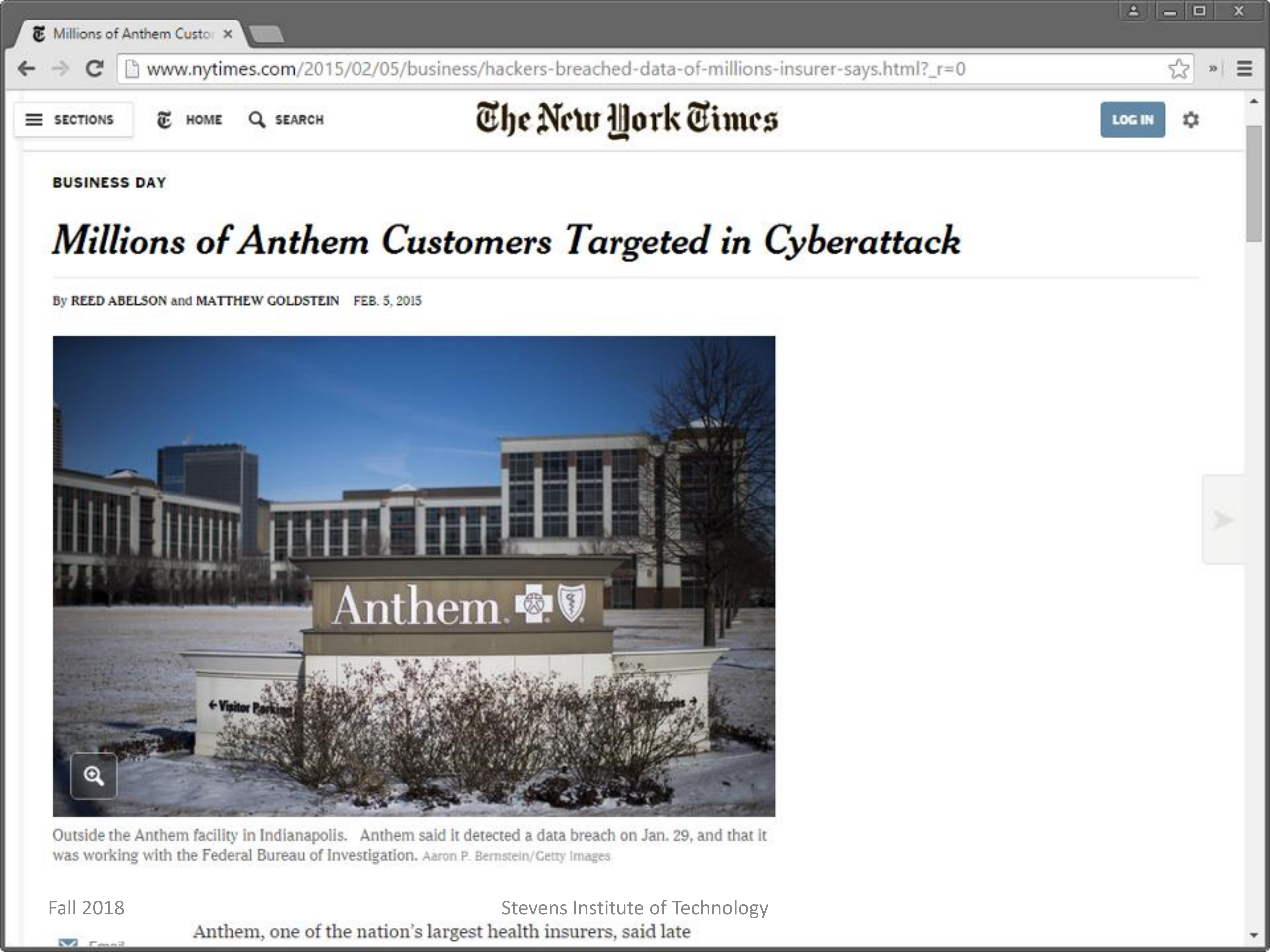
Consumer Applications to Represent 63 Percent of Total IoT Applications in 2017

Gartner, Inc. forecasts that 8.4 billion connected things will be in use worldwide in 2017, up 31 percent from 2016, and will reach 20.4 billion by 2020. Total spending on endpoints and services will reach almost $2 trillion in 2017.

Regionally, Greater China, North America and Western Europe are driving the use of connected things and the three regions together will represent 67 percent of the overall Internet of Things (IoT) installed base in 2017.

Consumer Applications to Represent 63 Percent of Total IoT Applications in 2017

The consumer segment is the largest user of connected things with 5.2 billion units in 2017, which represents 63 percent of the overall number of applications in use (see Table 1). Businesses are on pace to employ 3.1 billion connected things in 2017. "Aside from automotive systems, the applications that will be most in use by consumers will be smart TVs and digital set-top boxes, while smart electric meters and commercial security cameras will be most in use


Millions of Anthem Custo
www.nytimes.com/2015/02/05/business/hackers-breached-data-of-millions-insurer-says.html?_r=0
SECTIONS
HOME
SEARCH
The New York Times
LOG IN
Anthem.
← Visitor Parking

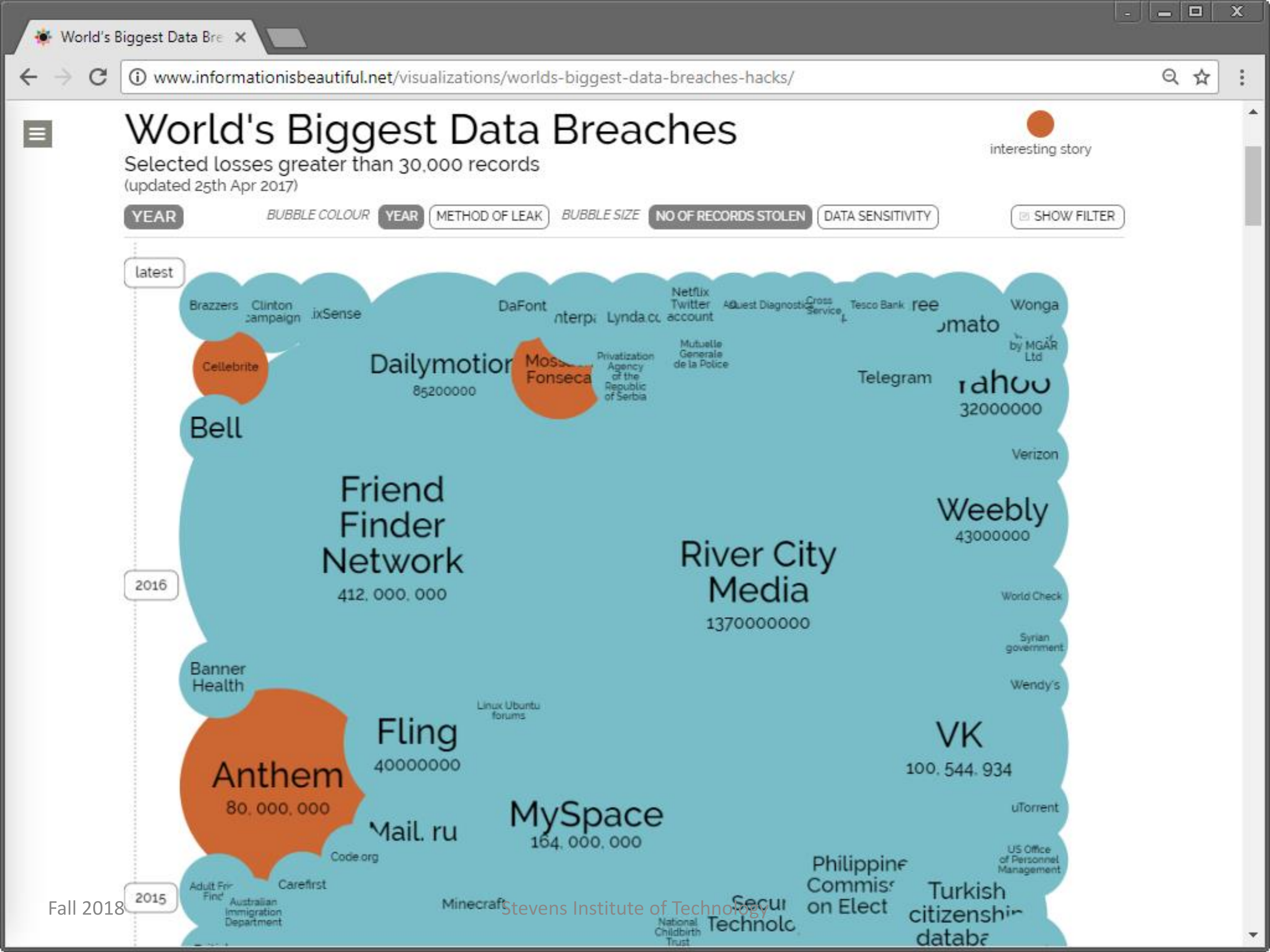
BUSINESS DAY

Millions of Anthem Customers Targeted in Cyberattack

By REED ABELSON and MATTHEW GOLDSTEIN FEB. 5, 2015

Outside the Anthem facility in Indianapolis. Anthem said it detected a data breach on Jan. 29, and that it was working with the Federal Bureau of Investigation. Aaron P. Bernstein/Getty Images

Anthem, one of the nation's largest health insurers, said late

World's Biggest Data Bre
www.informationisbeautiful.net/visualizations/worlds-biggest-data-breaches-hacks/
World's Biggest Data Breaches
Selected losses greater than 30,000 records
(updated 25th Apr 2017)
interesting story
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BUBBLE COLOUR
YEAR
METHOD OF LEAK
BUBBLE SIZE
NO OF RECORDS STOLEN
DATA SENSITIVITY
SHOW FILTER
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2016
2015
Brazzers
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Privatization Agency of the Republic of Serbia
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Telegram
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32000000
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Verizon
Friend Finder Network
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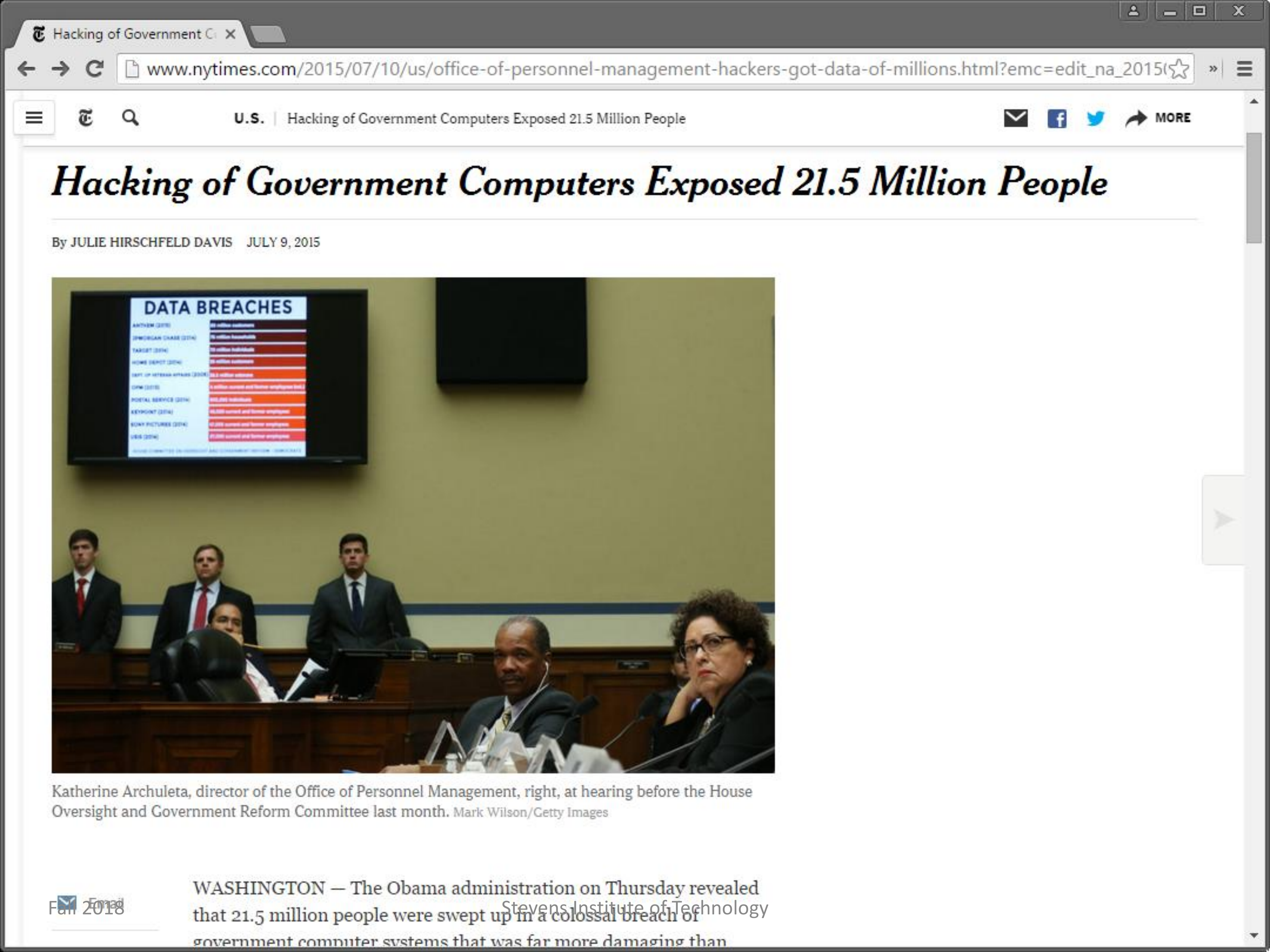
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Hacking of Government Computers Exposed 21.5 Million People
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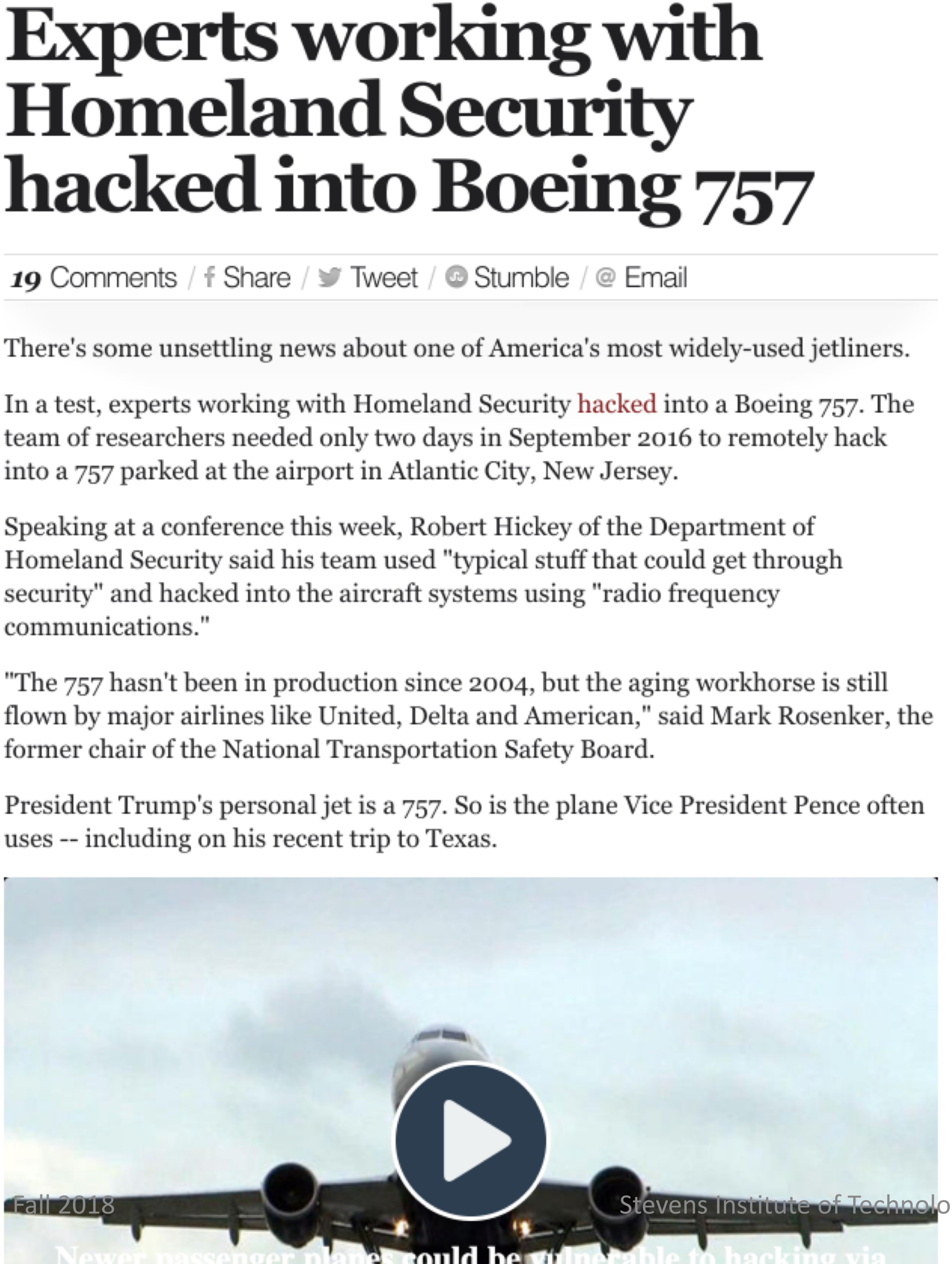
Hacking of Government Computers Exposed 21.5 Million People

By JULIE HIRSCHFELD DAVIS JULY 9, 2015

Katherine Archuleta, director of the Office of Personnel Management, right, at hearing before the House Oversight and Government Reform Committee last month. Mark Wilson/Getty Images

WASHINGTON — The Obama administration on Thursday revealed that 21.5 million people were swept up in a colossal breach of government computer systems that was far more damaging than



Experts working with Homeland Security hacked into Boeing 757

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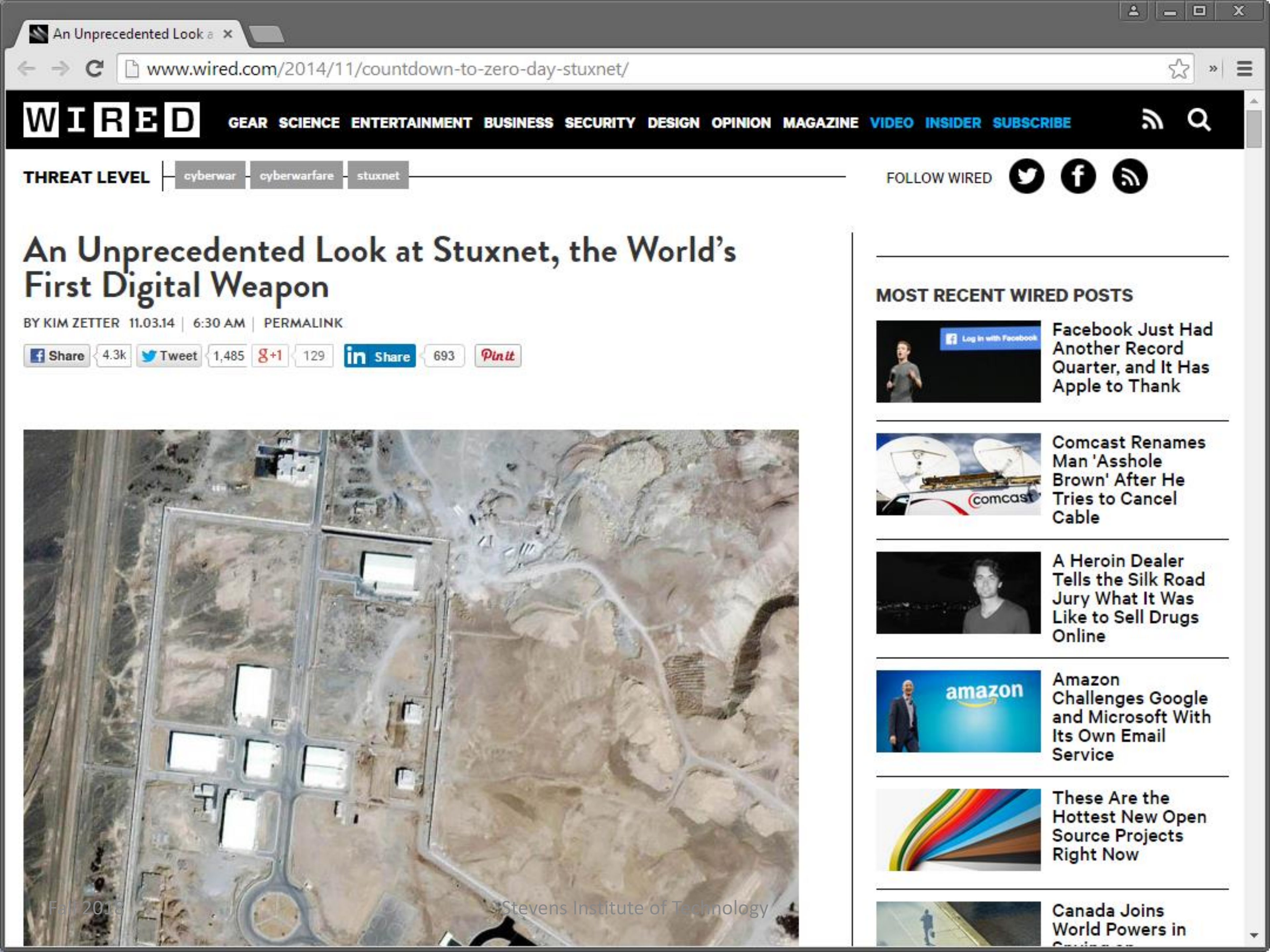
There's some unsettling news about one of America's most widely-used jetliners.

In a test, experts working with Homeland Security hacked into a Boeing 757. The team of researchers needed only two days in September 2016 to remotely hack into a 757 parked at the airport in Atlantic City, New Jersey.

Speaking at a conference this week, Robert Hickey of the Department of Homeland Security said his team used "typical stuff that could get through security" and hacked into the aircraft systems using "radio frequency communications."

"The 757 hasn't been in production since 2004, but the aging workhorse is still flown by major airlines like United, Delta and American," said Mark Rosenker, the former chair of the National Transportation Safety Board.

President Trump's personal jet is a 757. So is the plane Vice President Pence often uses -- including on his recent trip to Texas.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BY KIM ZETTER 11.03.14 | 6:30 AM | PERMALINK

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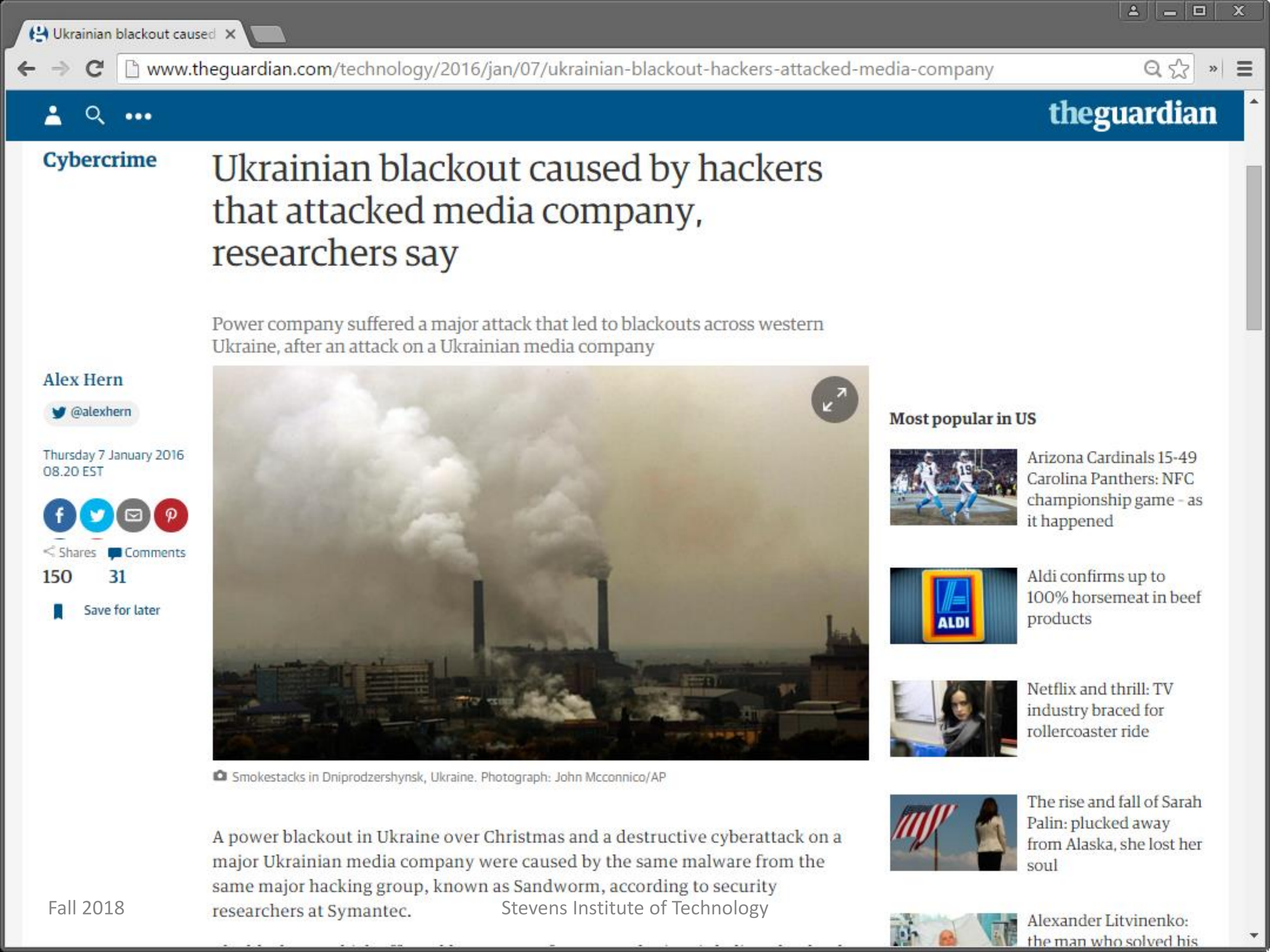

Ukrainian blackout caused
www.theguardian.com/technology/2016/jan/07/ukrainian-blackout-hackers-attacked-media-company
theguardian

Cybercrime

Ukrainian blackout caused by hackers that attacked media company, researchers say

Power company suffered a major attack that led to blackouts across western Ukraine, after an attack on a Ukrainian media company

Alex Hern

@alexhern

Thursday 7 January 2016
08.20 EST

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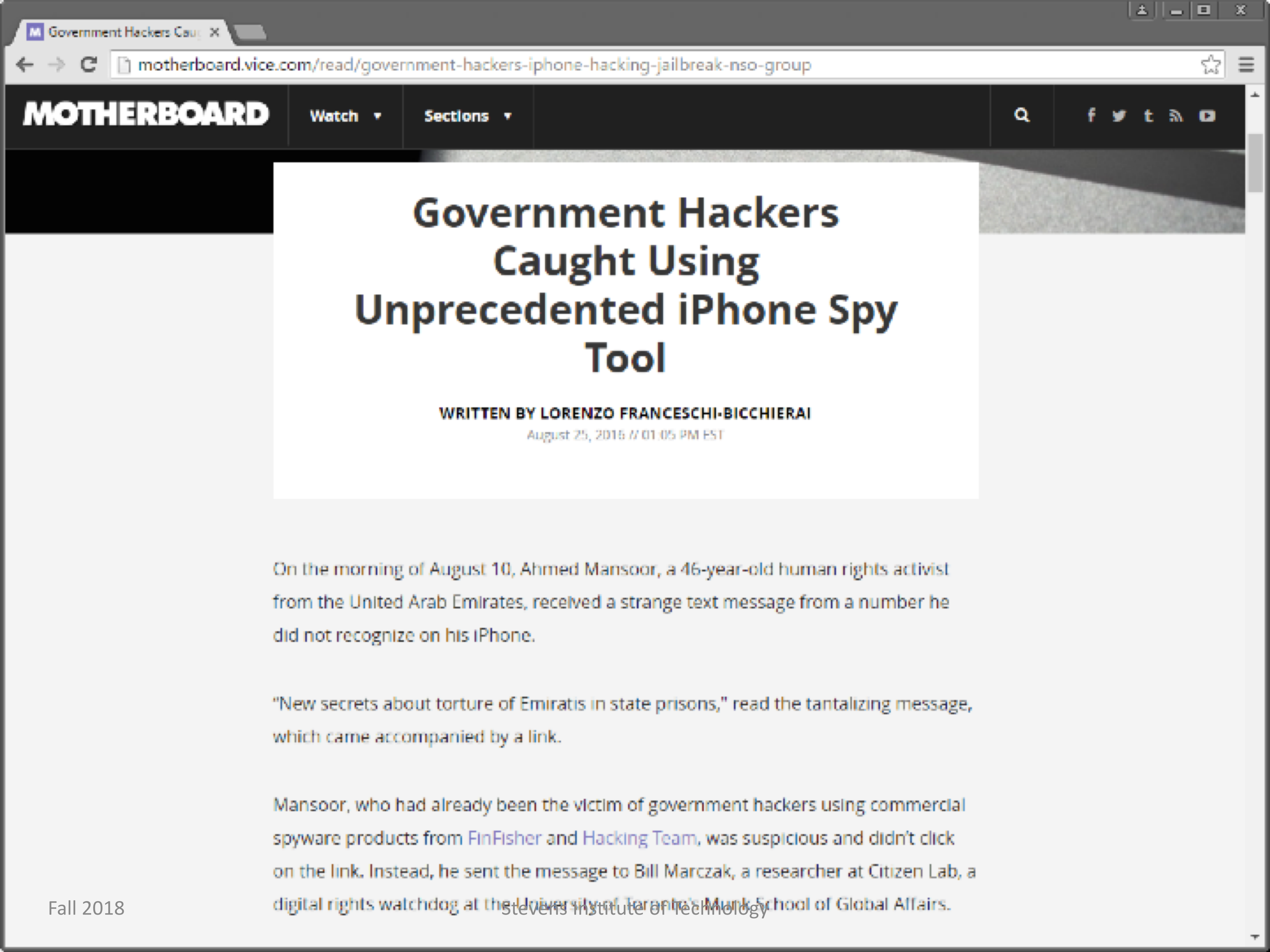
Smokestacks in Dniprodzershynsk, Ukraine. Photograph: John Mcconnico/AP

A power blackout in Ukraine over Christmas and a destructive cyberattack on a major Ukrainian media company were caused by the same malware from the same major hacking group, known as Sandworm, according to security researchers at Symantec.



Government Hackers Cau
motherboard.vice.com/read/government-hackers-iphone-hacking-jailbreak-nso-group
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Government Hackers Caught Using Unprecedented iPhone Spy Tool

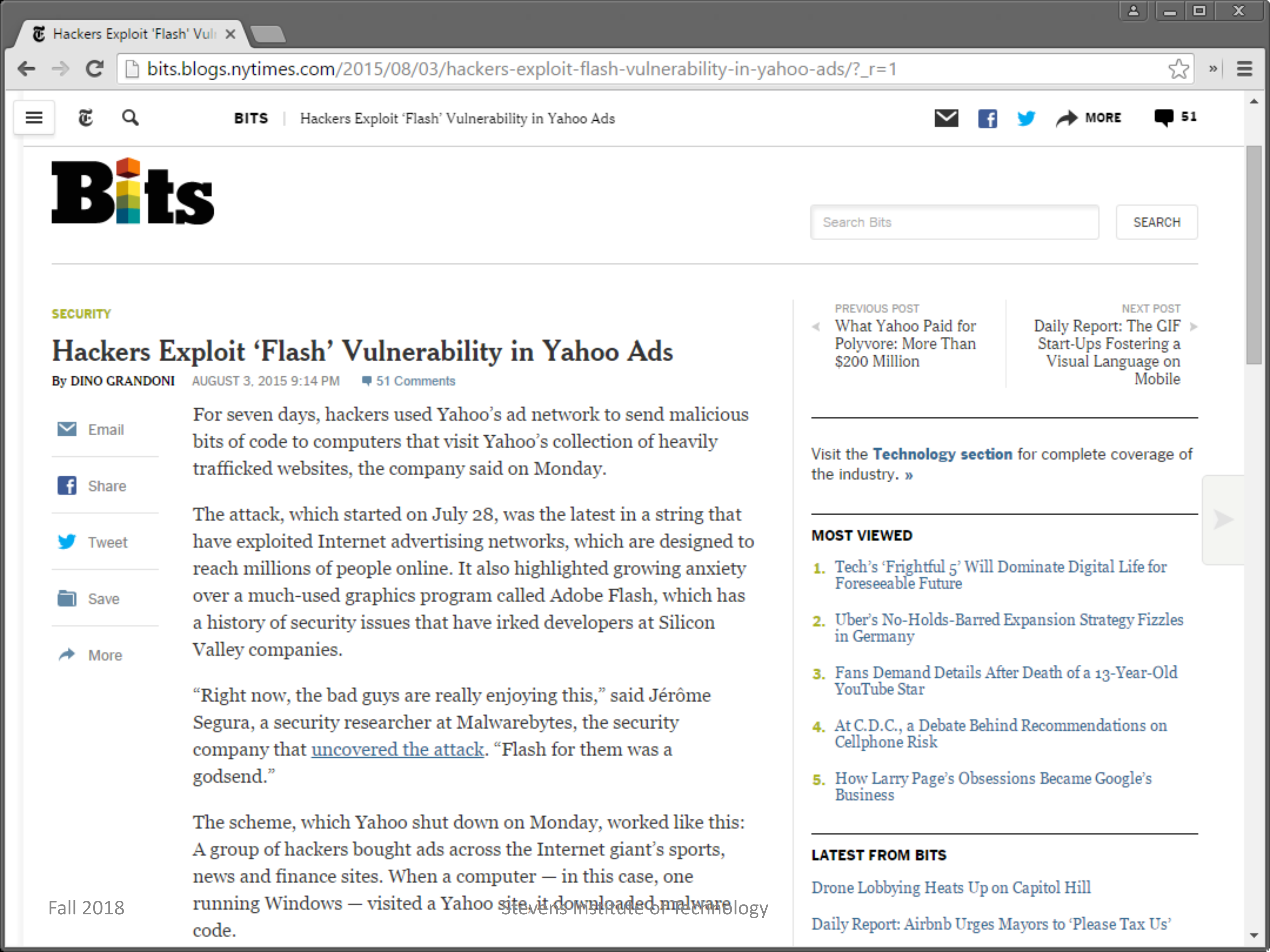
WRITTEN BY LORENZO FRANCESCHI-BICCHIERAI

August 25, 2016 // 01:05 PM EST

On the morning of August 10, Ahmed Mansoor, a 46-year-old human rights activist from the United Arab Emirates, received a strange text message from a number he did not recognize on his iPhone.

"New secrets about torture of Emiratis in state prisons," read the tantalizing message, which came accompanied by a link.

Mansoor, who had already been the victim of government hackers using commercial spyware products from FinFisher and Hacking Team, was suspicious and didn't click on the link. Instead, he sent the message to Bill Marczak, a researcher at Citizen Lab, a digital rights watchdog at the University of Toronto's Munk School of Global Affairs.


Hackers Exploit 'Flash' Vul
bits.blogs.nytimes.com/2015/08/03/hackers-exploit-flash-vulnerability-in-yahoo-ads/?_r=1
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SECURITY

Hackers Exploit 'Flash' Vulnerability in Yahoo Ads

By DINO GRANDONI AUGUST 3, 2015 9:14 PM 51 Comments

For seven days, hackers used Yahoo's ad network to send malicious bits of code to computers that visit Yahoo's collection of heavily trafficked websites, the company said on Monday.

The attack, which started on July 28, was the latest in a string that have exploited Internet advertising networks, which are designed to reach millions of people online. It also highlighted growing anxiety over a much-used graphics program called Adobe Flash, which has a history of security issues that have irked developers at Silicon Valley companies.

"Right now, the bad guys are really enjoying this," said Jérôme Segura, a security researcher at Malwarebytes, the security company that uncovered the attack. "Flash for them was a godsend."

The scheme, which Yahoo shut down on Monday, worked like this: A group of hackers bought ads across the Internet giant's sports, news and finance sites. When a computer — in this case, one running Windows — visited a Yahoo site, it downloaded malware code.

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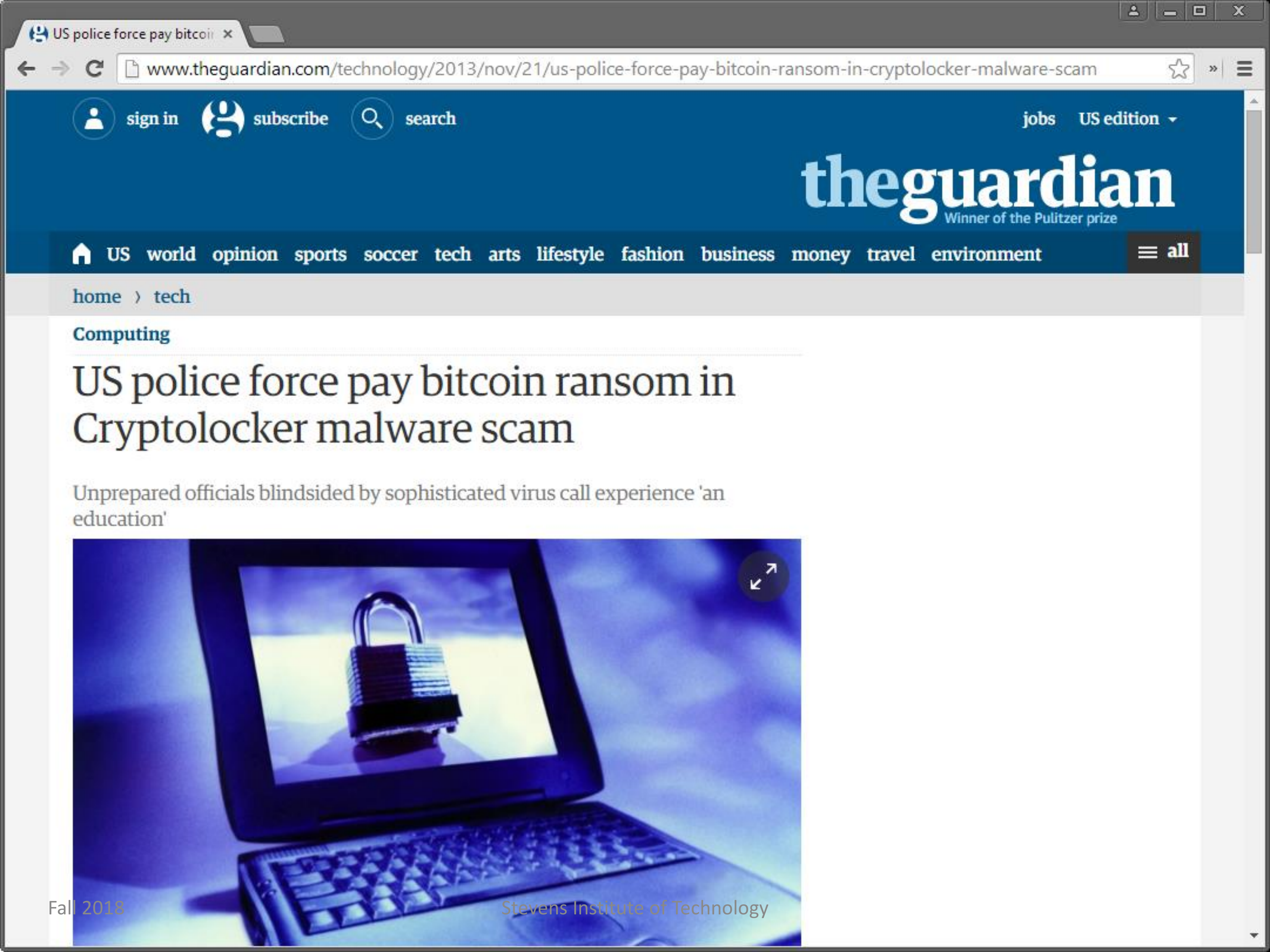
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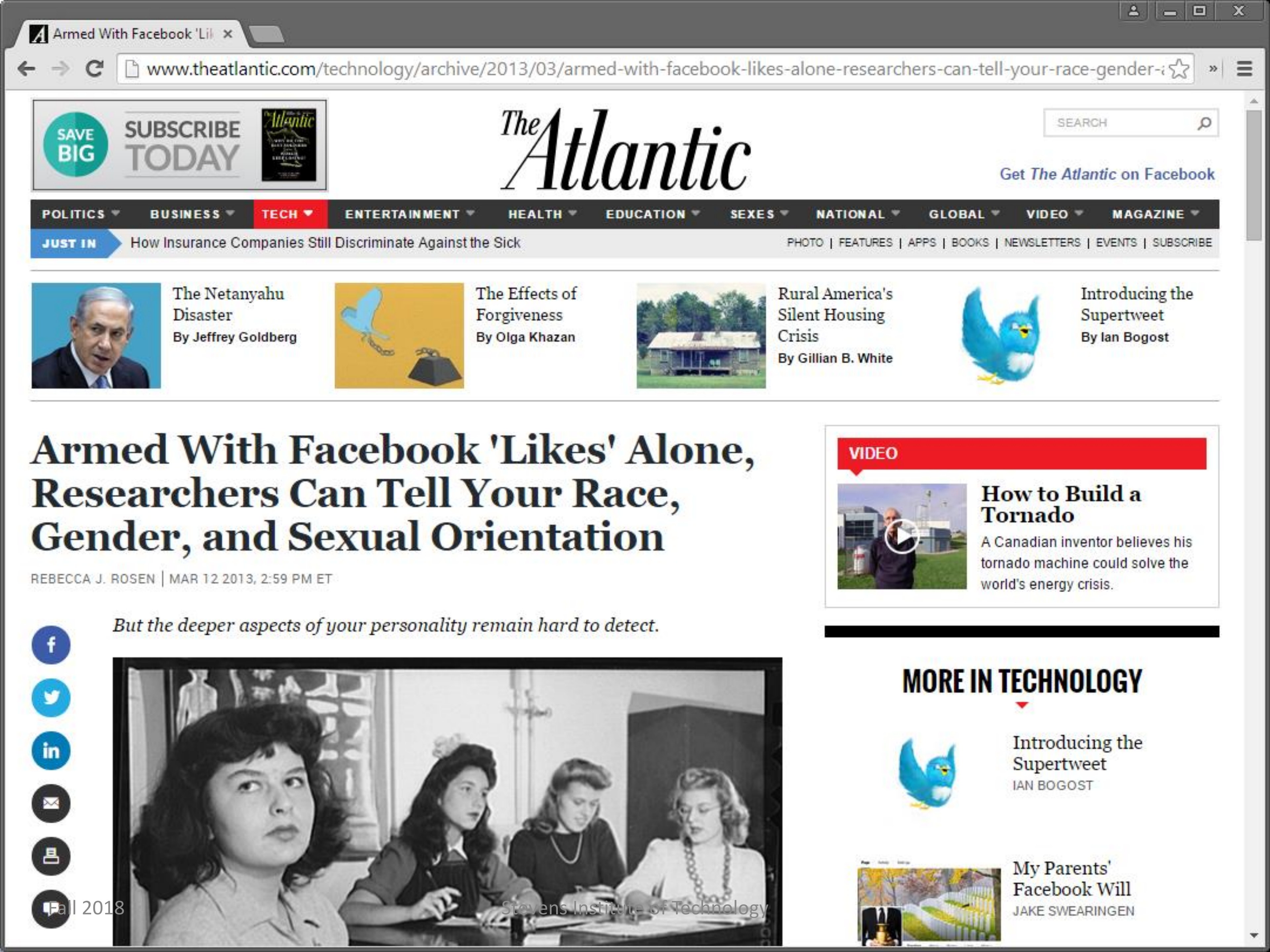
US police force pay bitcoin ransom in Cryptolocker malware scam

Unprepared officials blindsided by sophisticated virus call experience 'an education'



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REBECCA J. ROSEN | MAR 12 2013, 2:59 PM ET

But the deeper aspects of your personality remain hard to detect.

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A Canadian inventor believes his tornado machine could solve the world's energy crisis.

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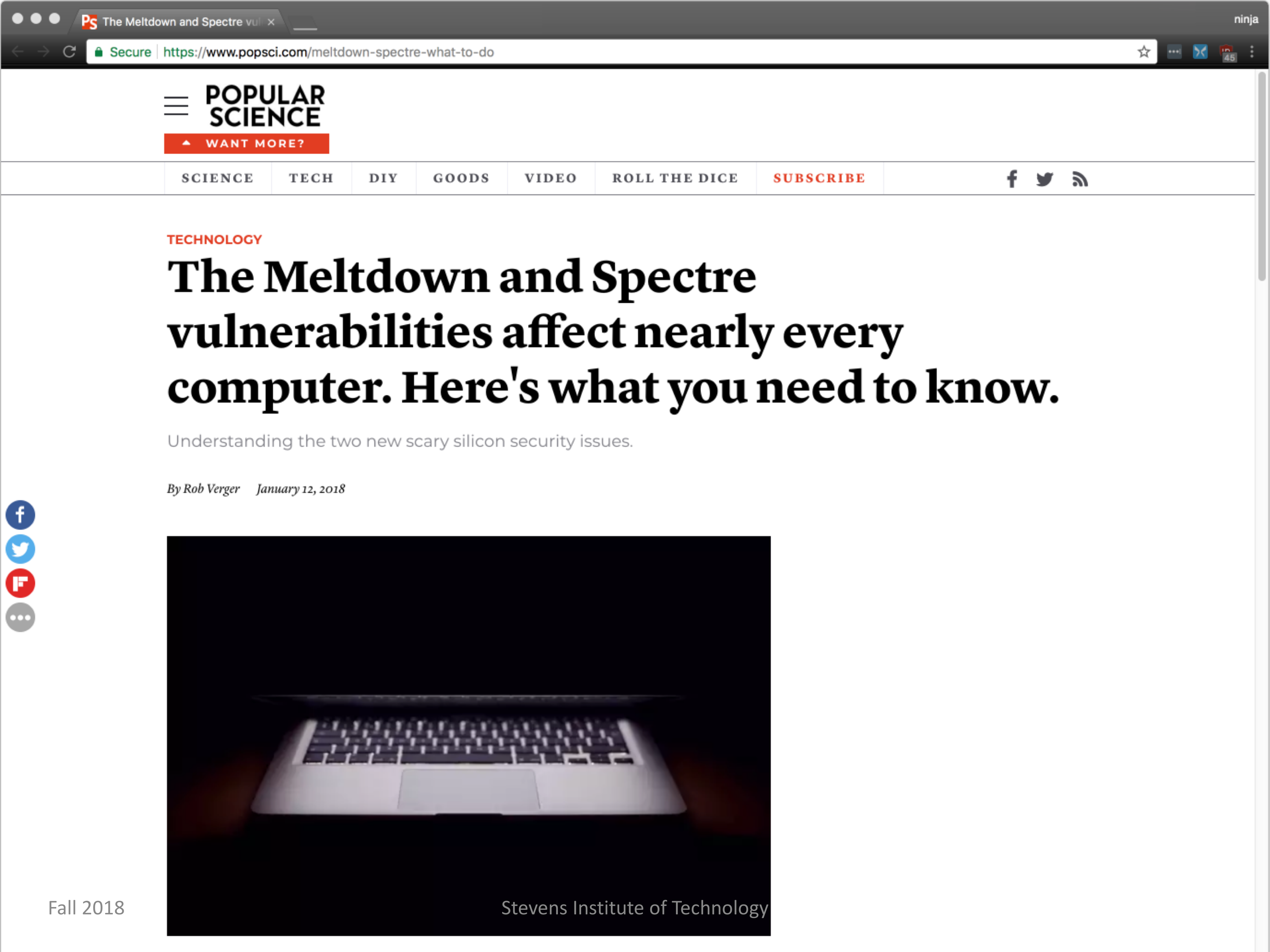


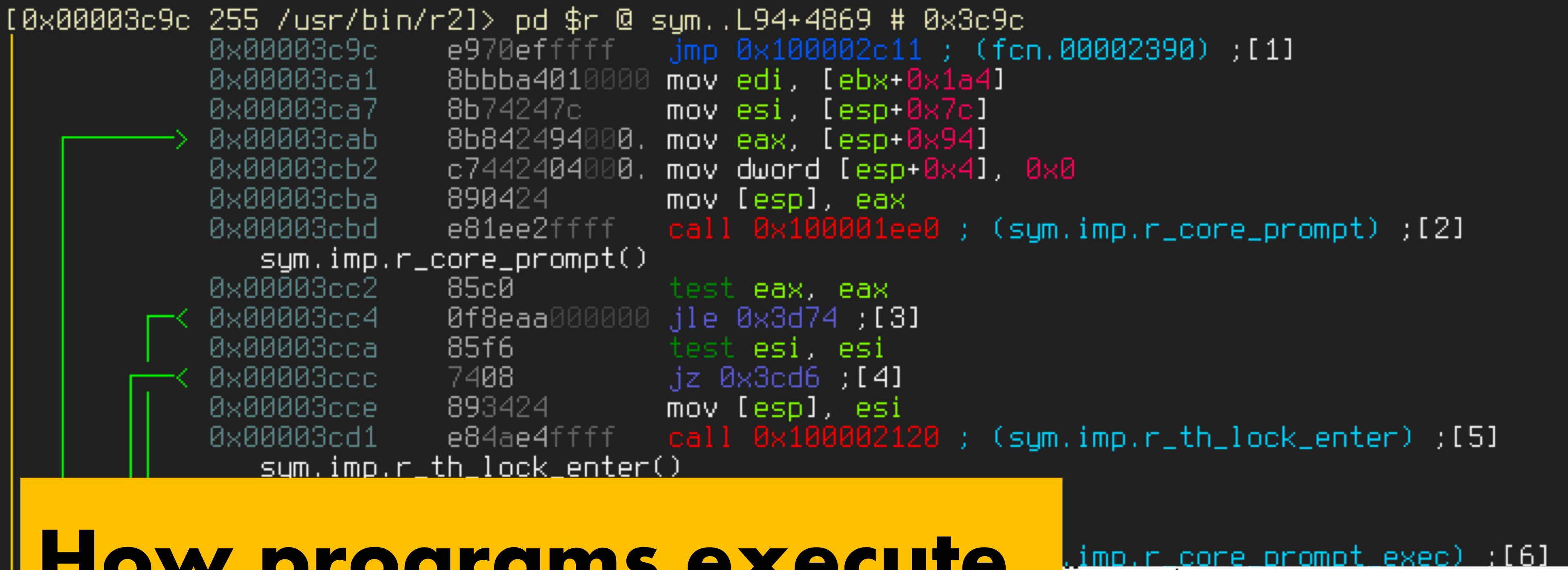
TECHNOLOGY

The Meltdown and Spectre vulnerabilities affect nearly every computer. Here's what you need to know.

Understanding the two new scary silicon security issues.

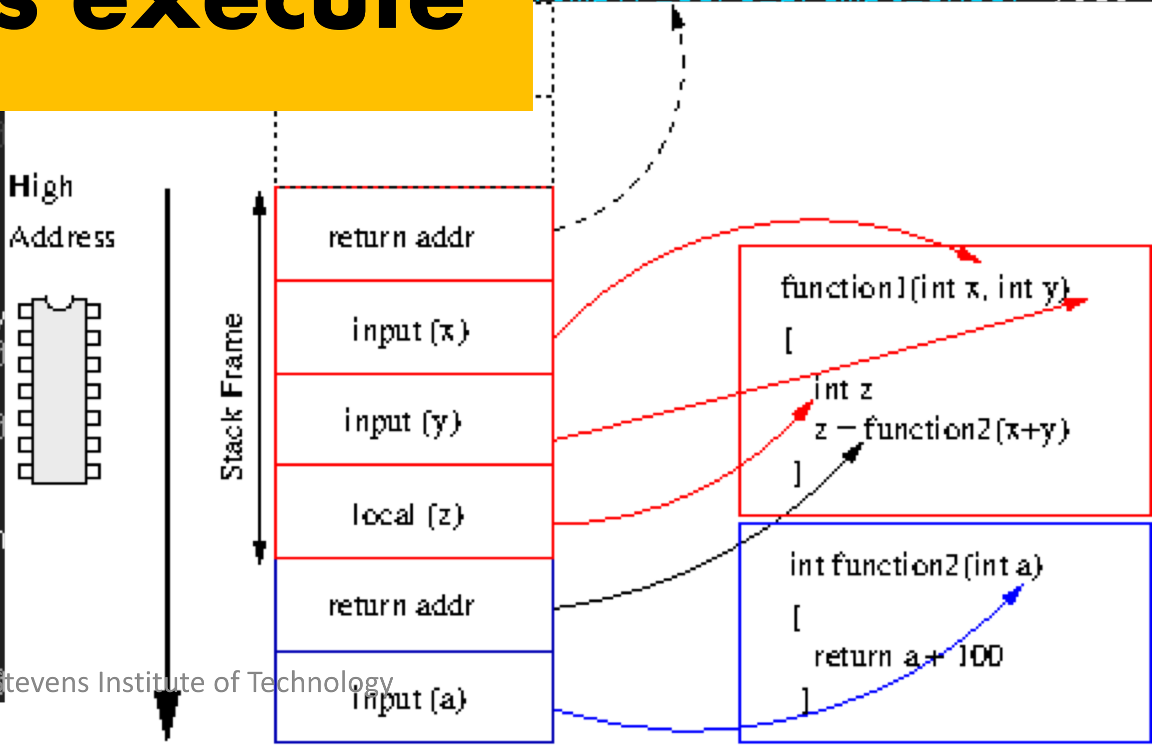
By Rob Verger *January 12, 2018*

Course Topics

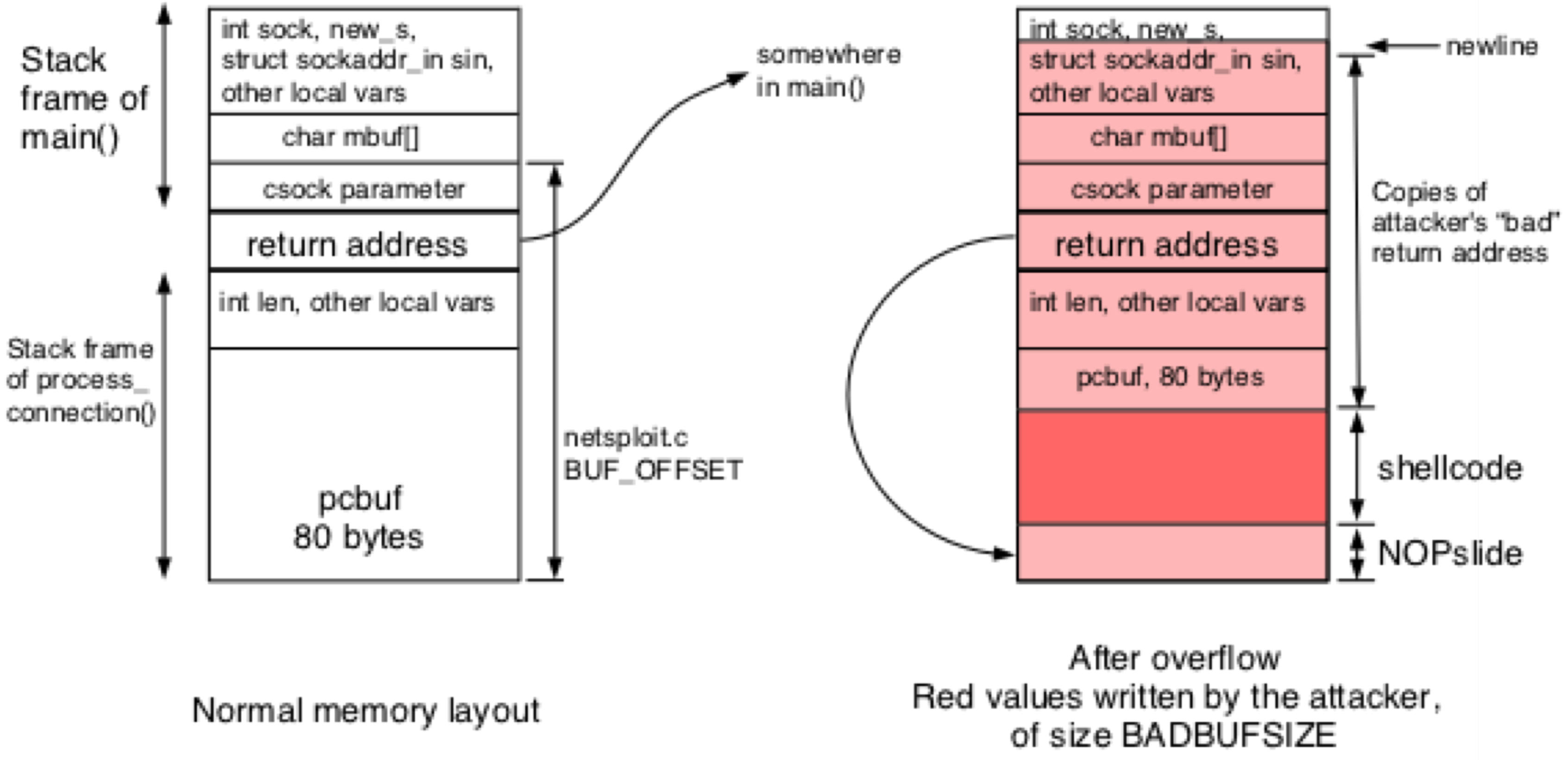


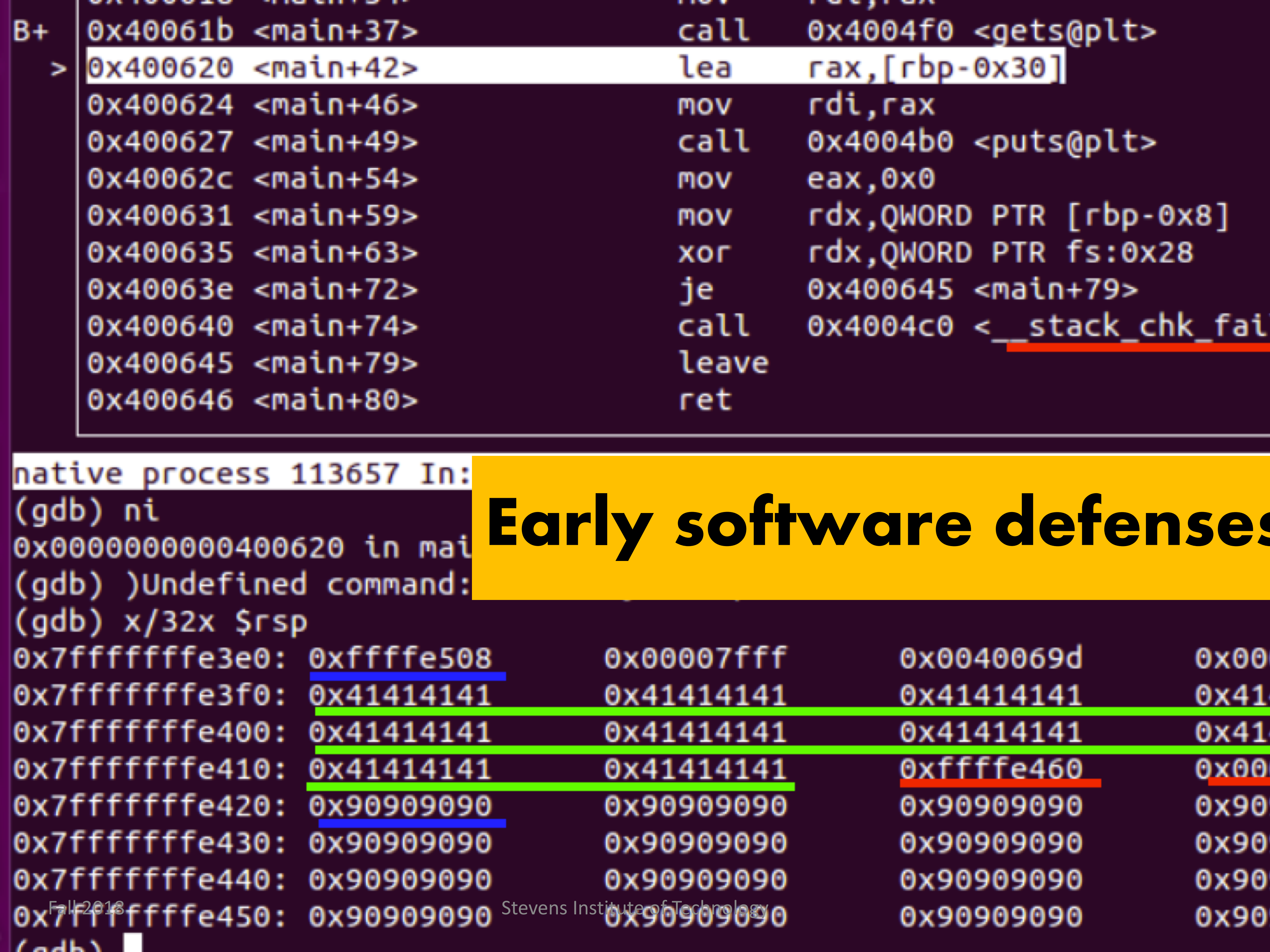
```
[0x00003c9c 255 /usr/bin/r2]> pd $r @ sym..L94+4869 # 0x3c9c
          0x00003c9c      e970efffff     jmp 0x100002c11 ; (fcn.00002390) ;[1]
          0x00003ca1      8bbba4010000   mov edi, [ebx+0x1a4]
          0x00003ca7      8b74247c       mov esi, [esp+0x7c]
      --> 0x00003cab      8b842494000.   mov eax, [esp+0x94]
          0x00003cb2      c7442404000.   mov dword [esp+0x4], 0x0
          0x00003cba      890424         mov [esp], eax
          0x00003cbd      e81ee2ffff     call 0x100001ee0 ; (sym.imp.r_core_prompt) ;[2]
             sym.imp.r_core_prompt()
          0x00003cc2      85c0           test eax, eax
        ,< 0x00003cc4      0f8eaa000000   jle 0x3d74 ;[3]
          0x00003cca      85f6           test esi, esi
       ,< 0x00003ccc      7408           jz 0x3cd6 ;[4]
          0x00003cce      893424         mov [esp], esi
          0x00003cd1      e84ae4ffff     call 0x100002120 ; (sym.imp.r_th_lock_enter) ;[5]
             sym.imp.r_th_lock_enter()
                                                                .imp.r_core_prompt_exec) ;[6]
          0x00003cef      0f842401000
          0x00003cf5      85f6
       ,< 0x00003cf7      7408
          0x00003cf9      893424
          0x00003cfc      e87fe2ffff
             sym.imp.r_th_lock_leav
       `> 0x00003d01      83bc2498000
       ,< 0x00003d09      745b
          0x00003d0b      8b842498000
          0x00003d12      890424
          0x00003d15      e806e5ffff
             sym.imp.r_th_wait_asyn
          0x00003d1a      85c0
       ,< 0x00003d1c      7548
          0x00003d1e      8b07
          0x00003d20      c744240812
```

How programs execute



Memory corruptions bugs


Stack frame of main()
int sock, new_s, struct sockaddr_in sin, other local vars
char mbuf[]
csock parameter
return address
int len, other local vars
Stack frame of process_connection()
pcbuf 80 bytes
netsploit.c BUF_OFFSET
somewhere in main()
Normal memory layout
int sock, new_s,
struct sockaddr_in sin, other local vars
char mbuf[]
csock parameter
return address
int len, other local vars
pcbuf, 80 bytes
newline
Copies of attacker's "bad" return address
shellcode
NOPslide
After overflow
Red values written by the attacker, of size BADBUFSIZE

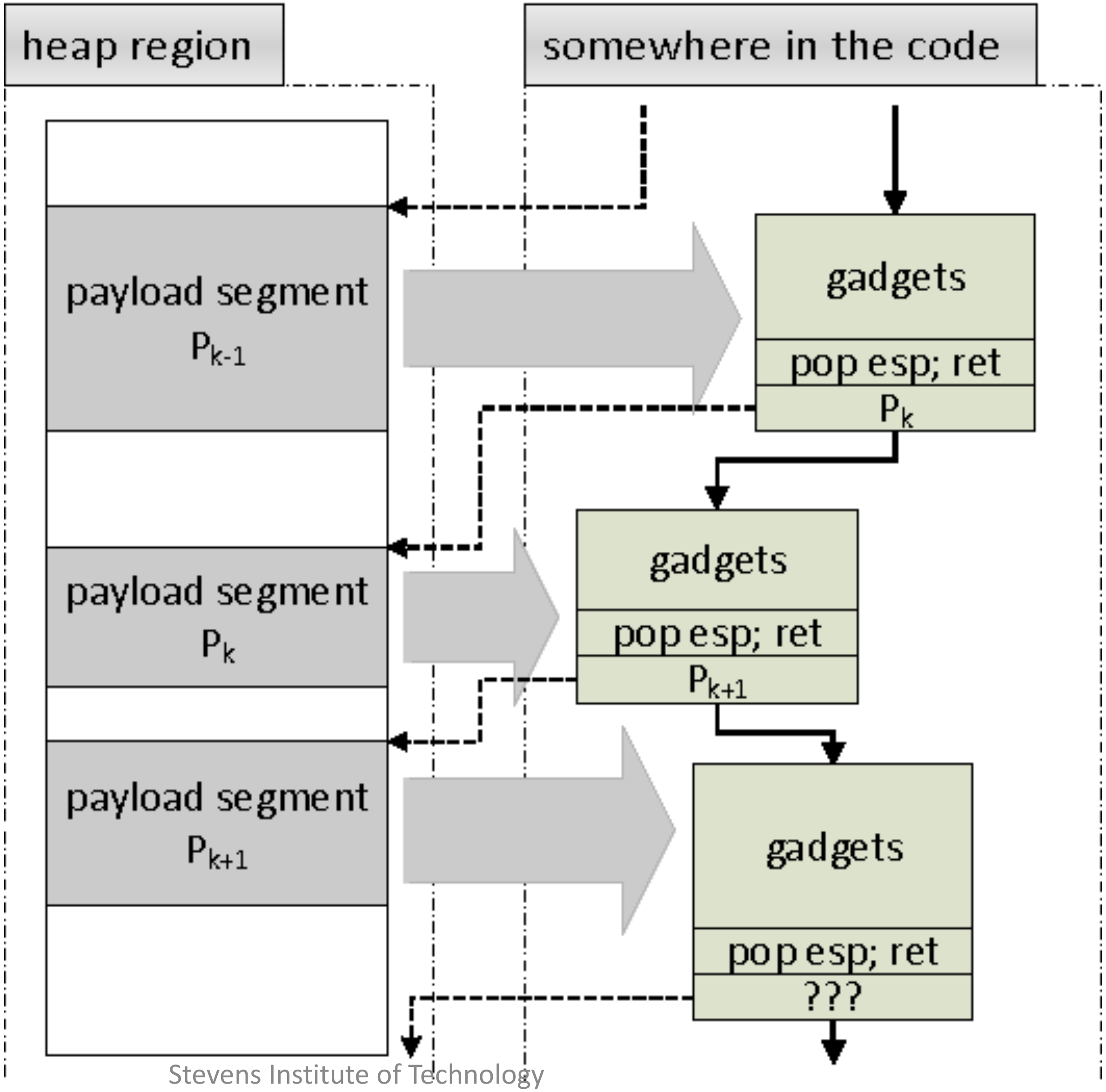


Early software defenses

```
   0x400618 <main+34>                 mov    rdi,rax
B+ 0x40061b <main+37>                 call   0x4004f0 <gets@plt>
 > 0x400620 <main+42>                 lea    rax,[rbp-0x30]
   0x400624 <main+46>                 mov    rdi,rax
   0x400627 <main+49>                 call   0x4004b0 <puts@plt>
   0x40062c <main+54>                 mov    eax,0x0
   0x400631 <main+59>                 mov    rdx,QWORD PTR [rbp-0x8]
   0x400635 <main+63>                 xor    rdx,QWORD PTR fs:0x28
   0x40063e <main+72>                 je     0x400645 <main+79>
   0x400640 <main+74>                 call   0x4004c0 <__stack_chk_fai
   0x400645 <main+79>                 leave
   0x400646 <main+80>                 ret

native process 113657 In:
(gdb) ni
0x0000000000400620 in mai
(gdb) )Undefined command:
(gdb) x/32x $rsp
0x7fffffffe3e0: 0xffffe508      0x00007fff      0x0040069d      0x00
0x7fffffffe3f0: 0x41414141      0x41414141      0x41414141      0x41
0x7fffffffe400: 0x41414141      0x41414141      0x41414141      0x41
0x7fffffffe410: 0x41414141      0x41414141      0xffffe460      0x00
0x7fffffffe420: 0x90909090      0x90909090      0x90909090      0x90
0x7fffffffe430: 0x90909090      0x90909090      0x90909090      0x90
0x7fffffffe440: 0x90909090      0x90909090      0x90909090      0x90
0x7fffffffe450: 0x90909090      0x90909090      0x90909090      0x90
(gdb) 
```

Modern Attacks



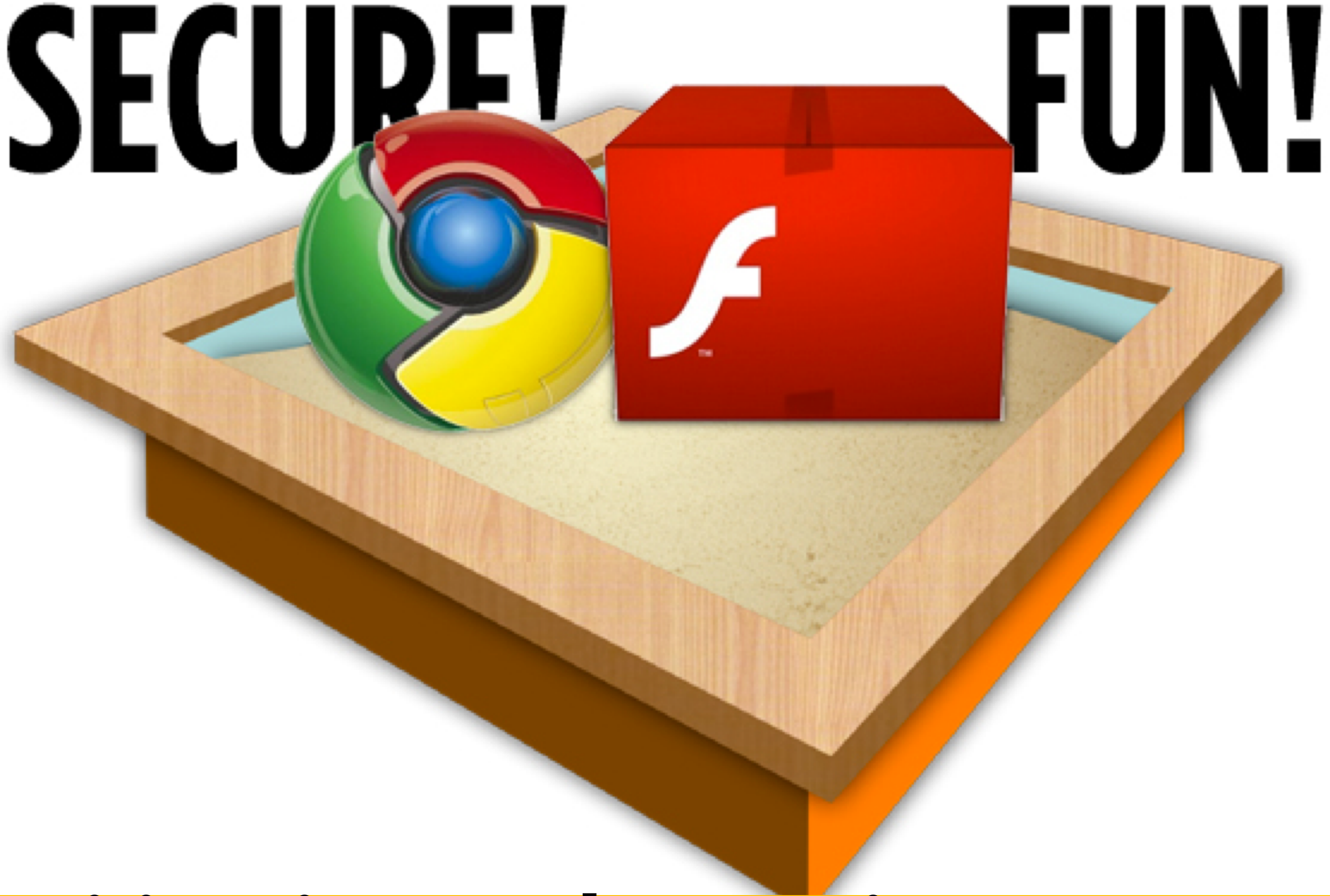
Contemporary Attacks

```
struct array {
 unsigned long length;
 unsigned char data[];
};
struct array *arr1 = ...;
unsigned long untrusted_offset_from_caller = ...;
if (untrusted_offset_from_caller < arr1->length) {
 unsigned char value = arr1->data[untrusted_offset_from_caller];
 ...
}
```

However, in the following code sample, there's an issue. If `arr1->length`, `arr2->data[0x200]` and`arr2->data[0x300]` are not cached, but all other accessed data is, and the branch conditions are predicted as true, the processor can do the following speculatively before `arr1->length` has been loaded and the execution is re-steered:

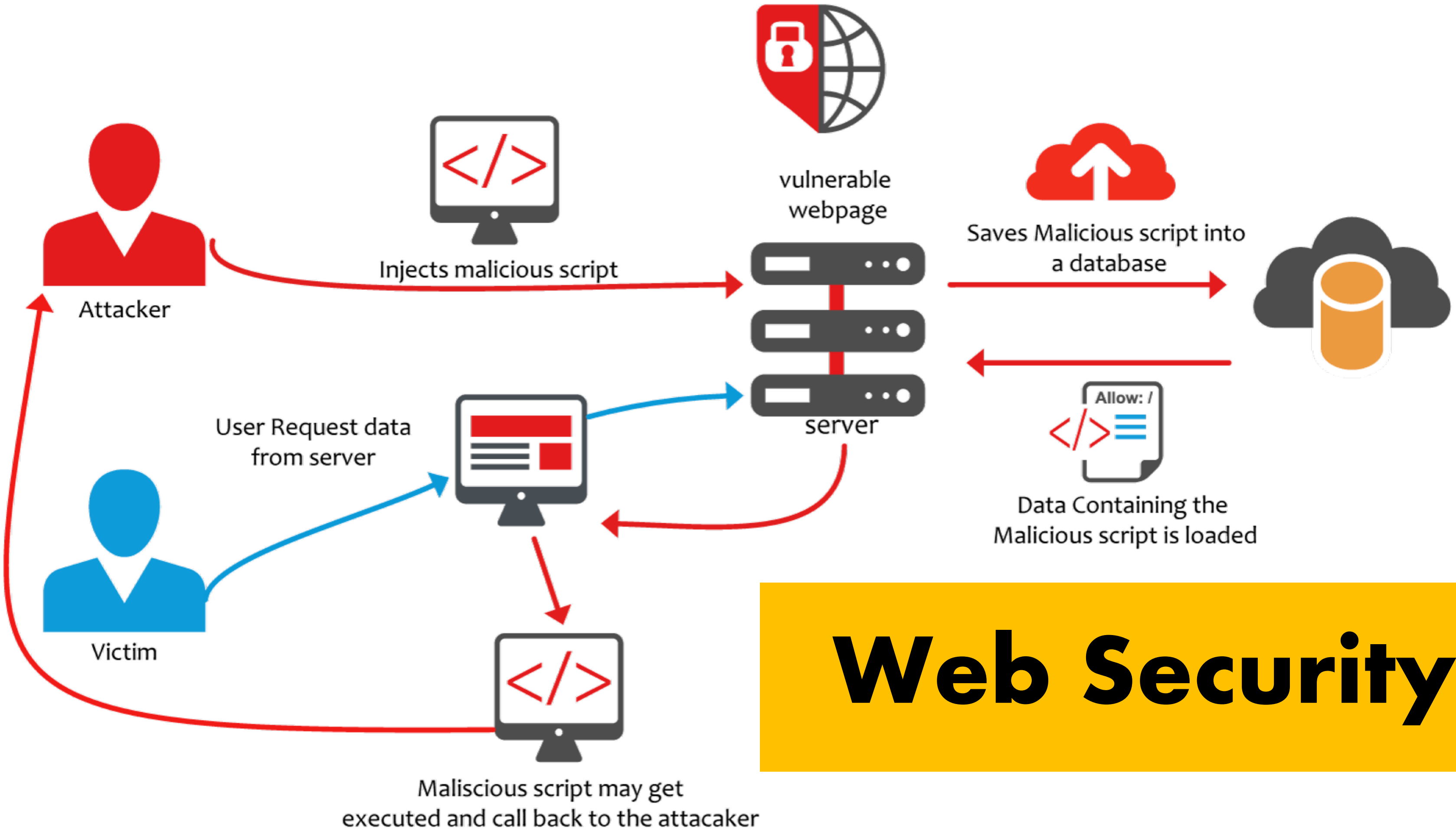
- load `value = arr1->data[untrusted_offset_from_caller]`
- start a load from a data-dependent offset in `arr2->data`, loading the corresponding cache line into the L1 cache

```
struct array {
 unsigned long length;
 unsigned char data[];
};
struct array *arr1 = ...; /* small array */
struct array *arr2 = ...; /* array of size 0x400 */
/* >0x400 (OUT OF BOUNDS!) */
unsigned long untrusted_offset_from_caller = ...;
if (untrusted_offset_from_caller < arr1->length) {
 unsigned char value = arr1->data[untrusted_offset_from_caller];
 unsigned long index2 = ((value&1)*0x100)+0x200;
 if (index2 < arr2->length) {
   unsigned char value2 = arr2->data[index2];
 }
}
```

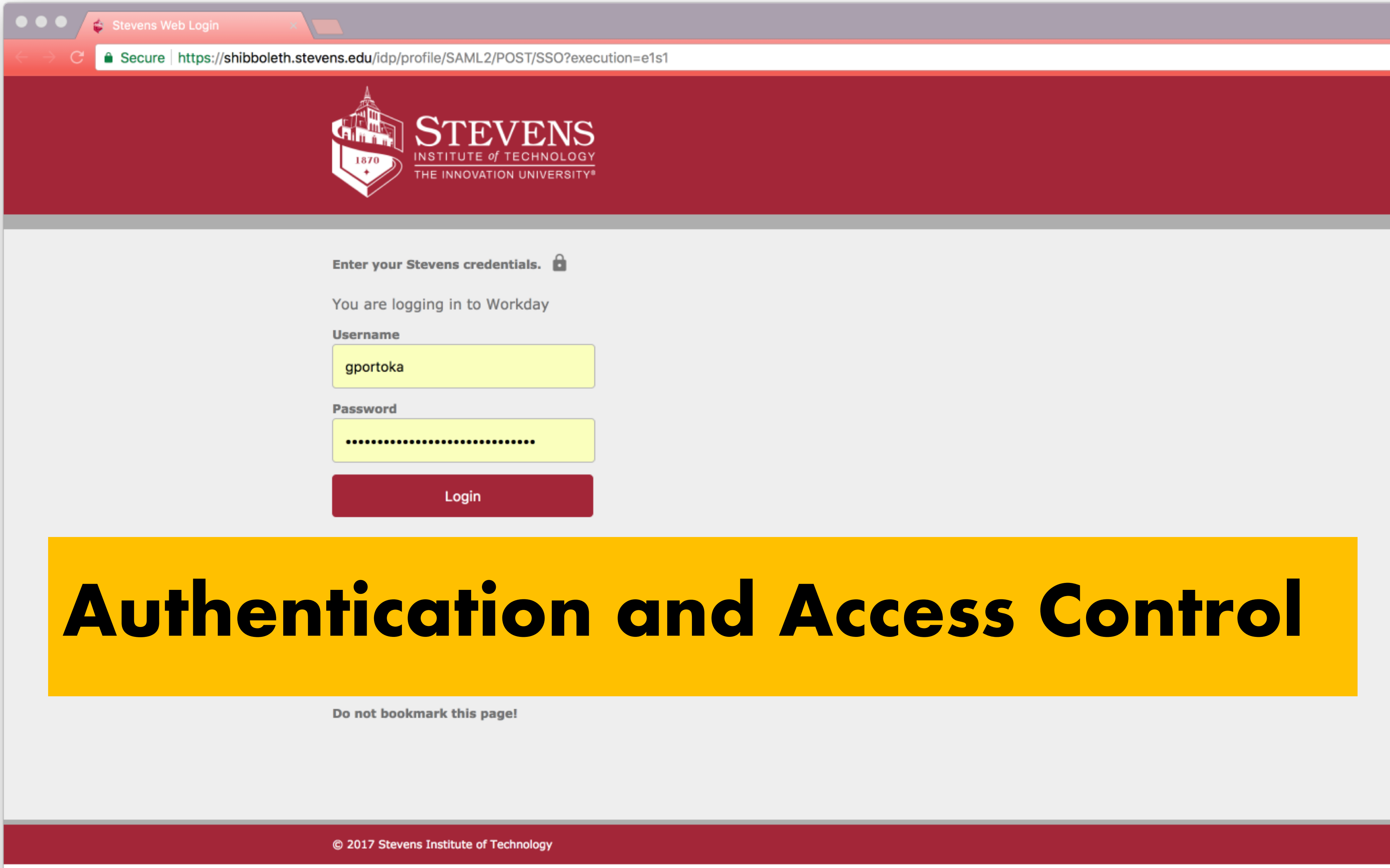


Mitigation and Containment: Sandboxing

Web Security


vulnerable webpage
Attacker
Injects malicious script
Saves Malicious script into a database
server
User Request data from server
Victim
Allow: /
Data Containing the Malicious script is loaded
Maliscious script may get executed and call back to the attacaker

Authentication and Access Control



https://shibboleth.stevens.edu/idp/profile/SAML2/POST/SSO?execution=e1s1

Enter your Stevens credentials.

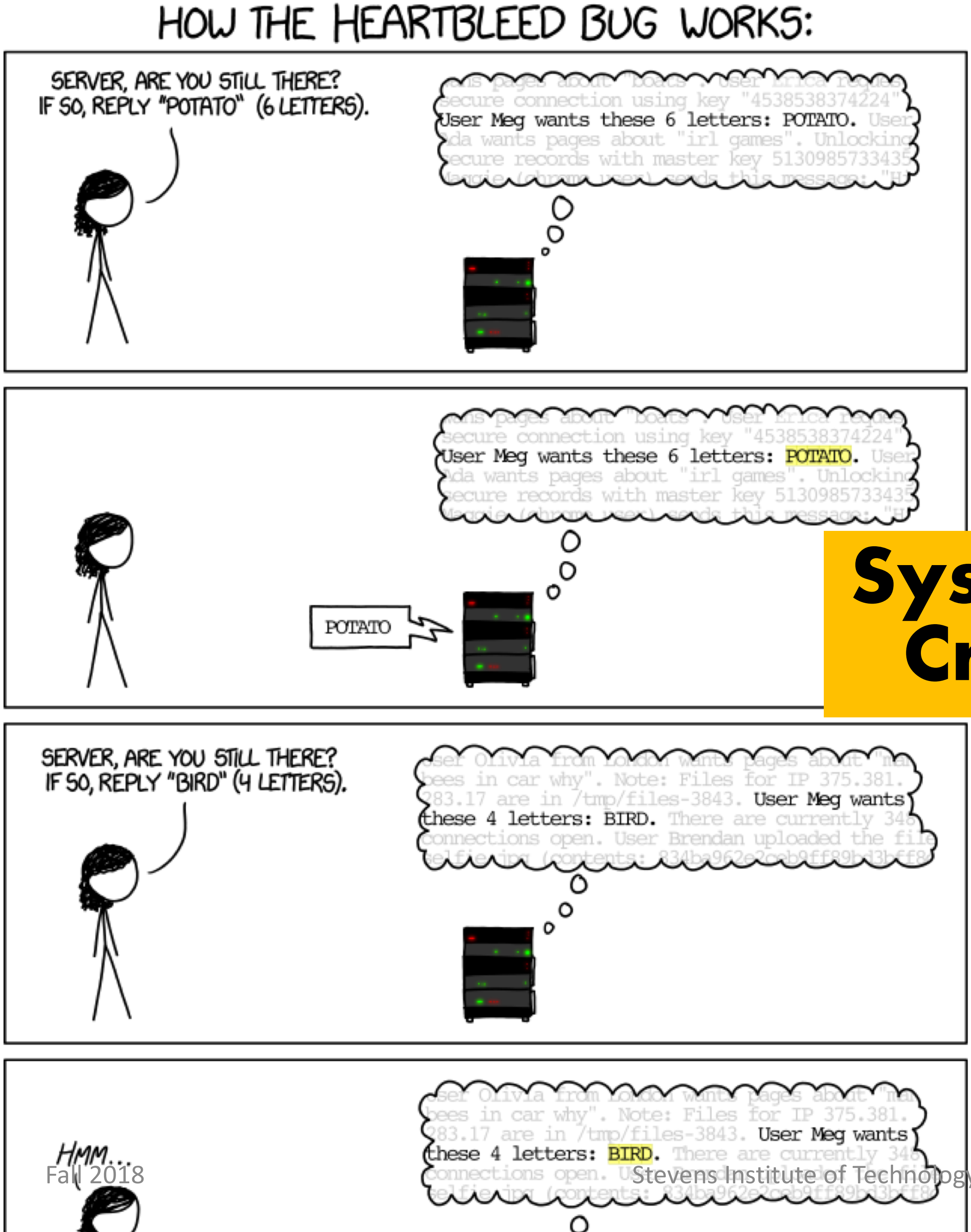
You are logging in to Workday

Username: gportoka

Password: ••••••••••••••••••••••••••••••••

Do not bookmark this page!

© 2017 Stevens Institute of Technology


HOW THE HEARTBLEED BUG WORKS:
SERVER, ARE YOU STILL THERE? IF SO, REPLY "POTATO" (6 LETTERS).
secure connection using key "4538538374224". User Meg wants these 6 letters: POTATO. User Ada wants pages about "irl games". Unlocking secure records with master key 5130985733435
POTATO
SERVER, ARE YOU STILL THERE? IF SO, REPLY "BIRD" (4 LETTERS).
bees in car why". Note: Files for IP 375.381.283.17 are in /tmp/files-3843. User Meg wants these 4 letters: BIRD. There are currently 346 connections open. User Brendan uploaded the file selfie.jpg (contents: 834ba962e2ceb9ff89bd3bff8
HMM...

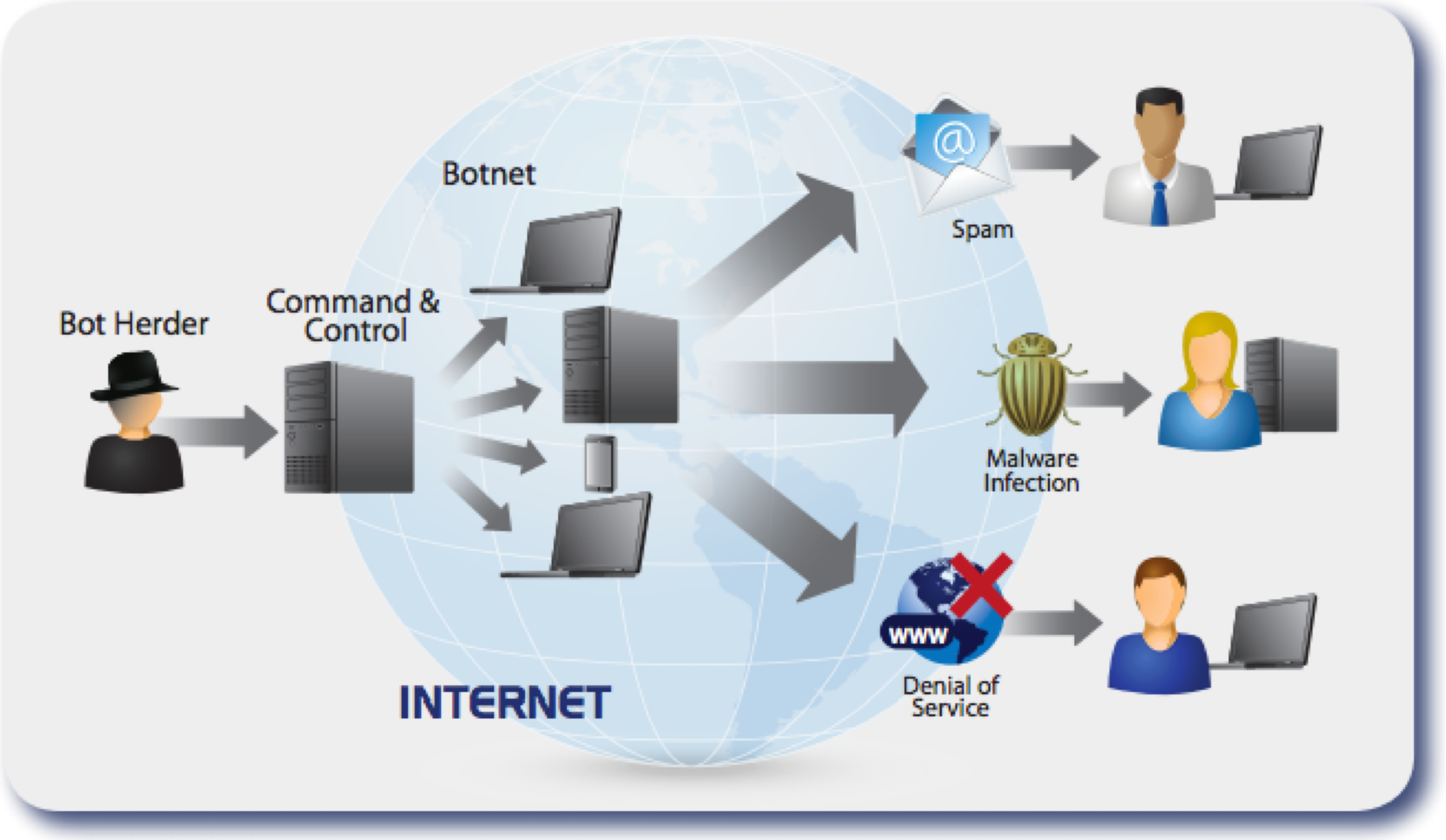
System Failures of Crypto Systems

Network Security

GRAPHIC BY NICOLAS RAPP
UNDERSEA CABLES, LANDINGS, AND FIBER-OPTIC MAPS WERE BUILT WITH DATA PROVIDED BY GEOTEL COMMUNICATIONS (GEO-TEL.COM)

Fall 2018

Stevens Institute of Technology



Malware, botnets, and DDoS

Overview

A (very short) introduction to systems security

General information

Information About the Course

All info, including syllabus, under

https://www.portokalidis.net/cs576.html

Lecture: Monday 6:15pm-8:45pm

Lab: Thursdays 3:05pm-3:55pm

- Make sure you are enrolled

Communication

Communication and discussion over Piazza:
https://piazza.com/stevens/fall2018/cs576/

Go to link and enroll

- **Use your Stevens email!**

Do not use canvas messaging to communicate

Use Piazza for most questions

- Sometimes your classmates can help you faster than the instructor or the TA

Textbook(s)

No textbook is mandatory

Mandatory reading material:

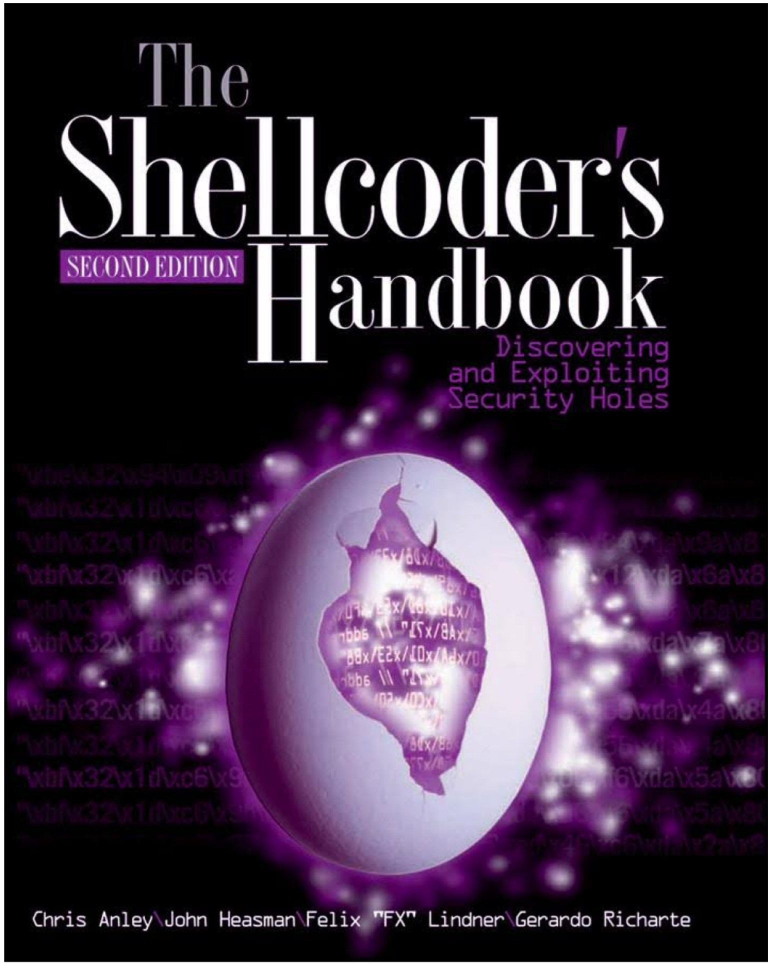
- Links to articles, papers, and book chapters in the syllabus
  - Check the website for the most up-to-date material
- The slides

Textbooks that may prove to be useful …

The Shellcoder's Handbook

The Shellcoder's Handbook: Discovering and Exploiting Security Holes

- By Chris Anley, John Heasman, Felix Lindner, Gerardo Richarte


The Shellcoder's Handbook
SECOND EDITION
Discovering and Exploiting Security Holes
Chris Anley\John Heasman\Felix "FX" Lindner\Gerardo Richarte

Grade Breakdown

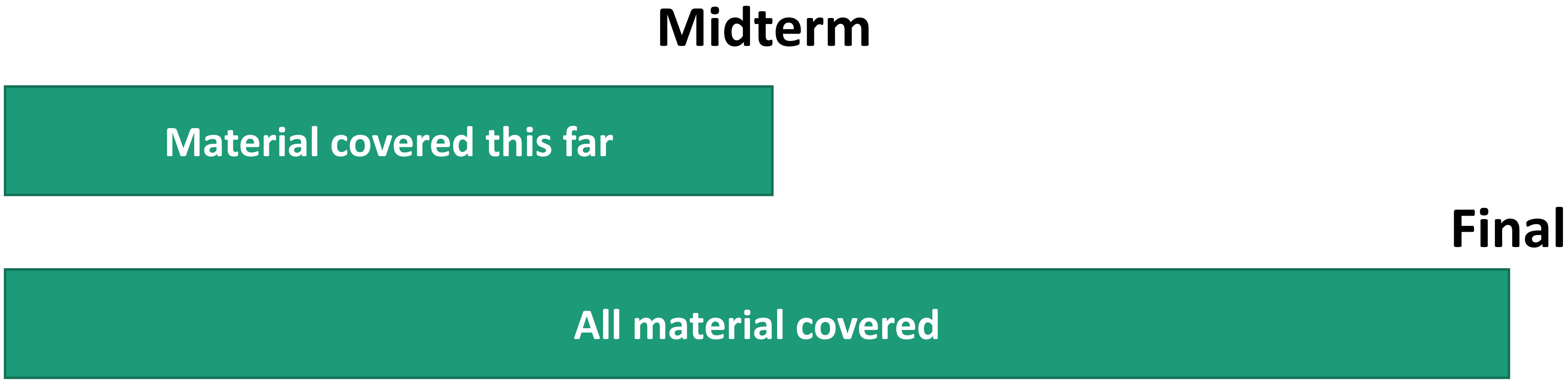
Exam I - Midterm	(25%)
Exam II – Final	(25%)
Quizzes	(10%)
Lab participation	(10%)
Homework assignments	(30%)

Exams

Relatively short (<=1hour)

Focused on understanding. May include multiple choice and short-answer questions, and code understanding questions

Online or on paper, but students must be in-class



Midterm

Material covered this far

Final

All material covered

Quizzes

Online quizzes over canvas

Based on comprehension of the reading material

Multiple attempts possible

Lab Section

Make sure you are registered for CS-576-LA

- Attendance will be taken at the start of each lab section

What is going to be happening in the lab section?

- Demonstration of tools and techniques
- You will participate in exercises
  - Bring your laptops and make sure they are charged

Make sure you have a linux-lab account

- If you do not have an account, you'll need to get one
- https://www.srcit.stevens.edu/wiki/index.php/Linux_Lab

Homework Assignments

There will be 5-7 take-home assignments

- To be done individually or small teams of 2 persons

For most assignments you will have 1-2 weeks to submit

- Starting late is a guaranteed way to fail

Assignments will need to run on linux-lab

Homework Timeliness

2 grace days for the semester

- Used automatically when you submit late
- Covers scheduling crunch, out-of-town trips, illnesses, minor setbacks

Once grace day(s) used up, get penalized **15% per day**

No submissions will be accepted later than **3 days after due date**

Cheating: Description

What is cheating?

- Sharing code: by copying, retyping, **looking at**, or supplying a file
- Describing: verbal description of code from one person to another
- Coaching: helping your friend to write a lab, line by line
- Searching the Web for solutions
- Copying code from a previous course or online solution

What is NOT cheating?

- Explaining how to use systems or tools
- Helping others with high-level design issues

Ignorance is not an excuse

Cheating: Consequences

Penalty for cheating:

- You will be reported to the Dean
- Penalties may include suspension, expulsion, and deduction of points

Detection of cheating:

- We have sophisticated tools for detecting code plagiarism

Don’t do it!

- Start early
- Ask us for help when you get stuck
    - Assuming you start early

Other Rules and Advice

Don't use your laptops in lectures, they **will** distract you

- If you don't plan on paying attention you may as well not attend lectures

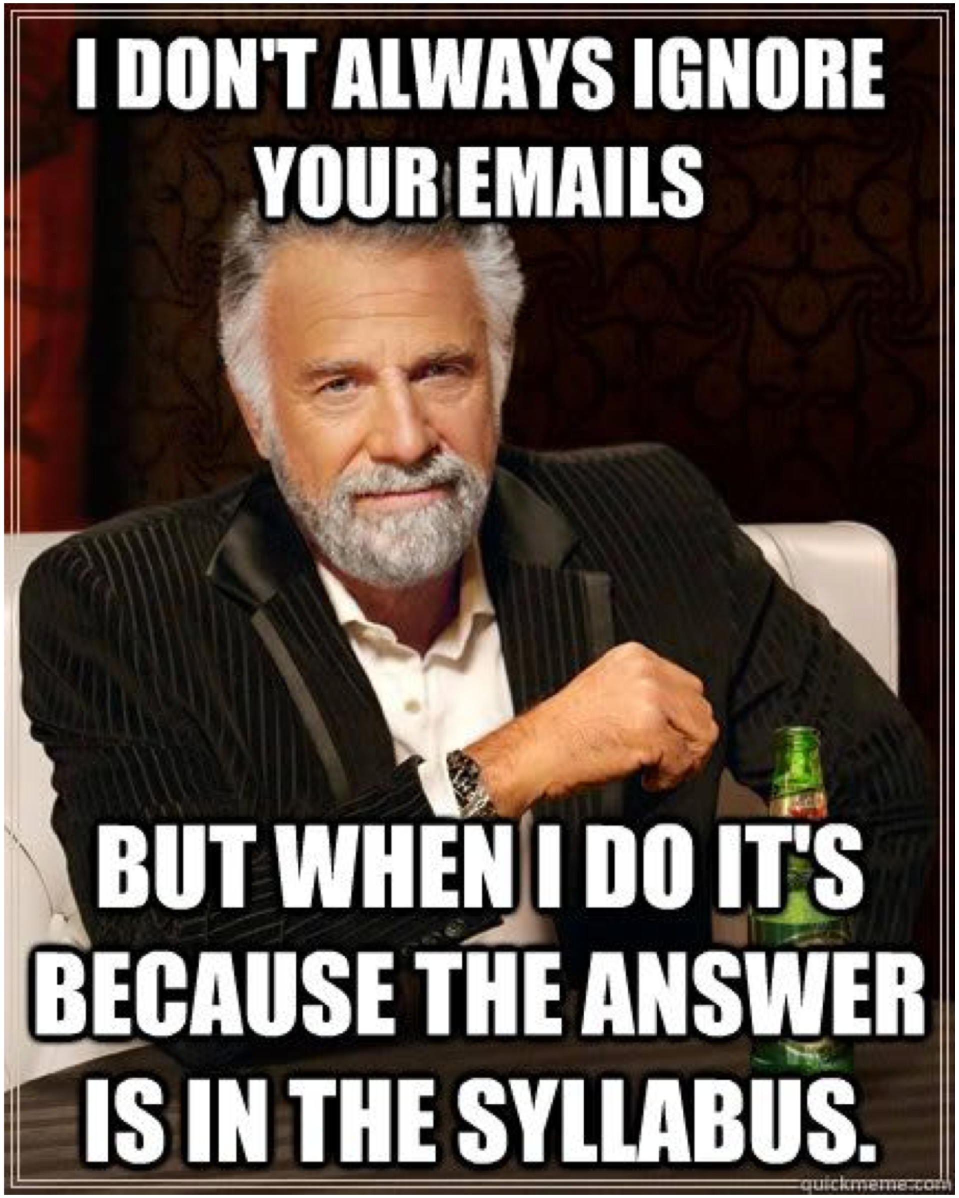
Electronic communications: forbidden

- No email, instant messaging, cell phone calls, etc

No recordings of ANY KIND

Office Hours

TBD – They will be announced on Piazza


I DON'T ALWAYS IGNORE YOUR EMAILS
BUT WHEN I DO IT'S BECAUSE THE ANSWER IS IN THE SYLLABUS.
quickmeme.com

Any questions this far?