Hacking Medical Devices

All your vital signs are belong to us …

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- ERNW GmbH in Heidelberg
- Team Lead: Pentests
- Research: Medical Devices

Agenda

- Motivation
- Publications
- The Problem
- Targets
- Findings so far
- Questions

Disclaimer

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Motivation

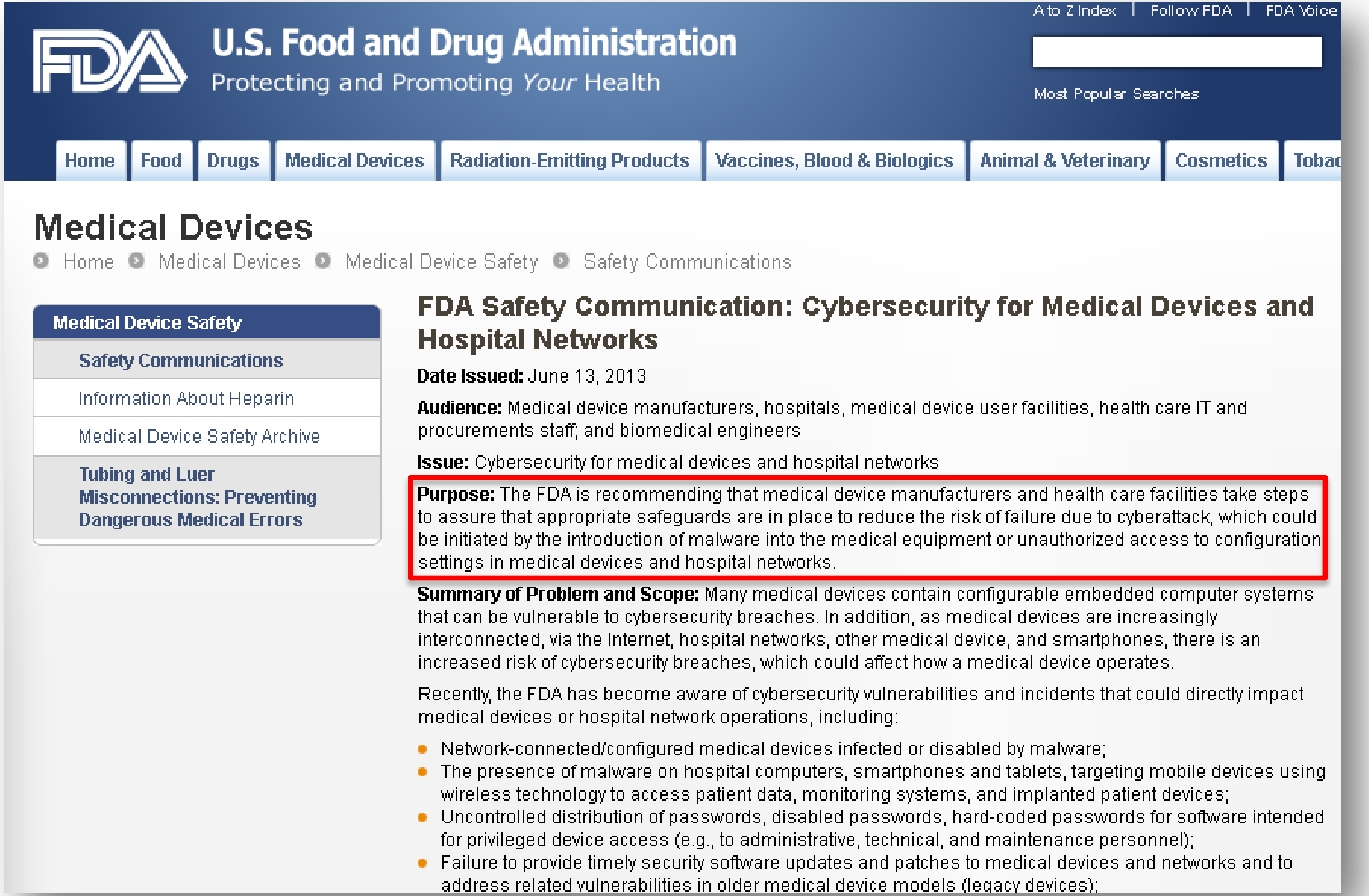
Make the world a safer place …

Motivation

- Importance
  - We trust these devices
  - Doctors trust these devices
- Technology
  - Rocket science: e.g. MRI
  - Proprietary protocols
  - Every device is different

Publications so far …

What has been done …



U.S. Food and Drug Administration
Protecting and Promoting *Your* Health

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Medical Devices

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Medical Device Safety
Safety Communications
Information About Heparin
Medical Device Safety Archive
Tubing and Luer Misconnections: Preventing Dangerous Medical Errors

FDA Safety Communication: Cybersecurity for Medical Devices and Hospital Networks

Date Issued: June 13, 2013

Audience: Medical device manufacturers, hospitals, medical device user facilities, health care IT and procurements staff; and biomedical engineers

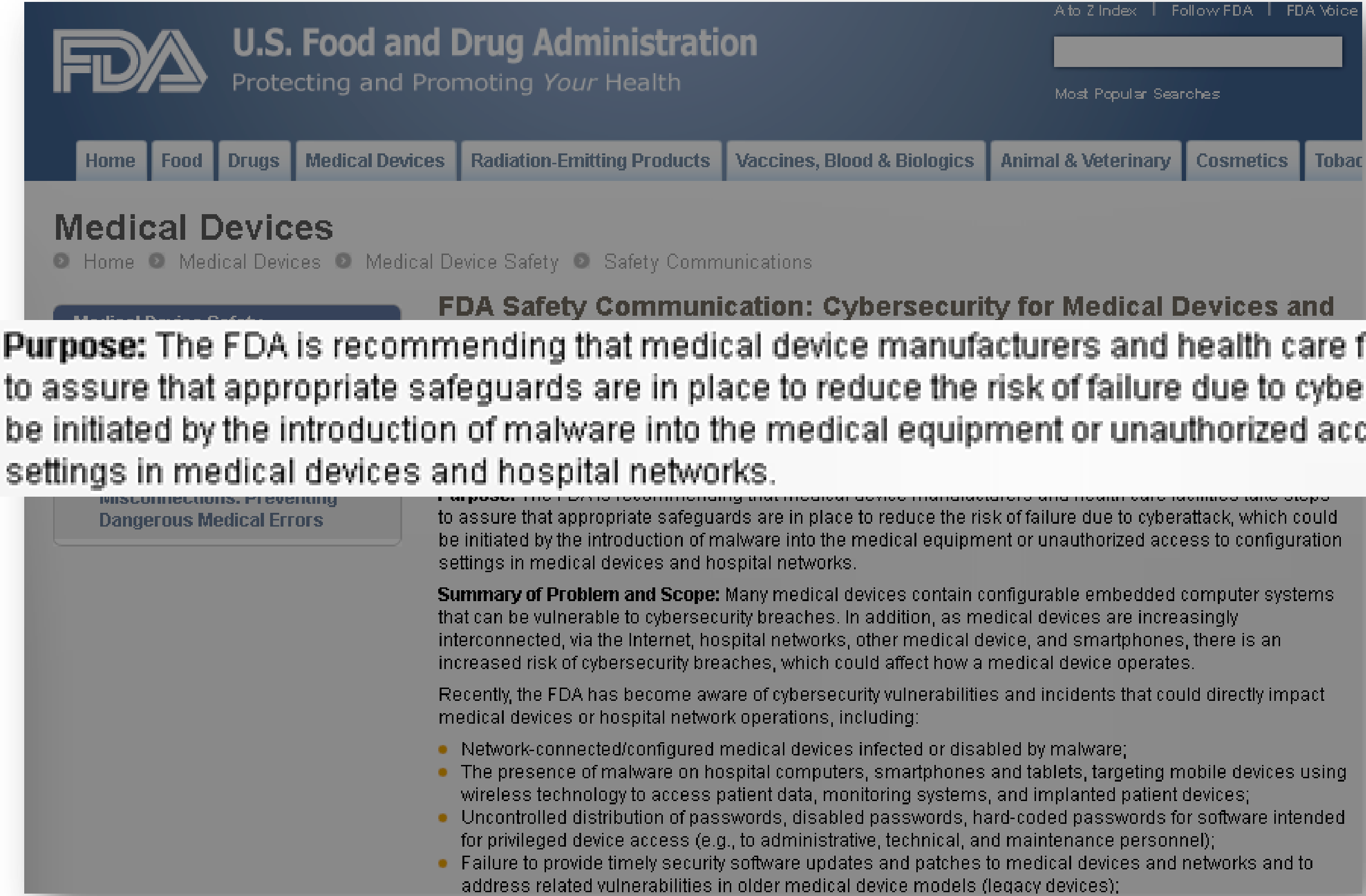
Issue: Cybersecurity for medical devices and hospital networks

Purpose: The FDA is recommending that medical device manufacturers and health care facilities take steps to assure that appropriate safeguards are in place to reduce the risk of failure due to cyberattack, which could be initiated by the introduction of malware into the medical equipment or unauthorized access to configuration settings in medical devices and hospital networks.

Summary of Problem and Scope: Many medical devices contain configurable embedded computer systems that can be vulnerable to cybersecurity breaches. In addition, as medical devices are increasingly interconnected, via the Internet, hospital networks, other medical device, and smartphones, there is an increased risk of cybersecurity breaches, which could affect how a medical device operates.

Recently, the FDA has become aware of cybersecurity vulnerabilities and incidents that could directly impact medical devices or hospital network operations, including:

- Network-connected/configured medical devices infected or disabled by malware;
- The presence of malware on hospital computers, smartphones and tablets, targeting mobile devices using wireless technology to access patient data, monitoring systems, and implanted patient devices;
- Uncontrolled distribution of passwords, disabled passwords, hard-coded passwords for software intended for privileged device access (e.g., to administrative, technical, and maintenance personnel);
- Failure to provide timely security software updates and patches to medical devices and networks and to address related vulnerabilities in older medical device models (legacy devices);



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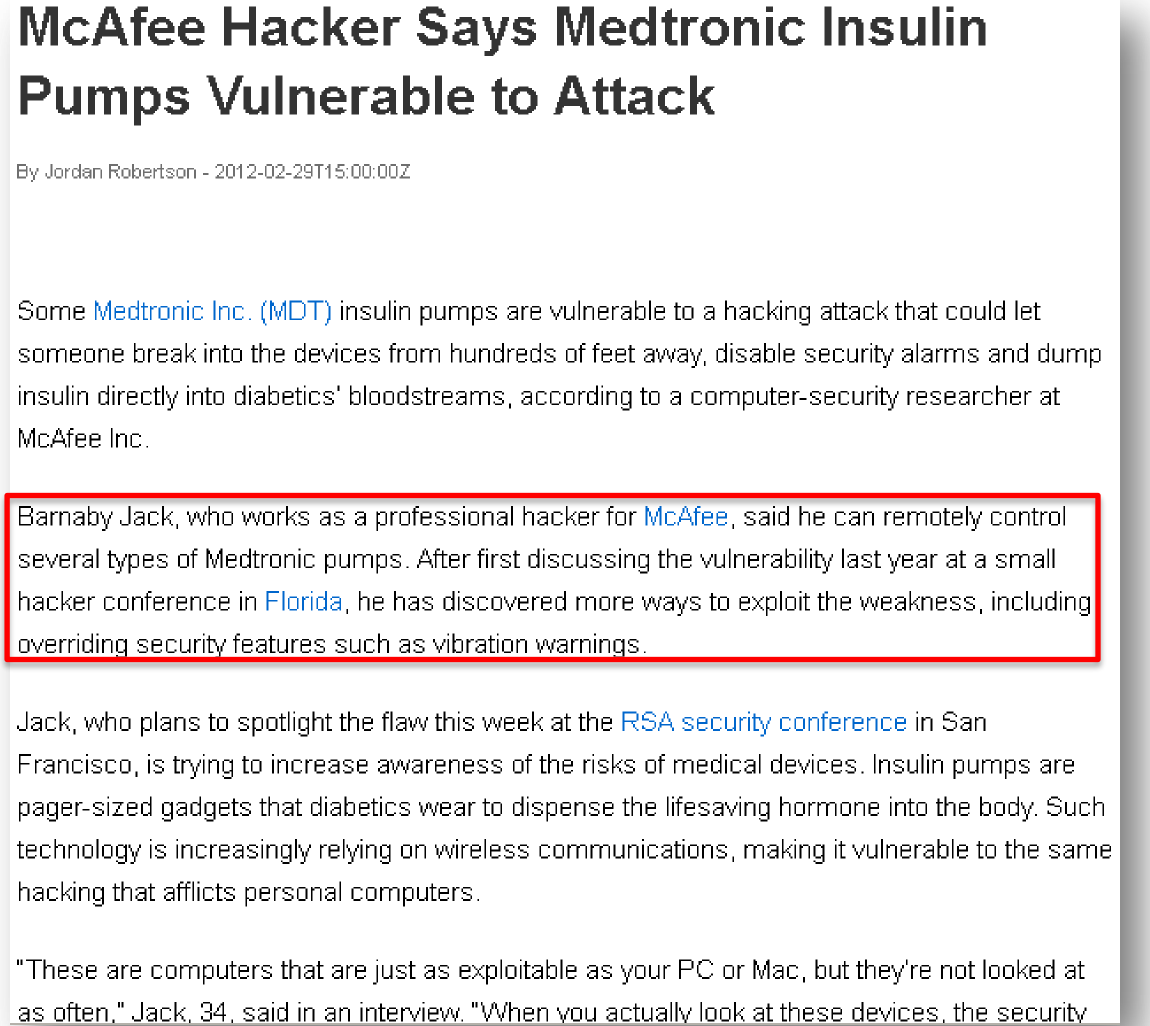


McAfee Hacker Says Medtronic Insulin Pumps Vulnerable to Attack

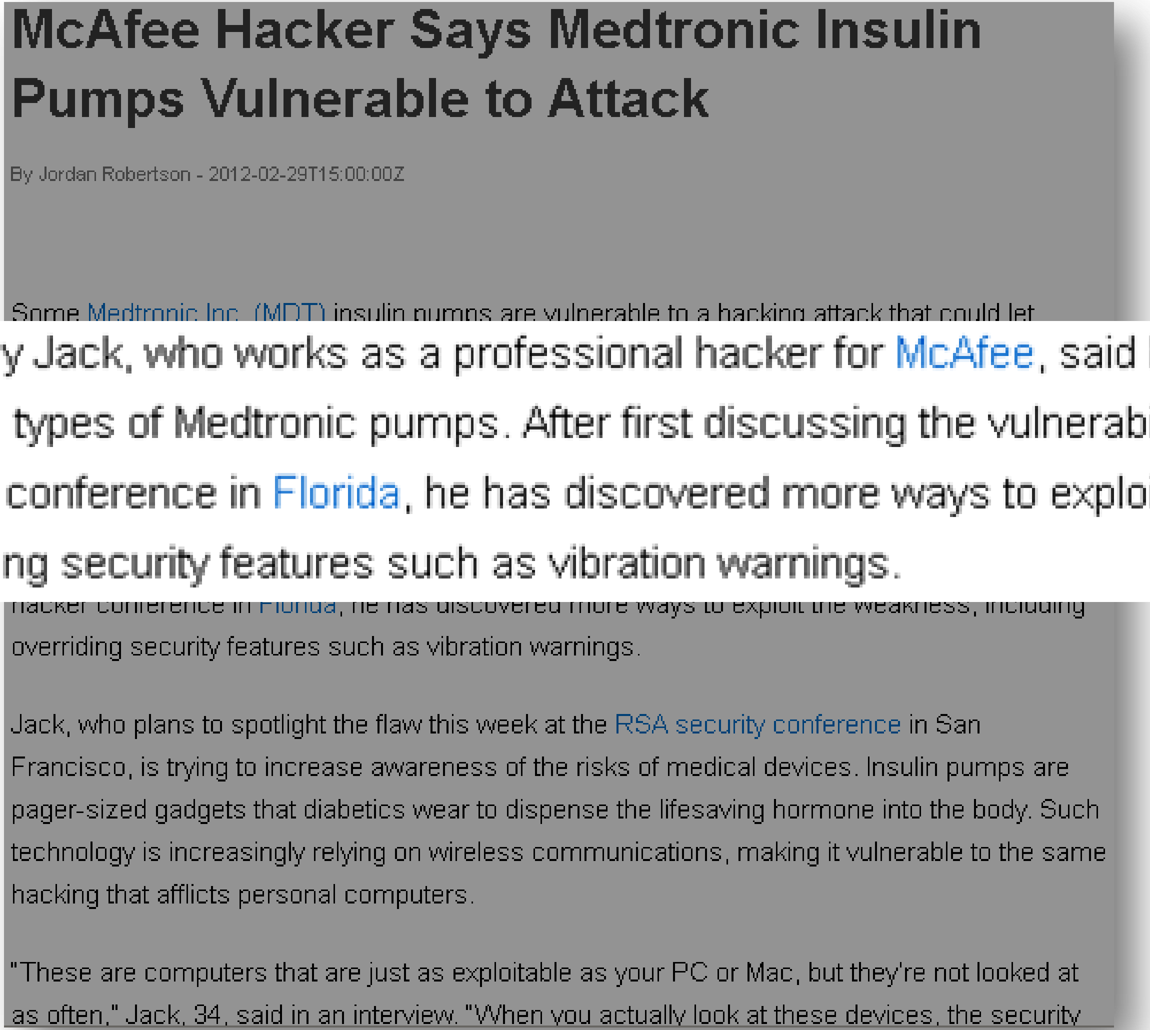
By Jordan Robertson - 2012-02-29T15:00:00Z

Some Medtronic Inc. (MDT) insulin pumps are vulnerable to a hacking attack that could let someone break into the devices from hundreds of feet away, disable security alarms and dump insulin directly into diabetics' bloodstreams, according to a computer-security researcher at McAfee Inc.

Barnaby Jack, who works as a professional hacker for McAfee, said he can remotely control several types of Medtronic pumps. After first discussing the vulnerability last year at a small hacker conference in Florida, he has discovered more ways to exploit the weakness, including overriding security features such as vibration warnings.

Jack, who plans to spotlight the flaw this week at the RSA security conference in San Francisco, is trying to increase awareness of the risks of medical devices. Insulin pumps are pager-sized gadgets that diabetics wear to dispense the lifesaving hormone into the body. Such technology is increasingly relying on wireless communications, making it vulnerable to the same hacking that afflicts personal computers.

"These are computers that are just as exploitable as your PC or Mac, but they're not looked at as often," Jack, 34, said in an interview. "When you actually look at these devices, the security



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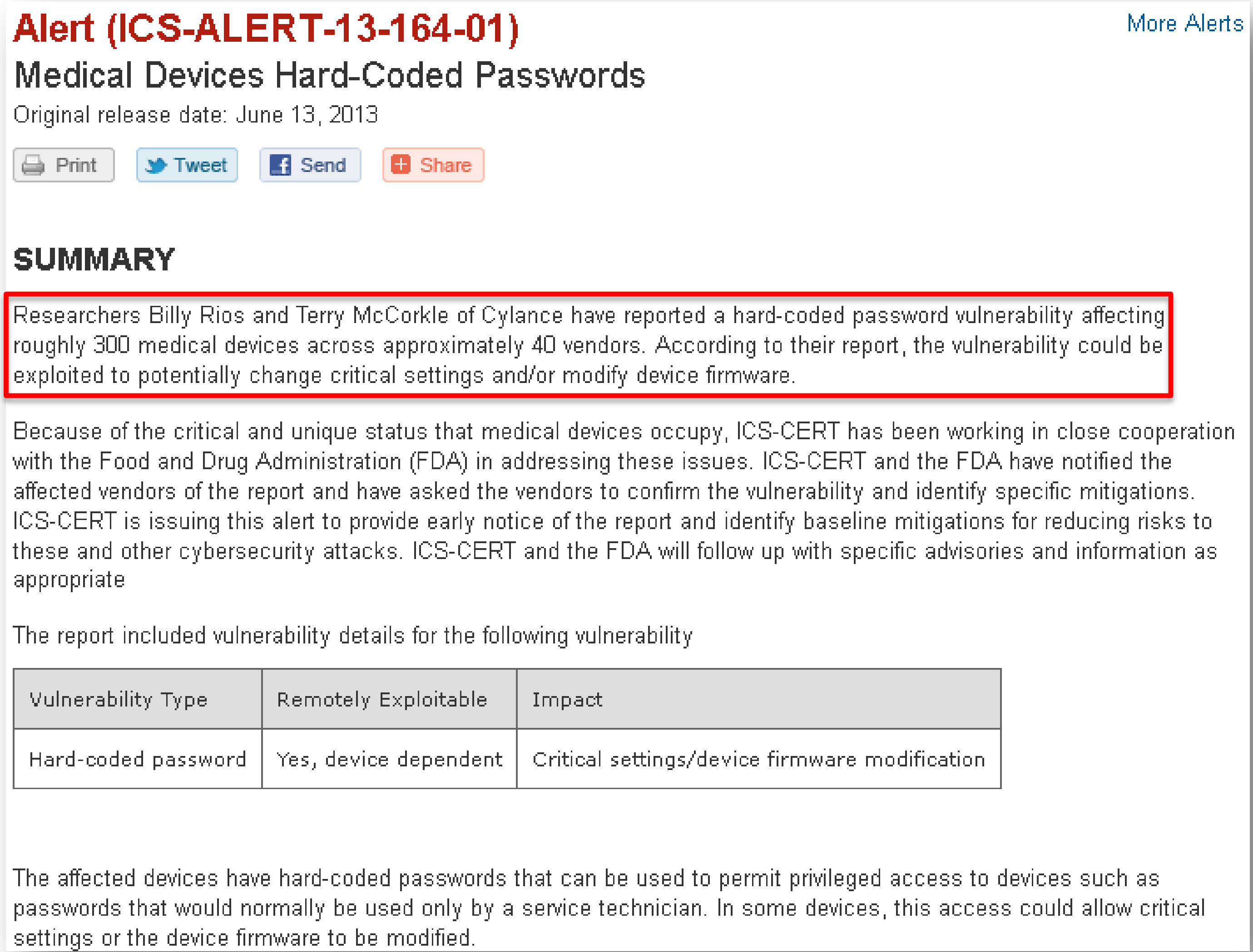


Alert (ICS-ALERT-13-164-01)

Medical Devices Hard-Coded Passwords

Original release date: June 13, 2013

SUMMARY

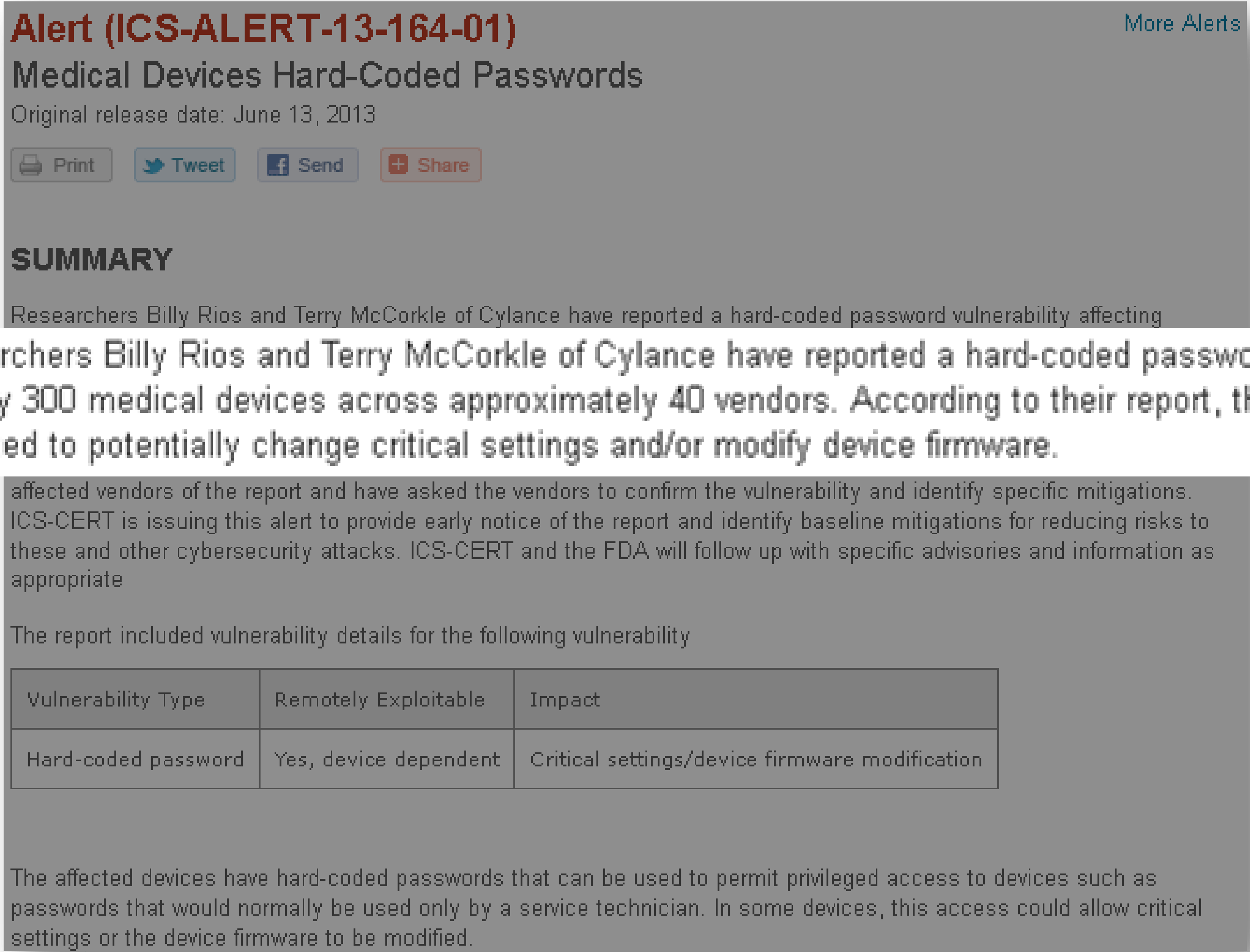
Researchers Billy Rios and Terry McCorkle of Cylance have reported a hard-coded password vulnerability affecting roughly 300 medical devices across approximately 40 vendors. According to their report, the vulnerability could be exploited to potentially change critical settings and/or modify device firmware.

Because of the critical and unique status that medical devices occupy, ICS-CERT has been working in close cooperation with the Food and Drug Administration (FDA) in addressing these issues. ICS-CERT and the FDA have notified the affected vendors of the report and have asked the vendors to confirm the vulnerability and identify specific mitigations. ICS-CERT is issuing this alert to provide early notice of the report and identify baseline mitigations for reducing risks to these and other cybersecurity attacks. ICS-CERT and the FDA will follow up with specific advisories and information as appropriate

The report included vulnerability details for the following vulnerability

Vulnerability Type	Remotely Exploitable	Impact
Hard-coded password	Yes, device dependent	Critical settings/device firmware modification

The affected devices have hard-coded passwords that can be used to permit privileged access to devices such as passwords that would normally be used only by a service technician. In some devices, this access could allow critical settings or the device firmware to be modified.



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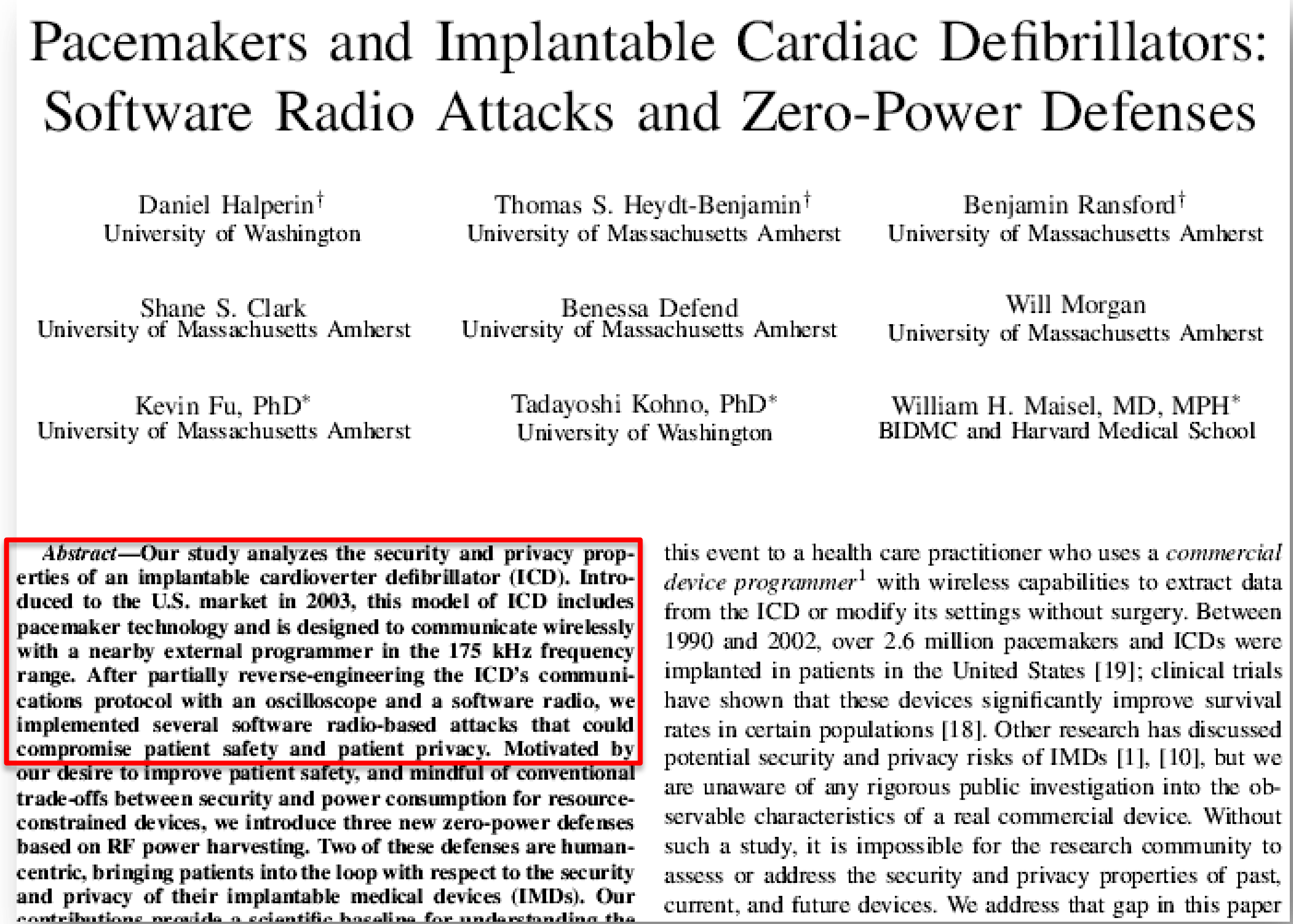

Pacemakers and Implantable Cardiac Defibrillators: Software Radio Attacks and Zero-Power Defenses

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Thomas S. Heydt-Benjamin†
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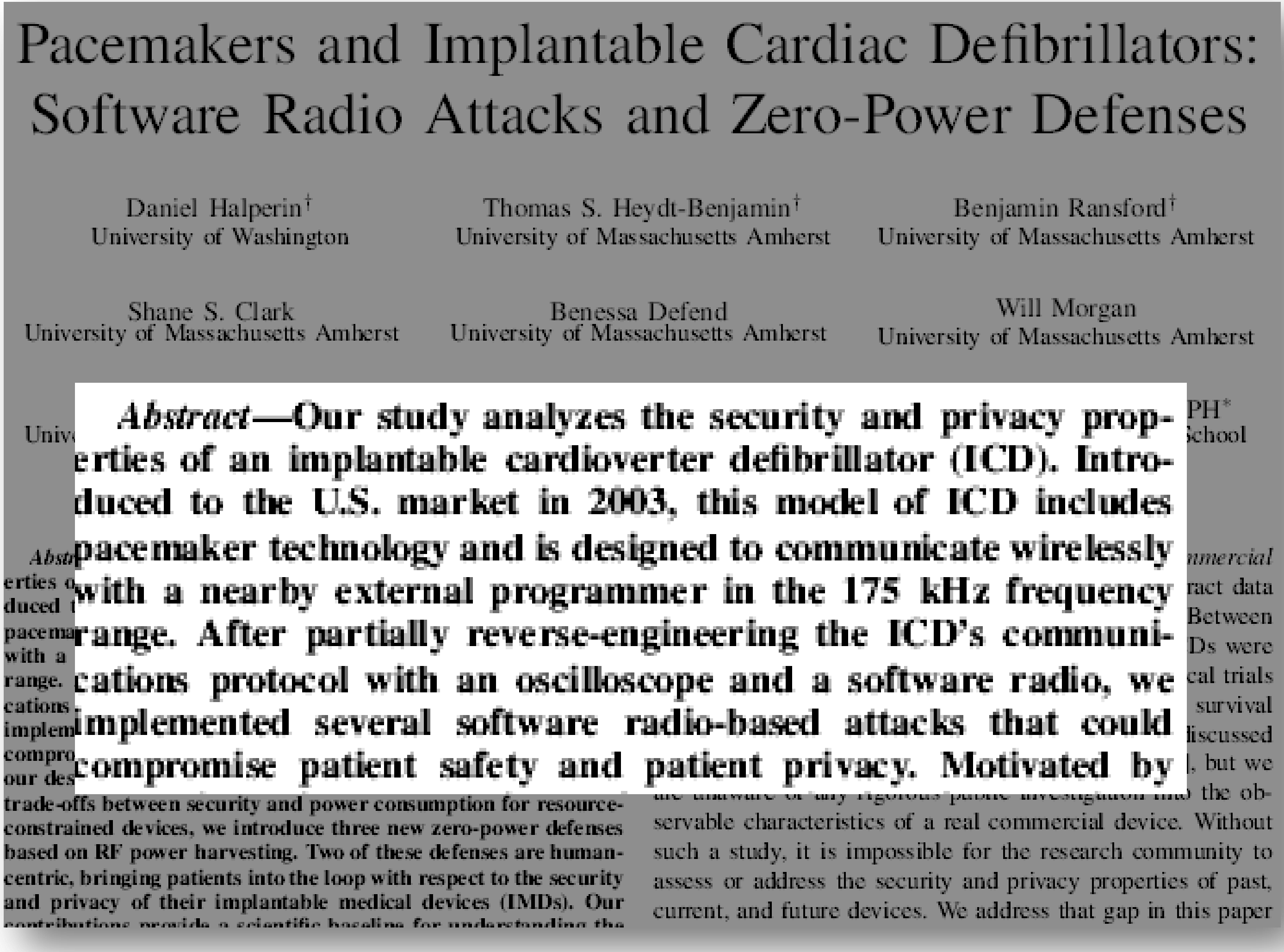
University of Washington

William H. Maisel, MD, MPH*
BIDMC and Harvard Medical School

***Abstract*—Our study analyzes the security and privacy properties of an implantable cardioverter defibrillator (ICD). Introduced to the U.S. market in 2003, this model of ICD includes pacemaker technology and is designed to communicate wirelessly with a nearby external programmer in the 175 kHz frequency range. After partially reverse-engineering the ICD's communications protocol with an oscilloscope and a software radio, we implemented several software radio-based attacks that could compromise patient safety and patient privacy. Motivated by our desire to improve patient safety, and mindful of conventional trade-offs between security and power consumption for resource-constrained devices, we introduce three new zero-power defenses based on RF power harvesting. Two of these defenses are human-centric, bringing patients into the loop with respect to the security and privacy of their implantable medical devices (IMDs). Our contributions provide a scientific baseline for understanding the**

this event to a health care practitioner who uses a *commercial device programmer*[1] with wireless capabilities to extract data from the ICD or modify its settings without surgery. Between 1990 and 2002, over 2.6 million pacemakers and ICDs were implanted in patients in the United States [19]; clinical trials have shown that these devices significantly improve survival rates in certain populations [18]. Other research has discussed potential security and privacy risks of IMDs [1], [10], but we are unaware of any rigorous public investigation into the observable characteristics of a real commercial device. Without such a study, it is impossible for the research community to assess or address the security and privacy properties of past, current, and future devices. We address that gap in this paper



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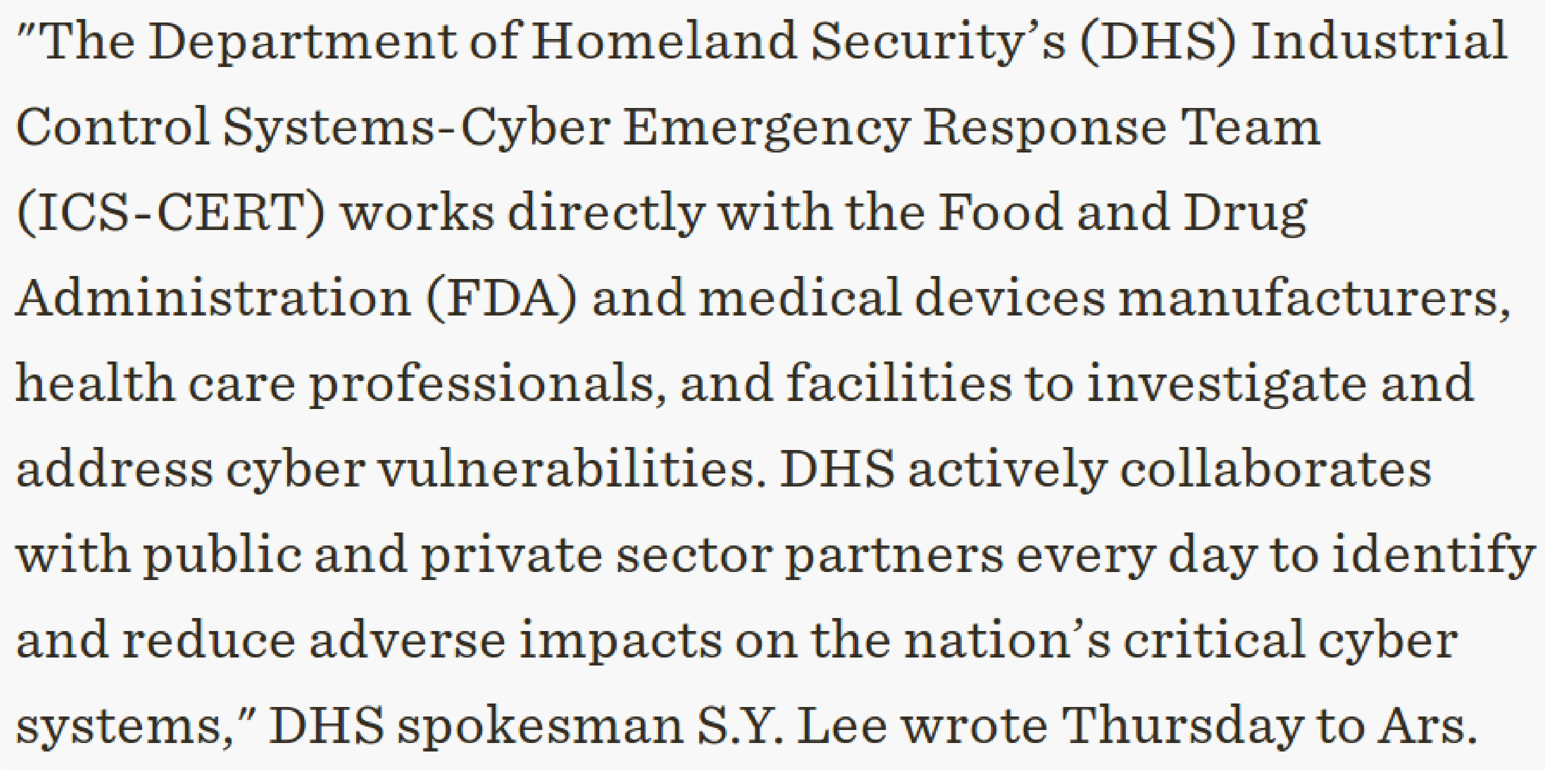
http://arstechnica.com/tech-policy/2014/10/feds-examining-medical-devices-for-fatal-cybersecurity-flaws/



"The Department of Homeland Security's (DHS) Industrial Control Systems-Cyber Emergency Response Team (ICS-CERT) works directly with the Food and Drug Administration (FDA) and medical devices manufacturers, health care professionals, and facilities to investigate and address cyber vulnerabilities. DHS actively collaborates with public and private sector partners every day to identify and reduce adverse impacts on the nation's critical cyber systems," DHS spokesman S.Y. Lee wrote Thursday to Ars.

The Problem

Anamnesis …

Siemens Sirecust BS1

In the old days ...

Nihon Kohden Neurofax EEG

In the old days ...

The Change

- Optimization of processes
  - Good or bad?
- New com options available
  - Lowering costs
- Especially on Intensive Care Units (ICUs)
- Interoperability
  - E-Health records
  - PACS
  - Personal Health

The Gathering

Standard anesthesia devices

Are we Ready?

- What about IT in hospitals?
  - Resources / Know-how
  - Different types of networks
    - Doctors
    - Patients
    - Devices
    - Guests
    - Research
  - “Semi-New” technologies on the rise -> No experience
  - Remote maintenance (non-optional?)

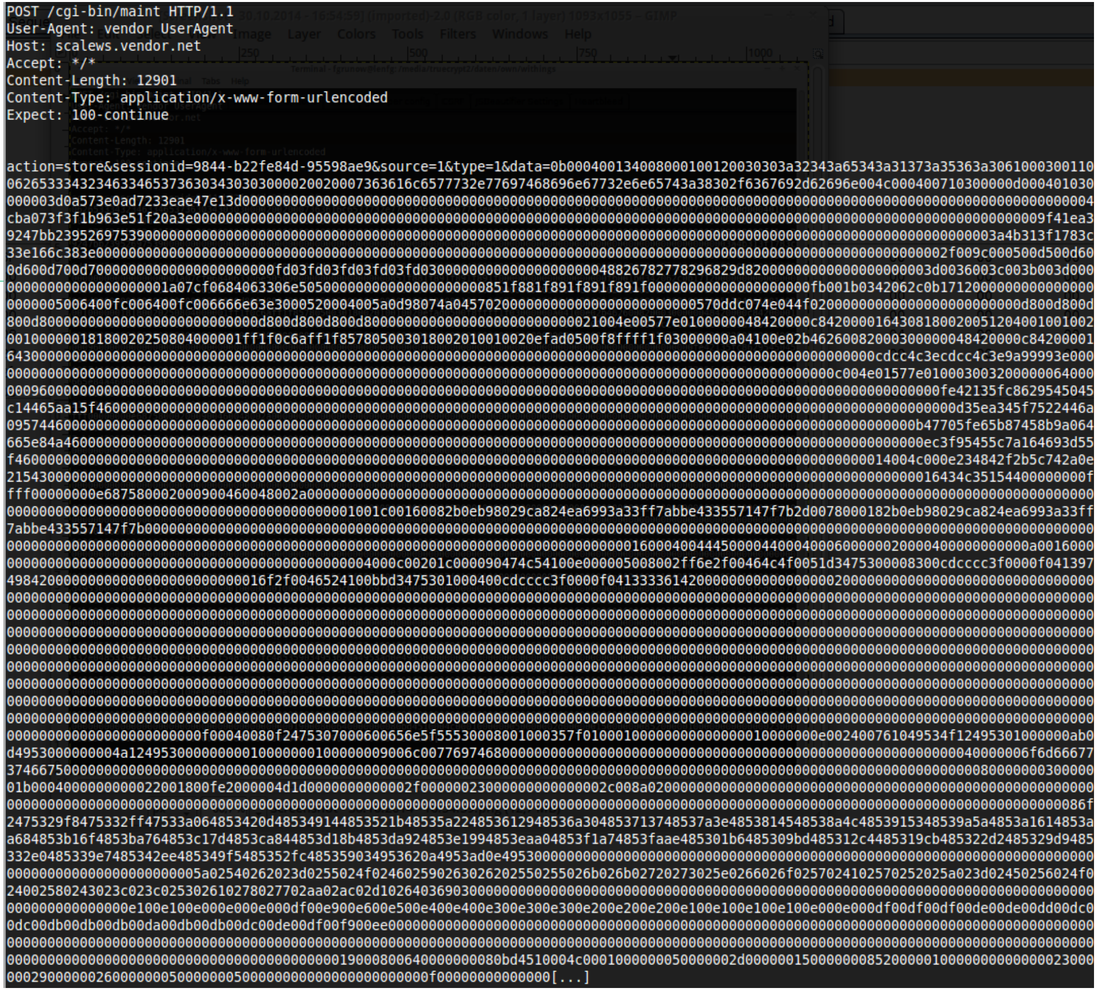
Are we Ready?

- What about home monitoring?
  - Devices for personal health
  - Transmitting wireless / Upload to provider
  - Need to be integrated without hassle
    - What could possibly go wrong?
    - Think pre-calculated encryption keys in home routers
  - Must not be expensive
  - Privacy?

The Scale

Home Monitoring

Privacy?



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User-Agent: vendor UserAgent
Host: scalews.vendor.net
Accept: */*
Content-Length: 12901
Content-Type: application/x-www-form-urlencoded
Expect: 100-continue

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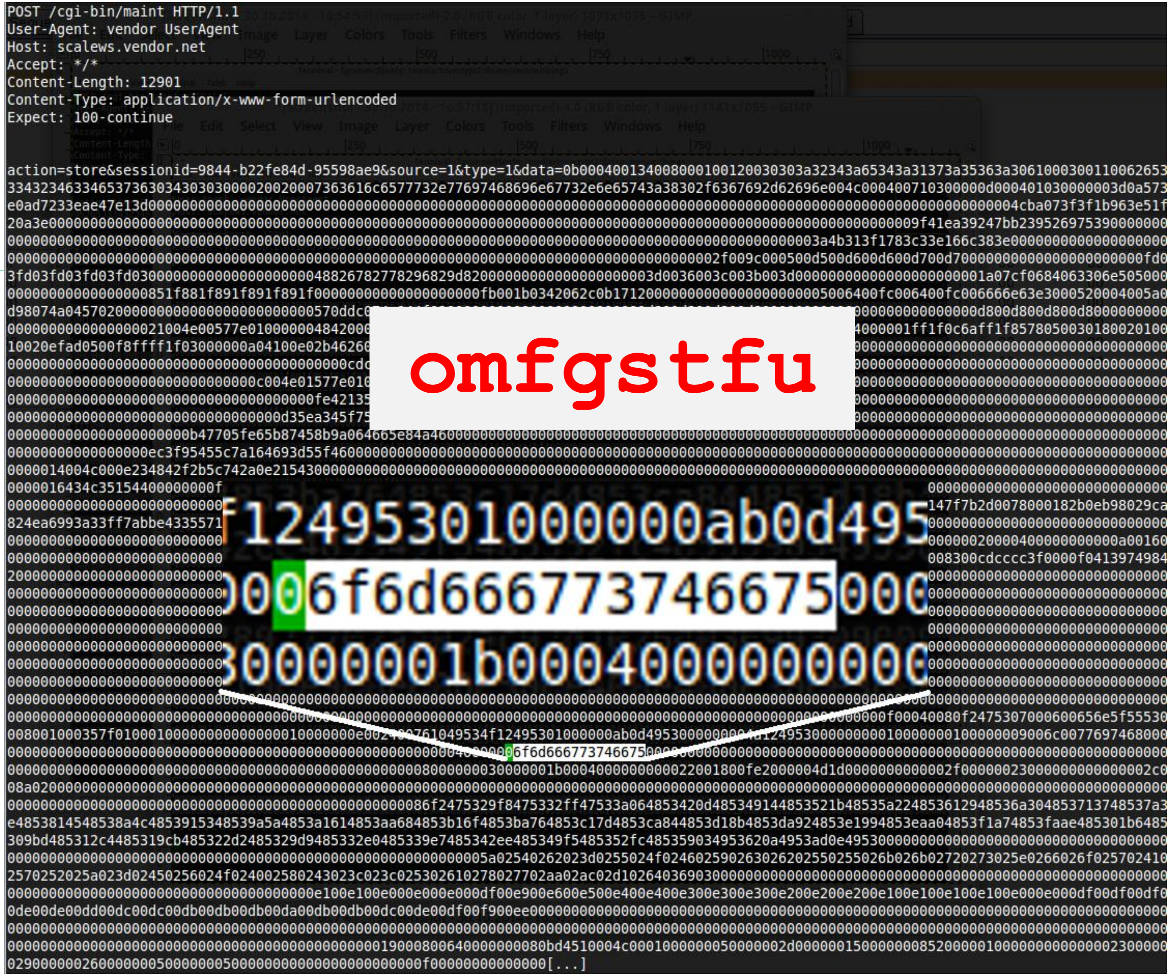
Privacy?

HTTP!



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Are they Ready?

- What about the vendors?
  - Same mistakes again?
  - Learning curve
    - WiFi
    - Car keys
    - Exploiting like in the old days?
  - “We are not really using this port, the board came with it!“
  - “We are fine, we have two network interfaces (trusted/untrusted)!”

What is Important for Compliance?

- Focus is on safety not security
  - Especially important in Germany
  - We do not even have these words …
  - Safety mostly works
    - Still have bugs like: "Device showing asystole alarm when patient is fine"
  - Does security?
    - "We only need to make sure that there are proper authorization mechanisms …"
    - "A hacker will always find a way …"
    - "510(k) assumes there is no hostile environment, doctor will not harm patient, patient will not harm himself or doctor"
  - Certification
    - Focus on safety, too

Problem Summary

- Little resources on customer´s side
- Little experience with incidents on vendor/hospital side
- Safety vs. Security

→ This could kill you!

Targets

What are we looking at?

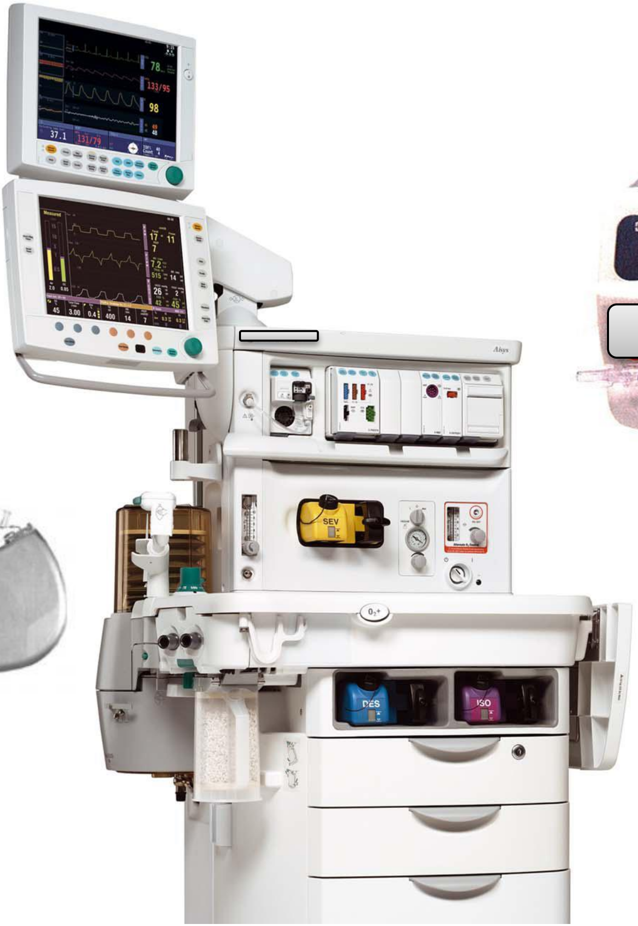
Targets

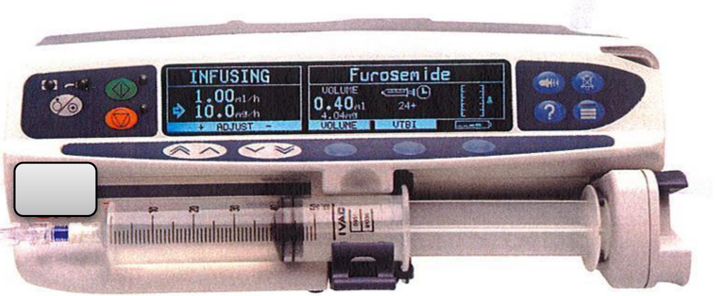
- Medical devices with enabled com
  - Com is in places you would never suspect
- “Severity Rating”:
  - Low: Monitoring stuff
  - Medium: Diagnostic systems
  - High: Feedback to patient

Monitoring

Diagnostic

Feedback


SEV
DES
ISO


INFUSING
1.00 ml/h
10.0 mg/h
ADJUST
Furosemide
VOLUME
0.40 ml
4.04mg
24+
VOLUME
VTBI
IVAC

Targets

- Hard to get hands on devices
- Vendors have little interest?
  - Lack of experience?
- Expensive
- Cooperations
  - What about liability?

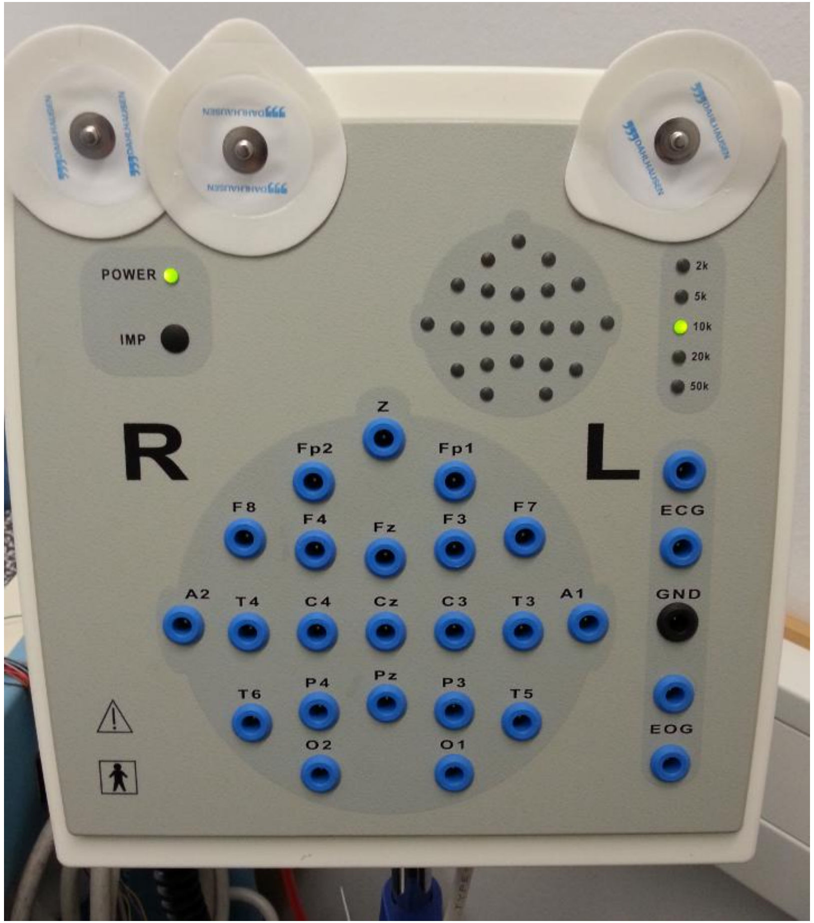
→ Hard to test!

Targets

What we looked at so far …

Target Example: EEG

- Measures “brain waves”
- Used in small/medium sized medical offices
- Grey box and software on a host
- Communication via LAN
  - Can be deployed in different rooms
- Grey box <- UDP -> Host
- No auth, no encryption, no security
- Full remote control of the box



Target example: EEG

Box for electrodes

Off-Topic for a Second …

- OpenEEG project
- Build your own EEG
- Do crazy Biofeedback stuff
- Brain-to-computer interface

DIY: EEG

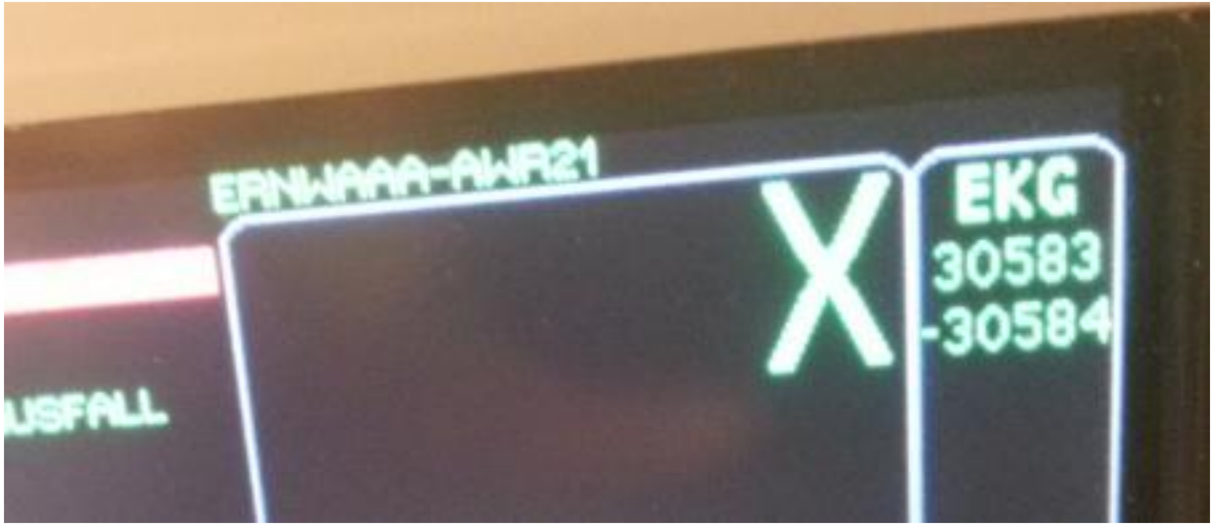
OpenEEG Project

Disclaimer

There will be no details yet on how the exploits work as this might pose a threat to life or the physical condition of patients!

Target: Patient Monitor 1

- Widely used in hospitals
  - ICU
  - During operation
- Monitors critical vital signs
  - SPO2
  - Blood Pressure
  - ECG
  - Temperature
  - Respiration
  - More …



Target: Patient Monitor 1

Unreasonable Configuration

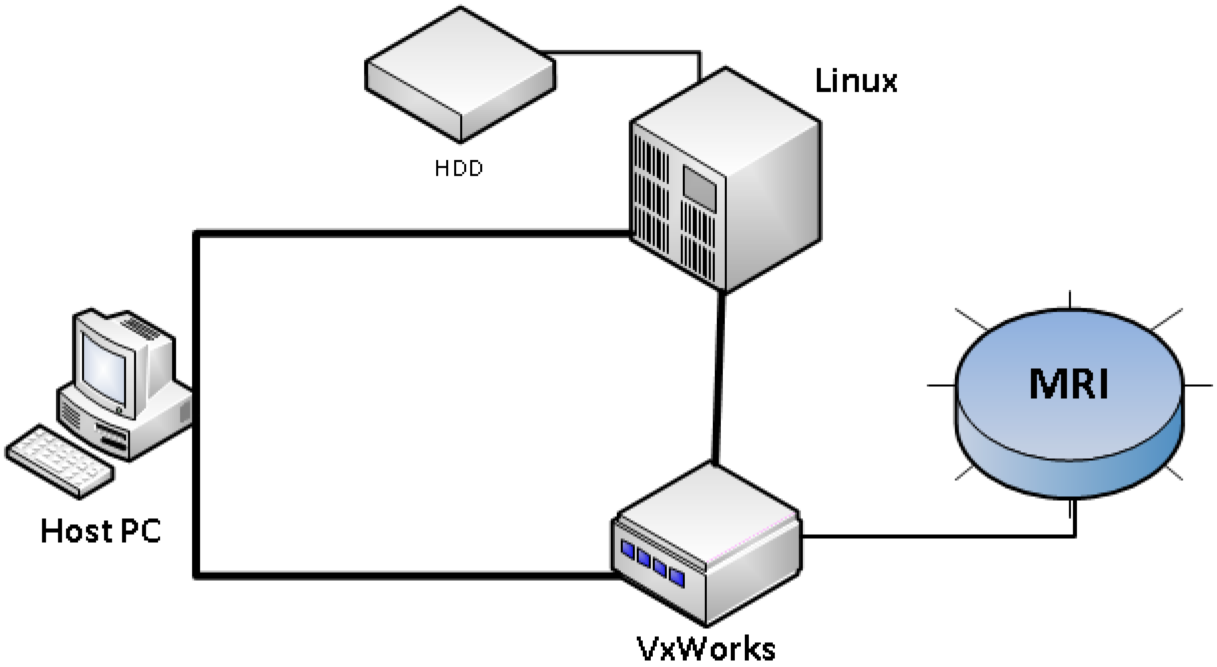
Target: MRI

- Really cool! ☺

Target: MRI

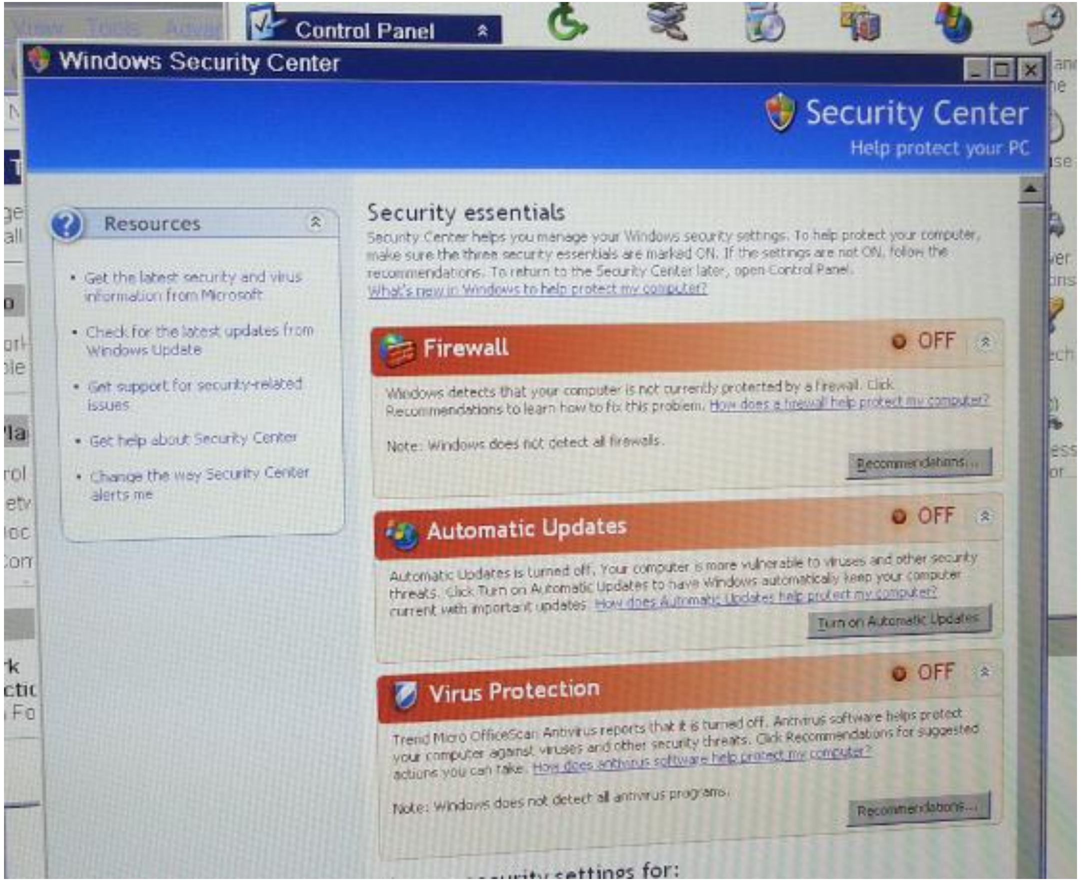
- Consists of:
  - Host System
    - Windows based PC
  - Image Processing System
    - Retrieves the raw data and constructs images
  - Control System
    - Controls hardware of the MRI (basically patient table, coils, etc.)

Target: MRI



Target: MRI

- Host System



Resources

- Get the latest security and virus information from Microsoft
- Check for the latest updates from Windows Update
- Get support for security-related issues
- Get help about Security Center
- Change the way Security Center alerts me

Security essentials

Security Center helps you manage your Windows security settings. To help protect your computer, make sure the three security essentials are marked ON. If the settings are not ON, follow the recommendations. To return to the Security Center later, open Control Panel.
What's new in Windows to help protect my computer?

Firewall ● OFF

Windows detects that your computer is not currently protected by a firewall. Click Recommendations to learn how to fix this problem. How does a firewall help protect my computer?

Note: Windows does not detect all firewalls.

Recommendations...

Automatic Updates ● OFF

Automatic Updates is turned off. Your computer is more vulnerable to viruses and other security threats. Click Turn on Automatic Updates to have Windows automatically keep your computer current with important updates. How does Automatic Updates help protect my computer?

Turn on Automatic Updates

Virus Protection ● OFF

Trend Micro OfficeScan Antivirus reports that it is turned off. Antivirus software helps protect your computer against viruses and other security threats. Click Recommendations for suggested actions you can take. How does antivirus software help protect my computer?

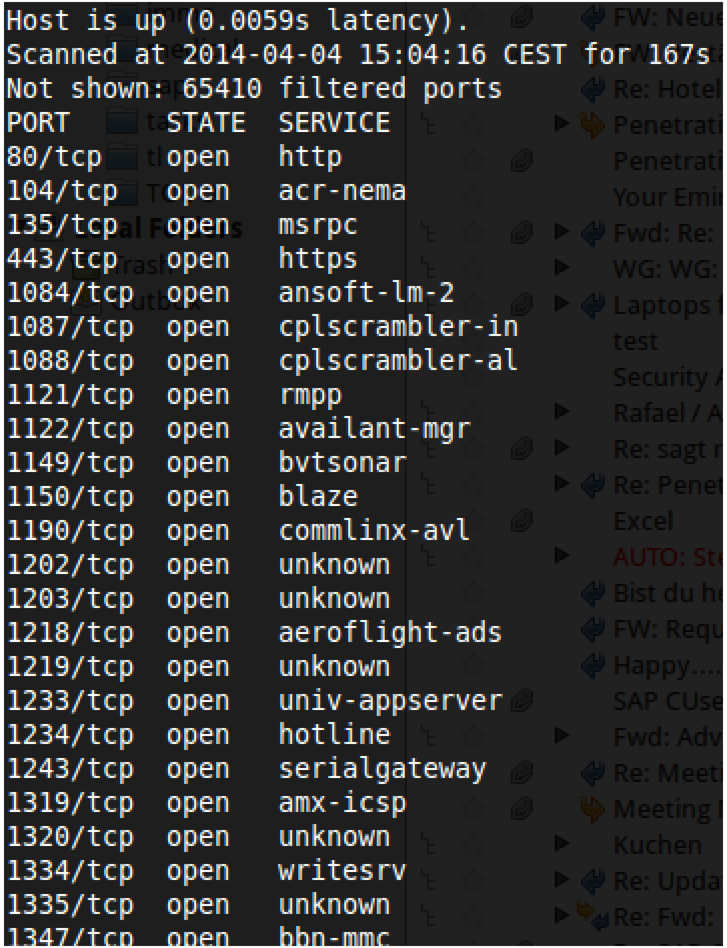
Note: Windows does not detect all antivirus programs.

Recommendations...

security settings for:

Target: MRI

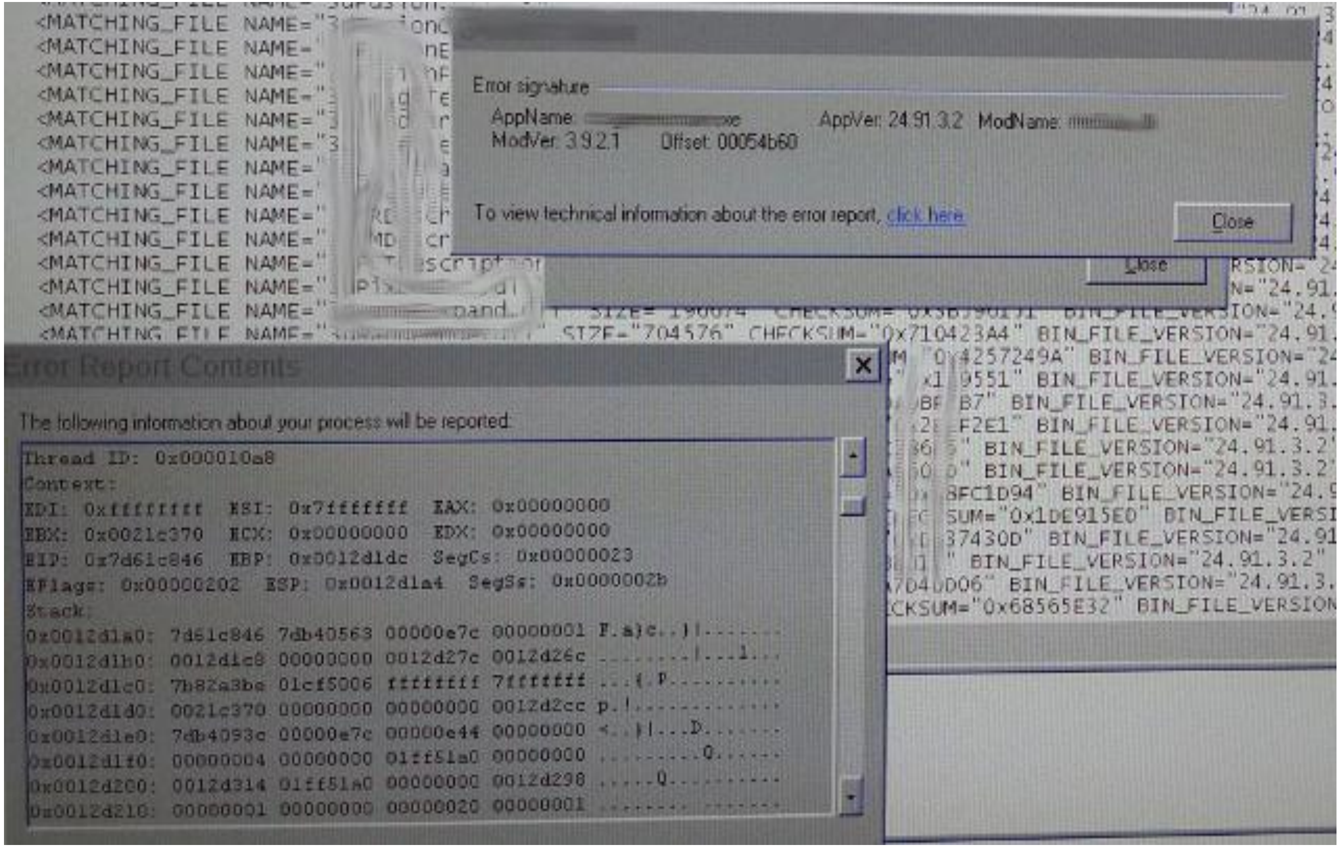
- Host System
- Open Ports: 114



```
Host is up (0.0059s latency).
Scanned at 2014-04-04 15:04:16 CEST for 167s
Not shown: 65410 filtered ports
PORT      STATE  SERVICE
80/tcp    open   http
104/tcp   open   acr-nema
135/tcp   open   msrpc
443/tcp   open   https
1084/tcp  open   ansoft-lm-2
1087/tcp  open   cplscrambler-in
1088/tcp  open   cplscrambler-al
1121/tcp  open   rmpp
1122/tcp  open   availant-mgr
1149/tcp  open   bvtsonar
1150/tcp  open   blaze
1190/tcp  open   commlinx-avl
1202/tcp  open   unknown
1203/tcp  open   unknown
1218/tcp  open   aeroflight-ads
1219/tcp  open   unknown
1233/tcp  open   univ-appserver
1234/tcp  open   hotline
1243/tcp  open   serialgateway
1319/tcp  open   amx-icsp
1320/tcp  open   unknown
1334/tcp  open   writesrv
1335/tcp  open   unknown
1347/tcp  open   bbn-mmc
```

Target: MRI

- Host System
- After portscan



```
<MATCHING_FILE NAME=" [redacted]
<MATCHING_FILE NAME=
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME=
<MATCHING_FILE NAME=
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
<MATCHING_FILE NAME="
```

Error signature

AppName: [redacted] AppVer: 24.91.3.2 ModName: [redacted]
ModVer: 3.9.2.1 Offset: 00054b60

To view technical information about the error report, click here

Close

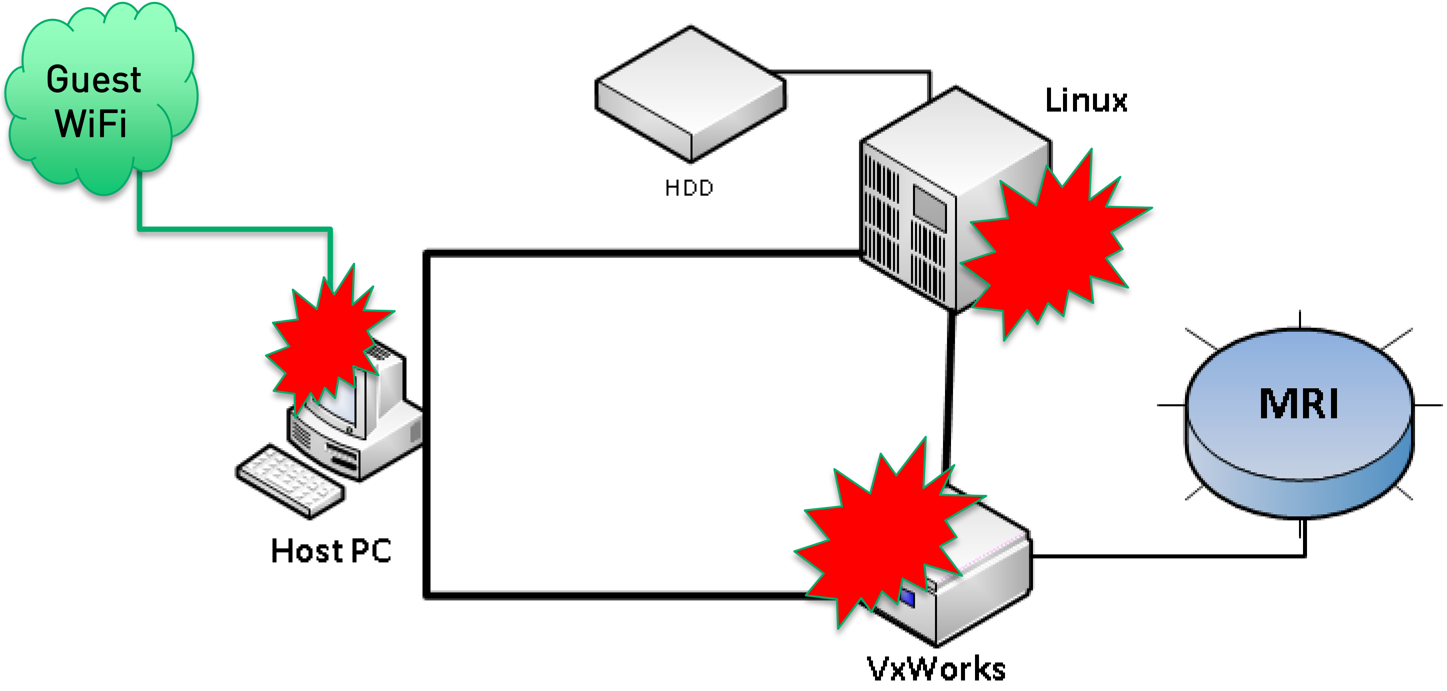
Error Report Contents

The following information about your process will be reported:

```
Thread ID: 0x000010a8
Context:
EDI: 0xffffffff  ESI: 0x7fffffff  EAX: 0x00000000
EBX: 0x0021c370  ECX: 0x00000000  EDX: 0x00000000
EIP: 0x7d61c846  EBP: 0x0012d1dc  SegCs: 0x00000023
EFlags: 0x00000202  ESP: 0x0012d1a4  SegSs: 0x0000002b
Stack:
0x0012d1a0: 7d61c846 7db40563 00000e7c 00000001 F.a}c..}|.......
0x0012d1b0: 0012d1c8 00000000 0012d27c 0012d26c ........|...l...
0x0012d1c0: 7b82a3be 01cf5006 ffffffff 7fffffff ...{.P..........
0x0012d1d0: 0021c370 00000000 00000000 0012d2cc p.!.............
0x0012d1e0: 7db4093c 00000e7c 00000e44 00000000 <..}|...D.......
0x0012d1f0: 00000004 00000000 01ff51a0 00000000 .........Q......
0x0012d200: 0012d314 01ff51a0 00000000 0012d298 .....Q..........
0x0012d210: 00000001 00000000 00000020 00000001 ................
```

```
SIZE="704576" CHECKSUM="0x710423A4" BIN_FILE_VERSION="24.91
M "0x4257249A" BIN_FILE_VERSION="24
x1 9551" BIN_FILE_VERSION="24.91.
BF B7" BIN_FILE_VERSION="24.91.3.
2 F2E1" BIN_FILE_VERSION="24.91.
" BIN_FILE_VERSION="24.91.3.2"
" BIN_FILE_VERSION="24.91.3.2"
8FC1D94" BIN_FILE_VERSION="24.9
SUM="0x1DE915E0" BIN_FILE_VERSI
37430D" BIN_FILE_VERSION="24.91
" BIN_FILE_VERSION="24.91.3.2"
7D4 D06" BIN_FILE_VERSION="24.91.3.
CKSUM="0x68565E32" BIN_FILE_VERSION
```

Target: MRI

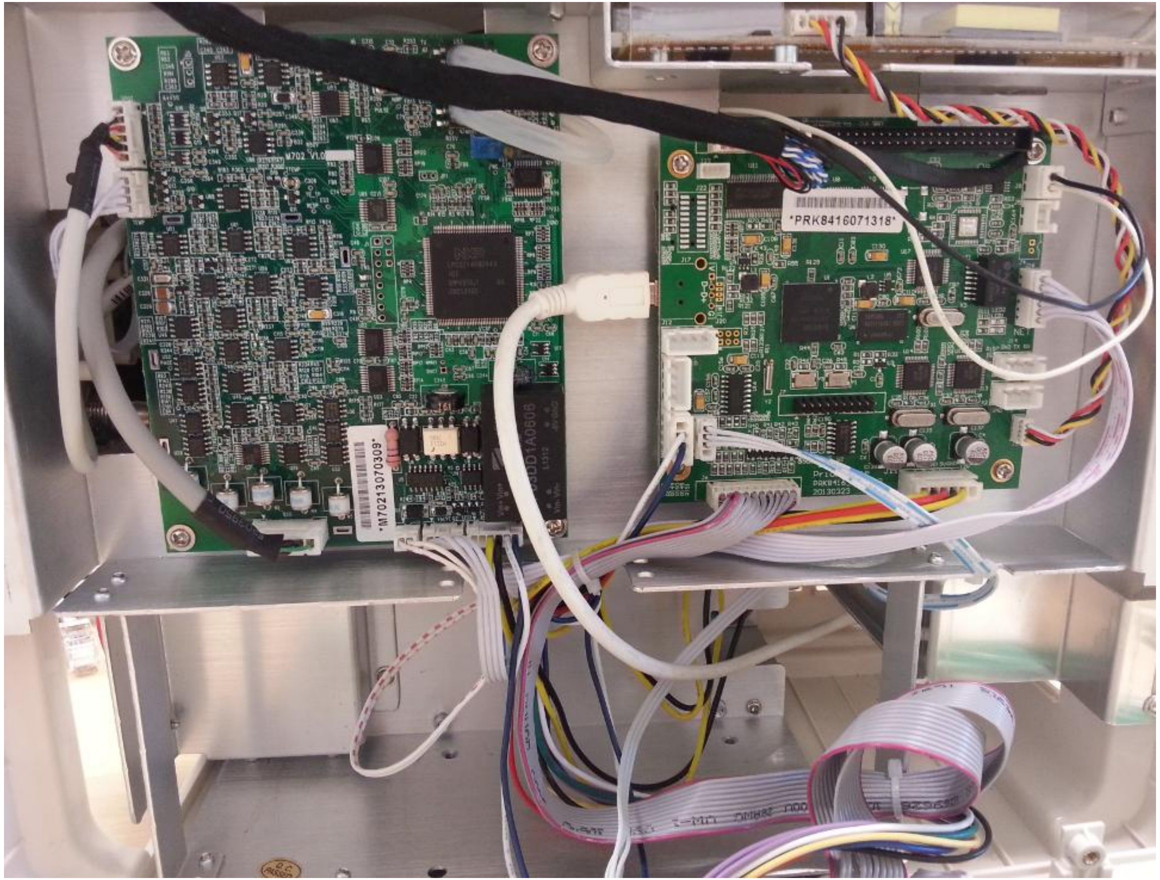


Target: Syringe Pump

Demo: Infusion Override

Target: Patient Monitor 2

- 2 central elements
  - ARM for peripherals and probably signal processing
    - Control the pump for blood pressure
    - Maybe FFT
  - ARM for user interaction
    - RX / TX to the peripheral board
    - ARM926EJ-S @ 400MHz
    - 64MB RAM



Target: Patient Monitor 2

Signal Processing / Frontend

Target: Patient Monitor 2

Demo: Pwning vital signs

Targets

- There is more to come!
  - Cooperations with hospitals
- Information Gathering reveals promising results
  - Radiology Equipment:
    - MRIs
    - X-Rays
  - Hospital Infrastructure
    - Physical Access Control Systems
  - Aneasthesia devices

Final Words …

- We need to test these devices!
- Responsible disclosure process is critical!
- Get your hands dirty! ☺
- There will be more publications from ERNW!

→ Stay tuned!

Questions?

Thank you!

Please consult your doctor or pharmacist for risks and side effects of this presentation …