The Return of Insecure Brazilian Voting Machines

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The Return of Insecure Brazilian Voting Machines

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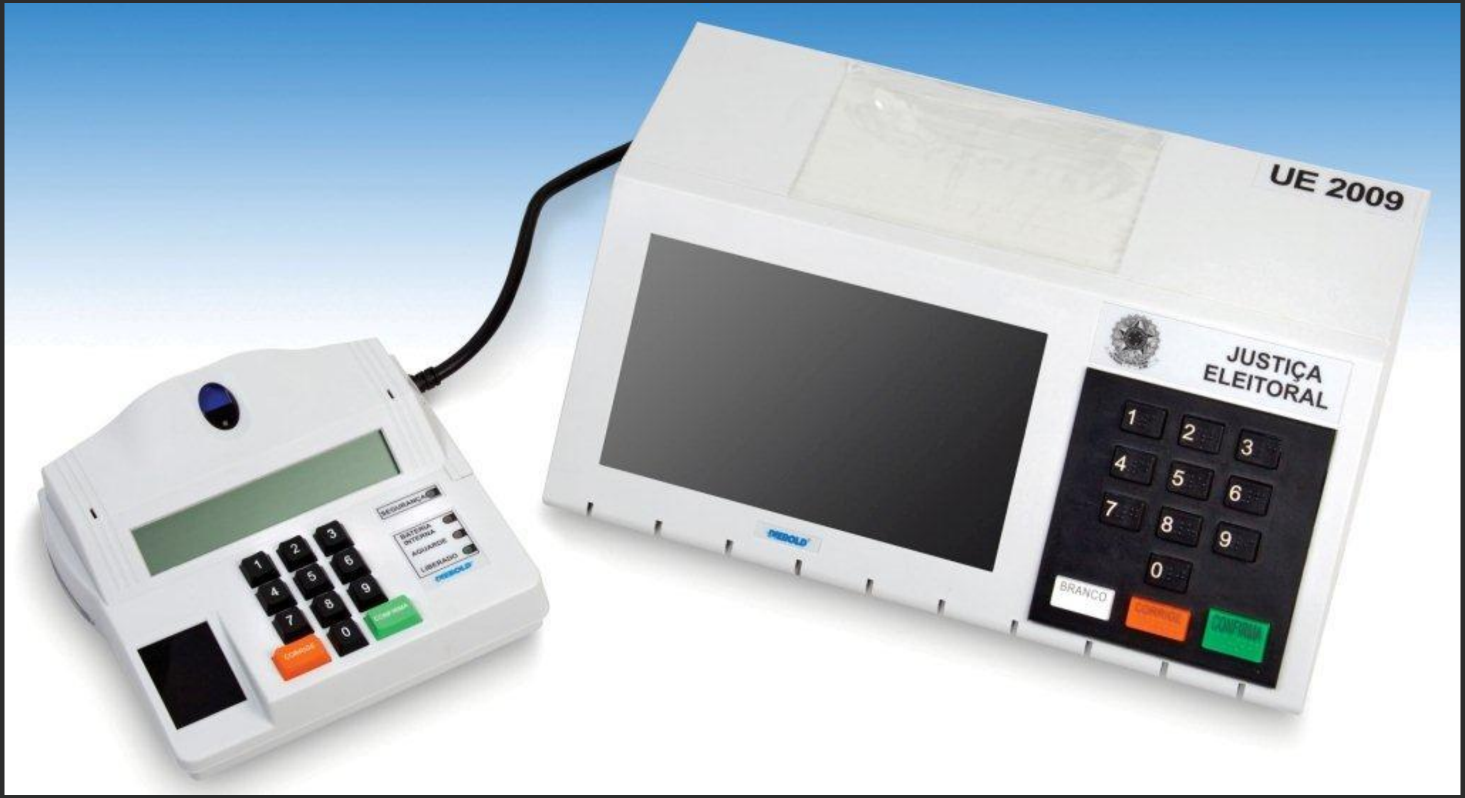
Joint work with Pedro Barbosa, Thiago Cardoso, Caio Lüders, Paulo Matias

Context

Brazilian elections are special:

- Massive (140M voters, 81% turnout)
- Held every 2 years
- Became electronic in 1996 (fully in 2000)
- Controlled/executed/judged by a single entity (SEC - Superior Electoral Court)

Context



Source: Diebold

Context

Brazilian paperless DRE voting machines:

- **Claimed** 100% secure (but only tested in 2012...)
- Hardware manufactured by **Diebold** (> 0.5M)
- Software written by SEC since 2006 (> 24M LOCs)
- Adopted GNU/Linux in 2008 (after **Windows CE...**)
- Experimented with **paper records** in 2002
- Identify 50% of the voters with **fingerprints** since 2011
- Highly vulnerable against **insiders**

Algorithm

1. Software **installation** (a card installs 50 machines)
2. Zero tape **printed** (7-8 AM)
3. Voting session **opened**
4. Votes **cast**
5. Voting session **closed (5PM)** and poll tape **printed**
6. Media **written** with public products (PT, DRV, LOG)
7. Public products **transmitted** to central tabulator

Public Security Tests

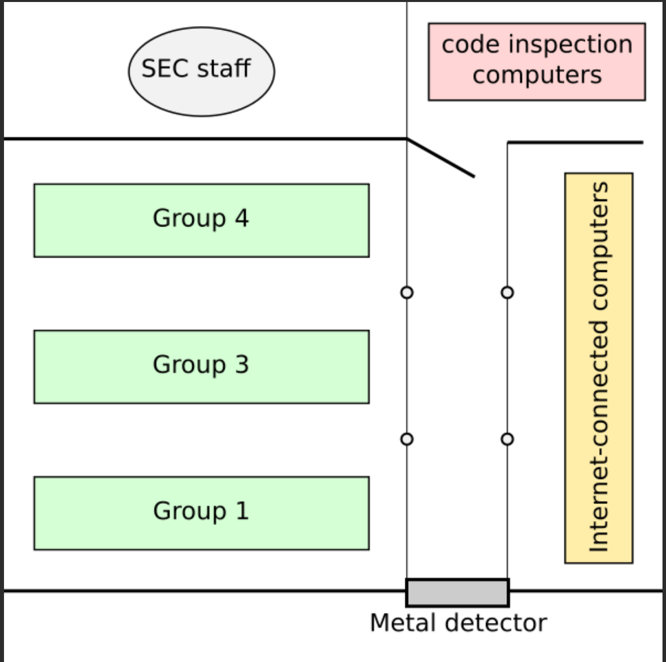
Objective: Untraceable violation of **ballot integrity/privacy**

Extremely restricted tests:

1. No **pen/paper** when inspecting source code
2. Only **3 days** to inspect code and **4 days** to mount attacks
3. Participants needed to be **pre-approved** by SEC
4. Attacks needed to be **pre-approved** by SEC
5. No **guarantees** about software version (correct or recent?)
6. Intrinsic **conflict of interests**

Public Security Tests?

"Brazil is the **only** country to **openly** evaluate its voting system"



Vulnerabilities from 2012

- Serious vulnerability in **vote shuffling mechanism**
- Massive **sharing** and insecure **storage** of keys
- Voting software checks **itself** through signatures
- No **ballot secrecy** or **integrity** of software/results
- **Insecure** development process
- **Inadequate** threat model
- Internal culture lacks **transparency**

Digital Record of the Votes (DRV)

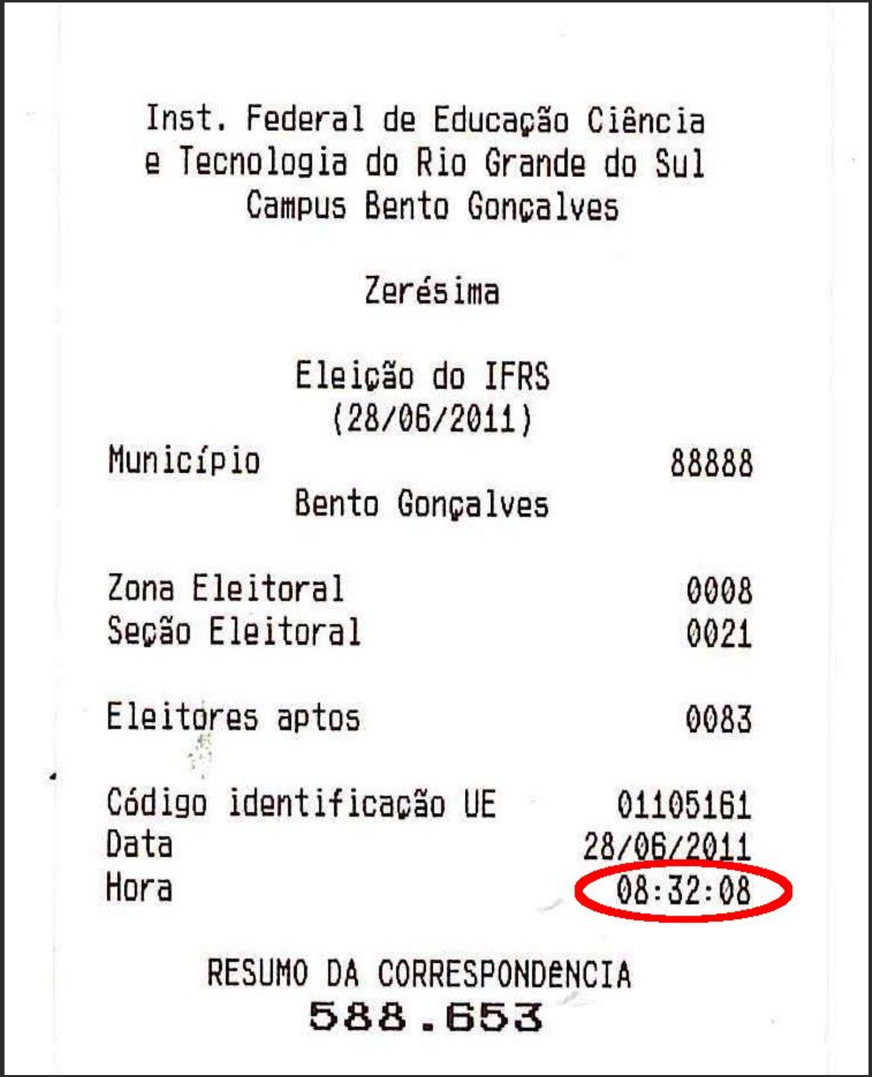
Governor	Senator	President
71	31	37
	BLANK	
13		
71	NULL	
		BLANK
		37

Warning: Advanced Cryptanalysis

```
grep -r rand *
```

Match in DRV.cpp! Seed?

```
srand(time(NULL))
```



Inst. Federal de Educação Ciência
e Tecnologia do Rio Grande do Sul
Campus Bento Gonçalves

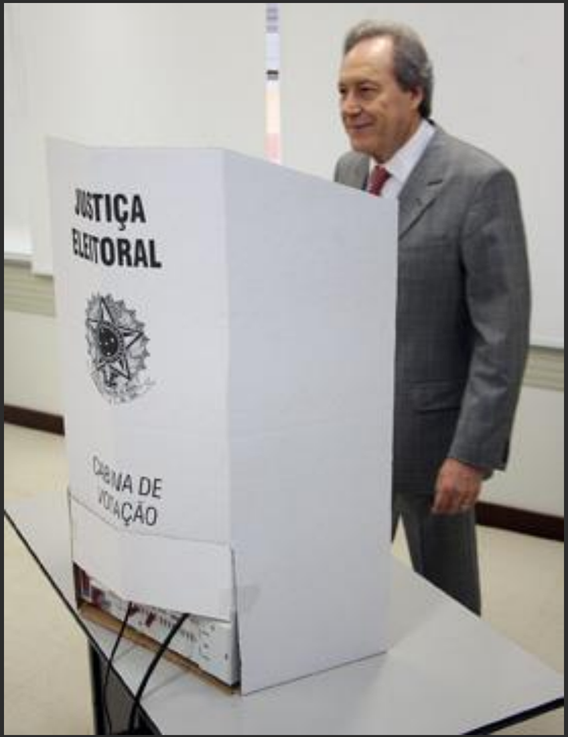
Zerésima

Eleição do IFRS
(28/06/2011)

Município	88888
Bento Gonçalves	
Zona Eleitoral	0008
Seção Eleitoral	0021
Eleitores aptos	0083
Código identificação UE	01105161
Data	28/06/2011
Hora	08:32:08

RESUMO DA CORRESPONDENCIA
588.653

Defense in depth?



```
File 1/1: lew.jpg
File name       : lew.jpg
File size       : 47009 Bytes
MIME type       : image/jpeg
Image size      : 276 x 360
Camera make     : Canon
Camera model    : Canon EOS-1Ds Mark III
Image timestamp : 2010:10:03 11:20:37
```

Conclusions from 2012

- Trivial to recover votes in order
- Trivial to recover a specific vote

Eliminate the DRV and do not store metadata!

"Fixed" by adopting **custom** algorithm with system entropy, although voting machine has **two hardware RNGs**

Installation as attack vector

2017: Researchers would not have access to cryptographic keys...

...but only because they erased them!

```
grep -r KEY *
```

Match in ueminix.c!

```
#define UEMINIX_BLOCK_KEY {0x34, ...}
```

Technical details

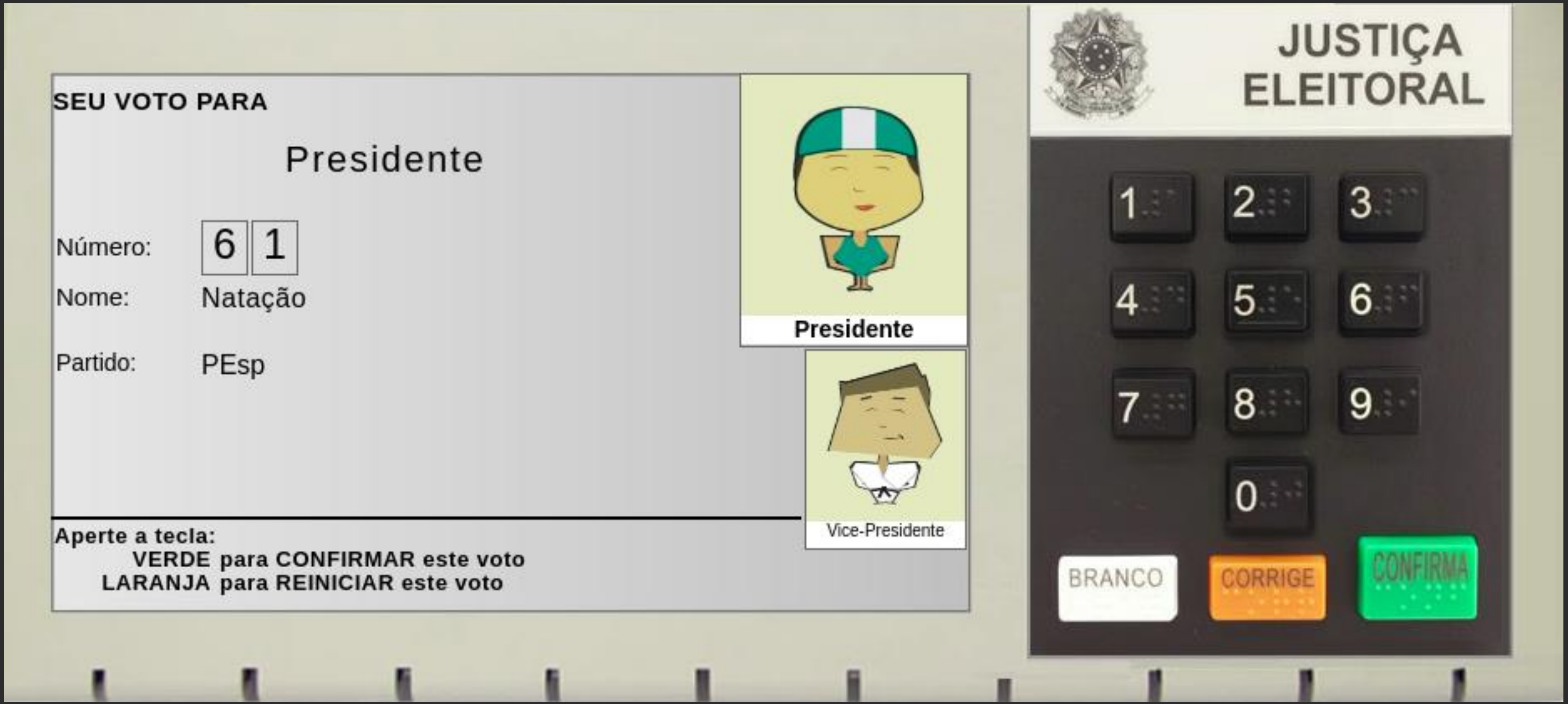
Many deployed cryptographic algorithms:
- Install cards encrypted with AES-XTS-256'
- ECC-based signatures for integrity checking

Signatures both in userland and kernel mode.

Keys for signing **results** also stored in install cards.

There is more!

- Found two shared libraries **without** signatures
- Manipulated **LOG contents**
- Tampered with key generation for **DRV**
- Plugged-in USB keyboard to **issue commands**
- Voting software was **linked** against them
- Changed software version/**screen contents**
- **Arbitrary code injection/execution**



SEU VOTO PARA

Presidente

Número: 6 1

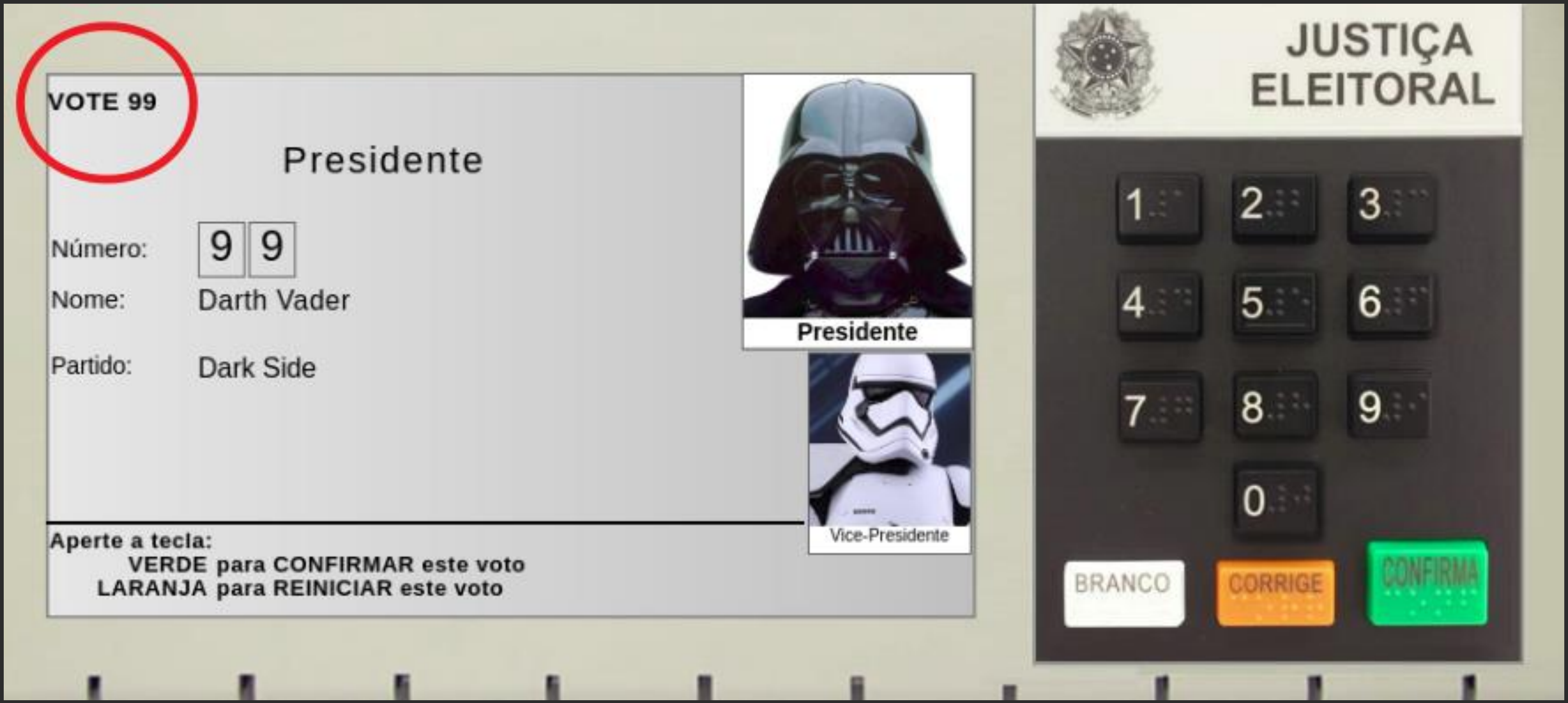
Nome: Natação

Partido: PEsp

Presidente

Vice-Presidente

Aperte a tecla:
VERDE para CONFIRMAR este voto
LARANJA para REINICIAR este voto



VOTE 99

Presidente

Número: 9 9

Nome: Darth Vader

Partido: Dark Side

Aperte a tecla:
VERDE para CONFIRMAR este voto
LARANJA para REINICIAR este voto

Conclusions from 2017

- **Insecure** encryption of install cards
- **Insecure** integrity checking
- Another team found same key without access to source code (**fully external attack**)

Automate signing, deploy proper key management!

"Fixed" by deriving keys from BIOS, still shared by all voting machines and vulnerable to **insiders**.

Current problems

1. Software is **secret** for > 20 years
2. Software is demonstrably **insecure**
3. No paper record for **recount**
4. No effective means to **audit** the system
5. **Conflicts of interest** everywhere
6. **Insider attacks** completely disregarded

Future

1. Voter-Verified Paper Audit Trail for **security**
2. Auditable software for **transparency**
3. Social control mechanisms for **participation**
4. Technical community needs to be **vocal**

With increasing political polarization, it is critical that elections can be **independently verified.**

Thanks! Questions?

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References:

[1] Software vulnerabilities in the Brazilian voting machine.
In: Design, Development, and Use of Secure Electronic Voting Systems (2014)
[2] Crowdsourced integrity verification of election results. (2016)
[3] The Return of Software Vulnerabilities in the Brazilian voting machine. (2018)