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# The Black Box Report

## SECURITY ALERT: July 4, 2005
## Critical Security Issues with Diebold Optical Scan Design

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Special thanks to Kalle Kaukonen for pre-publication review

On behalf of Black Box Voting, Inc.
A nonprofit, nonpartisan, 501c(3) consumer protection group for elections

# Executive Summary

The findings of this study indicate that the architecture of the Diebold Precinct-Based Optical Scan 1.94w voting system inherently supports the alteration of its basic functionality, and thus the alteration of the produced results each time an election is prepared.

The fundamental design of the Diebold Precinct-Based Optical Scan 1.94w system (AV OS) includes the optical scan machine, with an embedded system containing firmware, and the removable media (memory card), which should contain only the ballot box, the ballot design and the race definitions, but also contains a living thing – an executable program which acts on the vote data. Changing this executable program on the memory card can change the way the optical scan machine functions and the way the votes are reported. The system won't work without this program on the memory card. Whereas we would expect to see vote data in a sealed, passive environment, this system places votes into an open active environment.

With this architecture, every time an election is conducted it is necessary to reinstall part of the functionality into the Optical Scan system via memory card, making it possible to introduce program functions (either authorized or unauthorized), either wholesale or in a targeted manner, with no way to verify that the certified or even standard functionality is maintained from one voting machine to the next.

## Scope of these security issues

While recognizing that no security system is capable of defeating all conceivable or theoretical threats, even fifteen years ago (when the 1990 Federal Election Commission Standards were developed) vendors and election authorities were expected to "do everything that prudence dictates, and that the available resources permit, to institute a security program."

The 1990 FEC Standards, used to certify the system which is the subject of this study, required vendors to "obtain an acceptable level of confidence in the integrity, reliability, and inviolability of the entire election process." To accomplish this, according to the FEC Standards, vendors and election authorities are required to:

- protect the system from intentional, fraudulent manipulation, and from malicious mischief; and
- identify fraudulent or erroneous changes to the system.

Within the context of expected security responsibilities, one layer of security should be preventive cost factors. While the system will always be breakable, the feasibility of penetration should be inhibited by the cost of such an endeavor. What the author has identified, however, is an exceptionally flexible one-man exploit requiring only a few hundred dollars, mediocre technical ability, and modest persuasive skills (or, in lieu of persuasive skills, just a touch of inside access).

In the author's opinion the greatest problem in the system under review is the very design and architecture itself. Incorporated into the foundation of the Diebold Precinct-Based Optical Scan 1.94w system is the mother of security holes, and no apparent cure will produce infertility, or system safety.

This design would not appropriately be characterized as "a house with the door open." The design of the Diebold Precinct-Based Optical Scan 1.94w system is, in the author's own view, more akin to "a house with an unlockable revolving door."

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# Foreword

The word "security" in general usage is synonymous with "safety," but as a technical term "security" means that something is not only secure but that it has *been secured*.

Sir Karl Popper, generally regarded as one of the greatest philosophers of science of the 20th century, defined security: *"When our expectations are met, we can say that quality has been met. When our expectations are met once and again, despite errors, catastrophes and attacks which in principle could prevent our expectations to be met, we can say that security has been met. Security is not falsifiable."*

When more clarity as to the true meaning of the term is needed, refer to U.S. Federal Standard 1037C entitled "Telecommunications: Glossary of Telecommunication Terms," issued by the General Services Administration pursuant to the Federal Property and Administrative Services Act of 1949, as amended. [(1)]

## Security Through Obscurity?

In computer security, the idea "security through obscurity" (or "security by obscurity") has always been a controversial -- and nowadays almost univocally unacceptable principle in security engineering. It is often considered as a good joke. It relies on the use of secrecy of design and implementation to achieve a feeling of security. A system relying on security through obscurity may have serious security vulnerabilities, while its owners and designers wish that simply by not informing others of the flaws, no attacker will find them. This approach only creates an illusion of security. A classic example would be hiding a spare key under the doormat in case you get locked out of your house. Then you would be relying on "security through obscurity," reasoning that no burglar will ever look under the doormat, simply because you have not informed them about the hidden key.

## Defense in Depth

Neither should one assume that security can be assessed as a sum of its parts. More often, the true strength of security can be found in the strength of its weakest link. Therefore, true security can only be achieved through a framework concept of "defense in depth." Defense in depth is the proposition that a design invoking multiple layers of security is better than a single-layer protection mechanism. One should also always assume that some number of layers will be breached, and that systems might fail. Built-in mechanisms should be designed into the system to compensate for these failures. Layers in this context include, but are not limited to, technologies, operations, procedures and policies.

Protecting the perimeter alone is never sufficient protection. The perimeter is merely a part of the holistic security approach.

Equally important are the post mortem measures for these layers: how the system will detect the breach, contain the damage, trigger the alerts and facilitate the recovery. A noteworthy document by the National Security Agency entitled "Defense in Depth"[(2)] is recommended to the reader.

## Each Layer of Security Must Stand Alone

The reader of this document should put this document and the information it contains, which is ***provided for educational purposes only***, in the right context. Only awareness of the flaws will facilitate development of the countermeasures needed to hamper the effectiveness of the attack vectors. If the layers of protection are interconnected and relying on each other they are not true layers – it is just a one-layer system which is only as strong as its weakest point. Also bear in mind that layer interaction removes the layer separation. Therefore, a proper security analysis should always begin with the assumption that the previous layer has been compromised.

If that assumption cannot be made, the layers are interconnected and the dominoes will fall.

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# Contents



Diebold voting systems contain a number of attack vectors. This report pertains to memory card attacks. Details on the following attack vectors *are not included in this report*, and they will be the focus of other reports:

1. **Central Tabulator attacks**: Black Box Voting and the film crew for Votergate.tv, with security experts Mr. Harri Hursti and Dr. Herbert Thompson, conducted field testing in Leon County, successfully penetrating the central tabulator to change vote data using a Visual Basic script. Dr. Thompson has also developed a similar attack using a Java script. The specific procedures used by Dr. Thompson and the scripts themselves, are not part of this report.

2. **Remote Access attacks**: The Diebold system is vulnerable to remote access attack, including, but not limited to, exploitation of proprietary protocols in the optical scan system and a variety of exploits with port/socket TCP/3032, which is activated from GEMS and seems not to have access lists limiting the hosts/clients connecting. The specific procedures involved with remote access attacks into the Diebold voting system are not part of this report. Remote access was not used during the field tests for this particular study.

# Background for this project

Black Box Voting, Inc., a nonprofit 501c(3) consumer group for elections, provided the author with some program source code files, compiler source code, some executable files, Diebold employee e-mails, and user manuals for the 1.94w version of the Diebold Precinct-Based Optical Scan system.

The source code files and compiler, program files, and user manuals, were made freely available by Diebold and its predecessor, Global Election Systems on a public Internet FTP site. According to Guy Lancaster(3), (a key programmer for the Diebold Optical Scan system)(4), this Internet-based file transfer site was available for several years and was widely used.

On May 1, 2005, the author met with another security expert, Dr. Herbert Thompson, and they resolved to further examine potential security vulnerabilities in the Diebold voting system. The meeting between the author and Dr. Thompson was arranged by Black Box Voting.

On May 2, 2005, the author and Dr. Thompson, at the invitation of Leon County Election Supervisor Ion Sancho, visited the Leon County Elections Warehouse for a brief inspection and rudimentary testing of security vulnerabilities with Leon County's Diebold optical scan system. Dr. Thompson succeeded very quickly in penetrating the Diebold GEMS central tabulator, corrupting vote totals through the use of a Trojan horse in the form of a Visual Basic Script. This attack exploited features inherent in the Windows operating system and its built-in database functionalities and the MS Access-compatible vote database used with GEMS.

The author performed a rudimentary evaluation of another vulnerability, of the remote access type, with the Leon County precinct-based optical scan. His evaluation identified significant vulnerabilities with the RAS setup contained in documentation examined pertaining to Diebold touch-screens. The optical scan system in Leon County was found to use proprietary protocols, which appeared to be accessible to remote penetration using unauthorized means. Obviously, the author did not try these, but an individual intent on committing election fraud may also be willing to use these unauthorized methods to gain remote access.

Black Box Voting, Inc. arranged for the author to return to the U.S. in late May, 2005 and provided the author with additional publicly available source code files, Diebold memos, and user manuals. After examining the documents provided by Black Box Voting, the author discerned the architecture of the Diebold Precinct-Based Optical Scan 1.94w system, and developed several memory card exploits.

Black Box Voting then purchased a memory card read/write unit for the author to use in this study. The author was given permission to examine a set of memory cards used in Leon County to train poll workers. Black Box Voting arranged to pay Leon County for the cost of the cards. (The cards were returned to the county, but for security reasons, Leon County has opted not to use them again.)

On May 26, another visit was scheduled at the Leon County Elections Warehouse, and the author quickly penetrated the security of the Diebold Precinct-Based Optical Scan 1.94w system three times, each time with a different memory card manipulation.

Many more attack methods were identified, due to the architecture of the Diebold Precinct-Based Optical Scan 1.94w system. The author does not yet have additional permissions from voting authorities to perform proof of concept testing on these additional exploits.

For clarity, this report will differentiate, by highlighting in gray, those exploits demonstrated on May 26 in Leon County. Other exploits which the author deems to be highly likely to succeed but for which final "proof of concept" test opportunities have not yet been provided will not be highlighted.

**Sections on a gray background, like this, represent what was actually seen while in Leon County during proof of concept testing, and also earlier during preparation of the files for testing.**

# System Overview

It should be noted that Diebold acquired Global Election Systems in January, 2002; therefore some documentation, and the certification of this system, pre-dates Diebold Election Systems.

This document describes an exploitation of the Diebold Accu-Vote Precinct Optical Scan (AV OS) unit with firmware version 1.94w, which has been widely used in the U.S. since 1998. Two other Diebold optical scan versions have also been certified: version 1.96.4, and Central Count Accu-Vote OS 2.0.12.(5)

## Is this insecure architecture also on new versions?

Based solely on publicly available release documents, new features of the 1.96.x versions seem to pave the road for outside attacks in addition to attacks requiring some level of help from an insider.(6) Indeed, there are no indications in the materials reviewed to date by the author that exploits described in this report would not be achievable on all precinct-based Diebold optical scan versions, including the most recent version at the time of this writing, 1.96.4.

**The Diebold optical scan system consists of three components:** The optical scan reader used at the polling place to scan and interpret ballot data; the central tabulator, which resides on a standard PC computer using the Windows operating system, used at the county election office to collect and tally votes from polling places; and a removable data storage unit, the memory card that stores the votes.


Accu-Vote machine, placed in ballot holding "black box" as used at the polling place

**Diebold Optical Scan Voting Machine**

Before each election, the Diebold central tabulator program, called "GEMS," defines the races in the election. The optical scan machine is then connected to the GEMS server via an RS-232 serial port connection.

The removable storage (memory card) is placed into the optical scan machine, and GEMS writes information onto the memory card through the optical scan unit.

According to the Diebold optical scan user's manual, the programming of the memory card can also be done remotely by modem connection over a public telephone network.(7) After the cards have been programmed, they are interchangeable among voting machines with the same or similar firmware version. Therefore a single machine can be used to program all cards needed.

During the election, voters place filled-out ballots into the scanner, which interprets the ballot data and stores the totals (but not the individual votes) on the memory card. After the election, the data on the memory card is transferred into the central tabulator by a modem through a modem pool, or is physically brought to the county elections office and uploaded through an optical scan machine there via an RS-232 serial port connection. It is noteworthy that operational practices may vary -- from election office in-house operated modem pools to a virtual modem pool purchased as access service from a 3rd party provider.

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## Memory cards

For removable storage, the AV OS (Diebold Accu-Vote Precinct-Based Optical Scan) that was tested by the author uses standard Epson RBC 40 -pin battery refreshed memory cards. Epson discontinued the product line in late 1998 or early 1999, but compatible cards are still available from third party suppliers. Diebold (then called Global Election Systems) also was forced to change their supplier.[8]

These memory cards can be read and written with any Epson RBC compatible device, like the Cropscan Model 92 DLC, which is commercially available from a Minnesota company, CROPSCAN, Inc.[9] The Cropscan unit was used by the author for this study.


40-pin memory card placed in
Cropscan read-write unit

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# Findings

It has been known for years that Diebold uses its own proprietary programming language, Accu-Basic, for report-generation. This can be known from publicly available information, including compiler source code[(10)], an unfinished programming manual[(11)], AccuBasic source code files[(12)], pre-compiled files[(13)] and memos[(14)].

A large number of experts have reviewed this information but they have generally failed to understand the role and execution environment of Accu-Basic. A contributing factor could be that these critical pieces of information may have been omitted from official documentation, evidenced from the AccuVote-OS 1.94 Precinct Count User's Manual, Revision 2.0, July 18, 2002, page 14, which fails to list the executable program as an item stored in the memory card.[(15)]

Accu-Basic programming is a two phase process. First the Accu-Basic program source code needs to be pre-compiled with a compiler, converting it from a human readable source code form into token based pseudo-code. The pseudo-code is still a non-binary, ascii file. This first phase programming is normally done on a standard PC running Windows or *ix –variant operating system. The author used the FreeBSD platform. Then this pseudo-code is transferred to the final execution environment (that is, to the voting machine), where the pseudo-code is executed by an interpreter.

Note: The interpreter, built into the optical scan firmware, will execute the code following the instructions on the memory card. No information has been provided about the interpreter.

A publicly available Diebold memo from Guy Lancaster to Steve Ricke, dated 18 Nov 1999 17:28:23, subject "Re: Report Failure"[(16)] (Provided in Appendix), revealed that:

- The pre-compiled AccuBasic program is uploaded and is executed from the memory card.
- The AccuBasic program is not protected against corruption nor tampering with checksums.

This omission appears to be in conflict with the word and intention of the 1990 Federal Election Commission Standards, Chapter 5, specifically, but not limited to, articles 5.1, 5.3 and 5.5.[(17)]

## **Implications of this design**:

With this design, the functionality – the critical element to be certified during the certification process -- can be modified every time an election is prepared. Functionality is downloaded separately into each and every machine, via memory card, for every election. With this design, there is no way to verify that the certified or even standard functionality is maintained from one voting machine to the next.

With regard to certification, please also note that, because of the architecture, a trustworthy certification cannot be done separately for hardware and software. For a true understanding of the execution environment, the certifier must understand both of these components.

## The Accu-Basic subsystem:

If one understands the execution environment of the Accu-Basic sub-system, and responsibilities described in the partially written Accu-Basic programmers manual,[(18)] it can be determined that the Accu-Basic reporting functions include:

- ZERO_TOTAL_REPORT - to print the optional zero totals report on download;
- ELECTION_ZERO_REPORT - to print to official zero totals report prior to opening the polls;
- ELECTION_RESULTS_REPORT - to print the default results report after close of polls;
- TEST_ZERO_REPORT - to print the optional zero totals report prior to counting in the pre-election test mode;
- TEST_RESULTS_REPORT - to print the optional results report upon completion of a pre-election count test; and
- LABEL_REPORT - to print a memory card label.

In firmware release 1.94, AccuBasic is responsible for delivering the above functionalities. Note that there are clear indications that more functionality is planned to be driven by AccuBasic in future releases. Thus, the role of AccuBasic appears to be increasing, not diminishing.

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# Security exploits

Exploits available with this design include, but are not limited to:

1) **Paper trail falsification –** Ability to modify the election results reports so that they do not match the actual vote data

- 1.1) Production of false optical scan reports to facilitate checks and balances (matching the optical scan report to the central tabulator report), in order to conceal attacks like redistribution of the votes or Trojan horse scripts such as those designed by Dr. Herbert Thompson.[19]
- 1.2) An ingenious exploit presents itself, for a single memory card to mimic votes from many precincts at once while transmitting votes to the central tabulator. The paper trail falsification methods in this report will hide evidence of out-of-place information from the optical scan report if that attack is used.

2) Removal of information about pre-loaded votes

- 2.1) Ability to hide pre-loaded votes
- 2.2) Ability to hide a pre-arranged integer overflow

3) Ability to program conditional behavior based on time/date, number of votes counted, and many other hidden triggers.

According to public statements by elections officials[20], the paper trail produced by the precinct optical scan has been placed into the role of a vital safeguard mechanism. The paper report from the optical scan machine is the key record used to confirm the integrity of the central tabulator record.

The exploits demonstrated in the false optical scan machine reports ("poll tapes") shown on page 16 *do not change the votes, only the report of the votes*. When combined with the Trojan horse attack demonstrated by Dr. Thompson, this attack vector maintains an illusion of integrity by producing false reports to match the contaminated central tabulator report.

The exploit demonstrated in the poll tape with a true report containing false votes, shown on page 18, *changes the votes but not the report*. This example pre-stuffs the ballot box in such a way as to produce an integer overflow. In this exploit, a small number of votes is loaded for one candidate, offset by a large number of votes for the opposing candidate such that the sum of the numbers, because of the overflow, will be zero. The large number is designed to trigger an integer overflow such that after a certain number of votes is received it will flip the vote counter over to begin counting from zero for that candidate.

**Effect of Integer Overflow on Votes**

| Votes Cast | | Real Totals | | Pre-set overflow | | Votes Cast |
|---|---|---|---|---|---|---|
| A | B | A | B | A | B | |
| 0 | 0 | 0 | 0 | 65532 | 4 | 0 |
| 1 | 0 | 1 | 0 | 65533 | 4 | 1 |
| 0 | 1 | 1 | 1 | 65533 | 5 | 2 |
| 1 | 0 | 2 | 1 | 65534 | 5 | 3 |
| 0 | 1 | 2 | 2 | 65534 | 6 | 4 |
| 1 | 0 | 3 | 2 | 65535 | 6 | 5 |
| 1 | 0 | 4 | 2 | 0 | 6 | 6 |
| 1 | 0 | 5 | 2 | 1 | 6 | 7 |
| 0 | 1 | 5 | 3 | 1 | 7 | 8 |
| 1 | 0 | 6 | 3 | 2 | 7 | 9 |

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The author has not yet had the opportunity to run ballots using a pre-arranged integer overflow. However, combining the false report method (demonstrated on page 16) with the pre-arranged integer overflow (demonstrated on 18) seems to be an especially efficient exploit because it is a one-step process that takes out both the actual process and its safeguard at the same time, while surviving scrutiny of almost anything short of a full manual recount.

It is important to understand that, because the AccuBasic program is aware of the election definitions and structure, attacks can be prepared months ahead of time, before the candidate and ballot design have been decided. (Measures like ballot rotation have no affect on these exploits whatsoever, and do not need to be considered.)

## Delivery mechanisms for memory card tampering

Delivery of a malicious program can be achieved with multiple methods; among them:

- Direct alterations to the memory cards themselves.
- Replacement of the ".abo" (AccuBasic executable) file(s) in the central tabulator before election definitions are uploaded to memory cards. In this approach the election office, while not necessarily aware of the situation, will distribute the malicious code when preparing the elections.
- The central tabulator approach (.abo file replacement) will also enable even remote work. Remote attacks can either use a technical approach or a social engineering approach. Social engineering can turn out to be quite effective to deliver malicious code to the GEMS computer. An example of this could be providing an automated CD/DVD disc or USB device "patch" or update, delivered to the elections office accompanied by a phone call recommending its installation. Even if checksums were to be implemented in future versions of the firmware to protect the executable on the memory card, using GEMS to contaminate the memory card will neutralize the checksums because the program is inserted before the checksums are calculated.

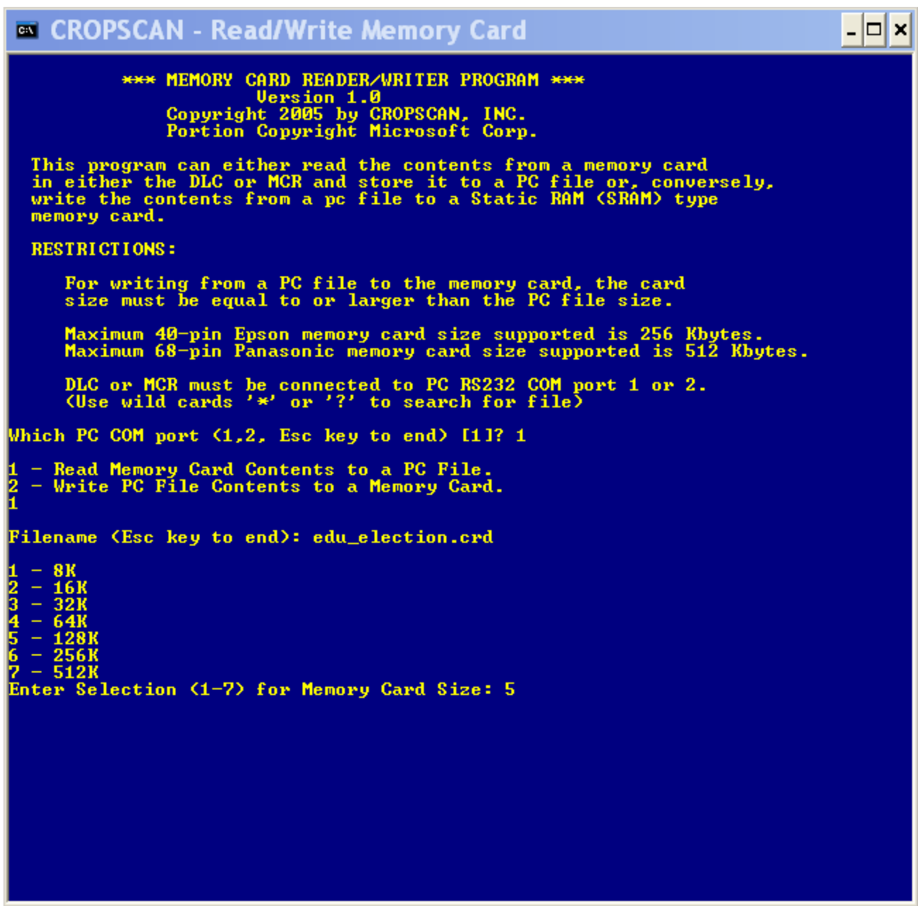
Remote programming of the card eliminates protection offered by seals or physical access to the card.

# Proof of concept in detail

To show that the executable program on the memory card controls the optical scan report and the user interface, and to test the memory card alteration theory, the author was able to test sample cards from Leon County, Florida. These memory cards contained an election constructed for the purpose of educating poll workers for future elections. All relevant elements were identical to the platform and implementation of all elections run within the environment in question.

A Cropscan (Model 92 DLC), with software provided by Cropscan Inc., was used to produce a raw image of the contents of the memory card. The contents of the memory card has a dependency to the architecture of the firmware, but *not* to the carrier media format, so it should be safe to assume that versions of the hardware with different media formats inherit the vulnerabilities described later.

The author followed the instructions that come with the standard Cropscan package before starting the read-write program.




When the author viewed the raw dump of the image file, which can be done using any hexadecimal or binary file editor, it became self-evident where the starting position of the executable pseudo-code was. Because the program is stored after election specific data, it is safe to assume that the starting location is not fixed.

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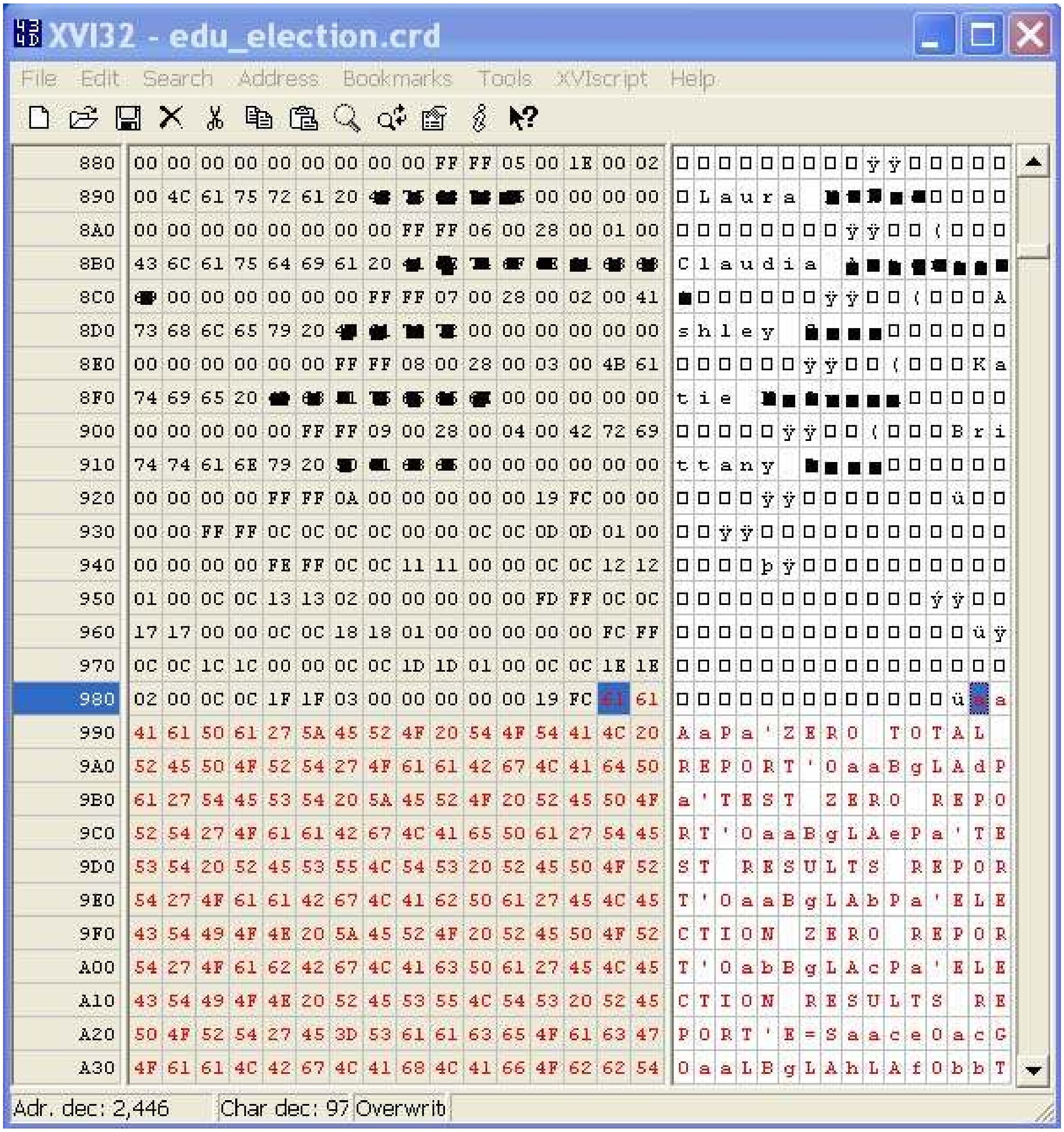


(Surnames of high school students redacted)

The tool used in this example is XVI32, version 2.51, by Christian Maas, publicly available under a freeware license.(21)

The author also found the end location of the executable block to be self-evident.

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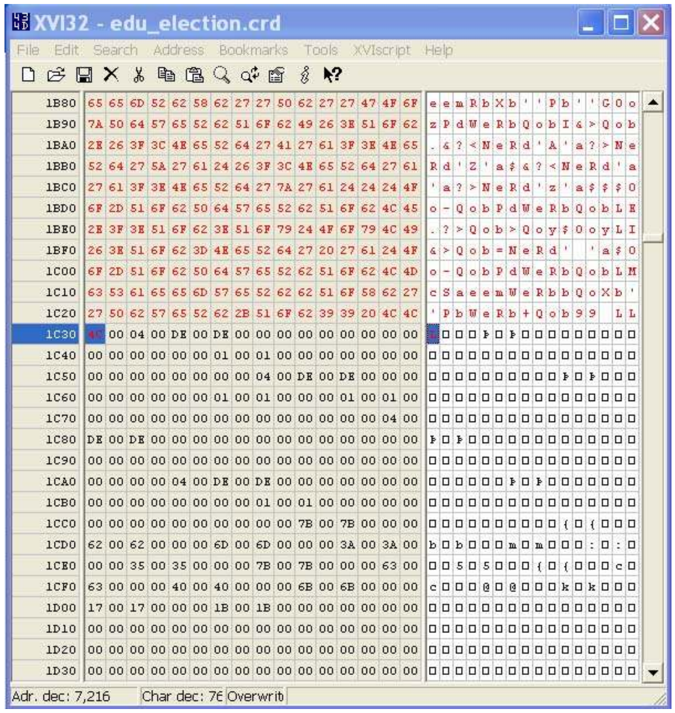


This shows the maximum length of the program -- in this particular case 7216 (dec) – 2446 (dec) = 4770 bytes.

The author wrote and pre-compiled his own program. Please note that the compiler has been publicly available for several years[(22)]. This significantly helps the average Joe to make his own program for the voting machine, although for sophisticated programmers this help is far from necessary. The compiler output is a pseudo-code in the format for GEMS to upload to the card. By visually comparing the content formats, it became clear that the output pseudo-code coming out of the compiler cannot be carbon copied to the memory card. The author made certain modifications before overwriting the executable block in the image file. These modifications are normal for cross-platform ascii feed-in files and technical by nature. Therefore the author opened the compiled file with a hex file editor and made the following modifications:

- Deleted the 3 first characters (´F “´ or 46 20 22 (hex))
- Found and replaced with nothing, effectively deleting and removing the occurrences of the string: ´"(line feed)F "´ (22 0A 46 20 22 hex)) from the file
- Found and replaced string ´\n´ (standard tag for line feed) with (line feed) (5C 6E (hex) with 0A (hex))

(Note: There may be additional modifications, having a cosmetic effect, but this will work without additional modifications.)

- Deleted the last 2 characters (´”´(line feed or 22 0A (hex))

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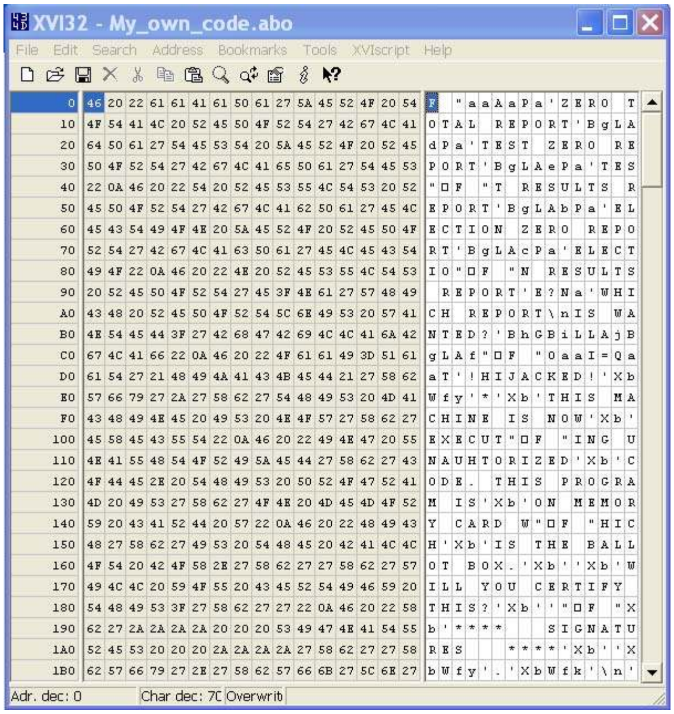
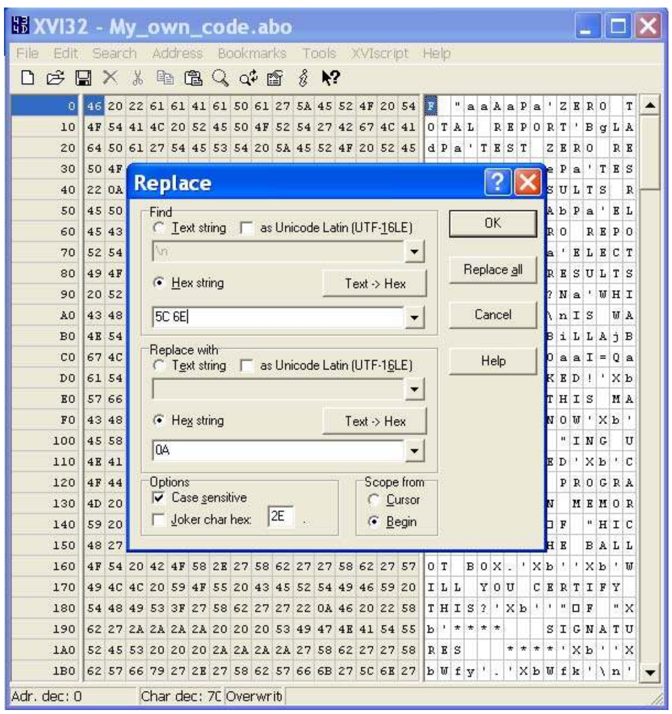
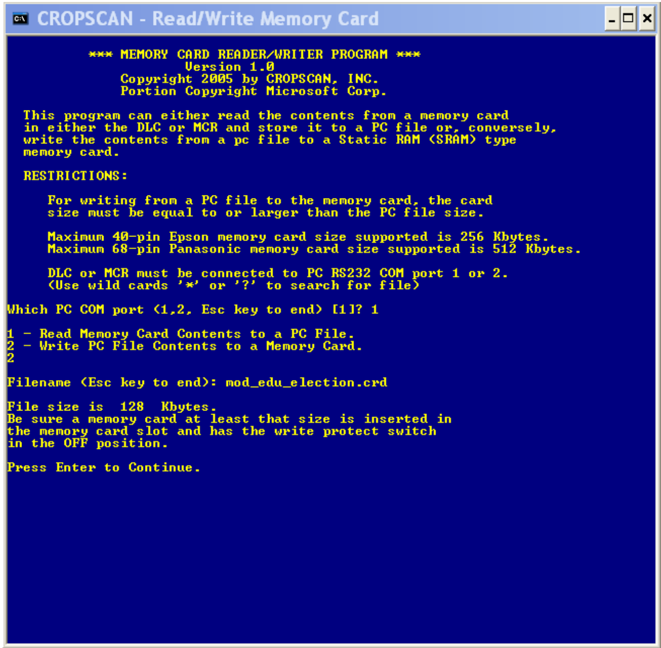


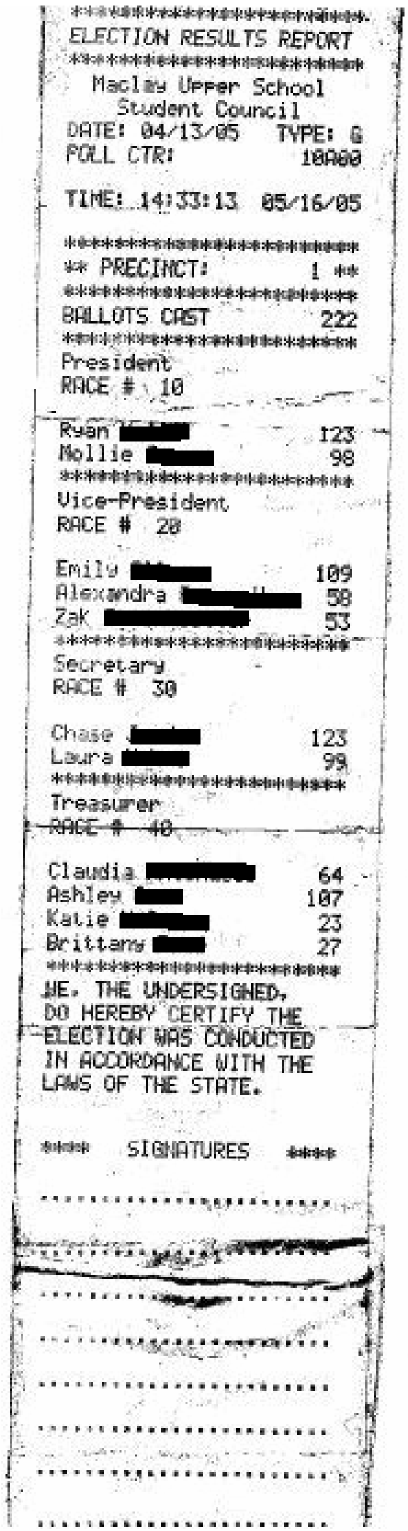




Different tools behave different ways, so the reader should take care while using cut and paste and avoid changing the placement of the data after the executable block. (Use the "overwrite" toggle, not the "insert" option if applicable to the tool) The author filled enough blanks to make the program block match the length of the original block to cause it be overwritten completely. After finding the beginning of the program again he used 'cut and paste' to overwrite the existing block with his new code. After verification that there is no offset for the rest of the data and that the length of the file remained intact, the author saved the file with new name and wrote it back to the memory card.




After this, later the memory card was inserted to the Optical Scan unit, and it was verified that the voting system functionalities changed according the programming concepts the author had chosen.

Below is an image of an untampered optical scan report ( “poll tape”) from Leon County. This report is produced by the memory card from an election used to train poll workers.


*************************
ELECTION RESULTS REPORT
*************************
Maclay Upper School
Student Council
DATE: 04/13/05 TYPE: G
POLL CTR: 10A00

TIME: 14:33:13 05/16/05

*************************
** PRECINCT: 1 **
*************************
BALLOTS CAST 222
*************************
President
RACE # 10

Ryan [redacted] 123
Mollie [redacted] 98
*************************
Vice-President
RACE # 20

Emily [redacted] 109
Alexandra [redacted] 58
Zak [redacted] 53
*************************
Secretary
RACE # 30

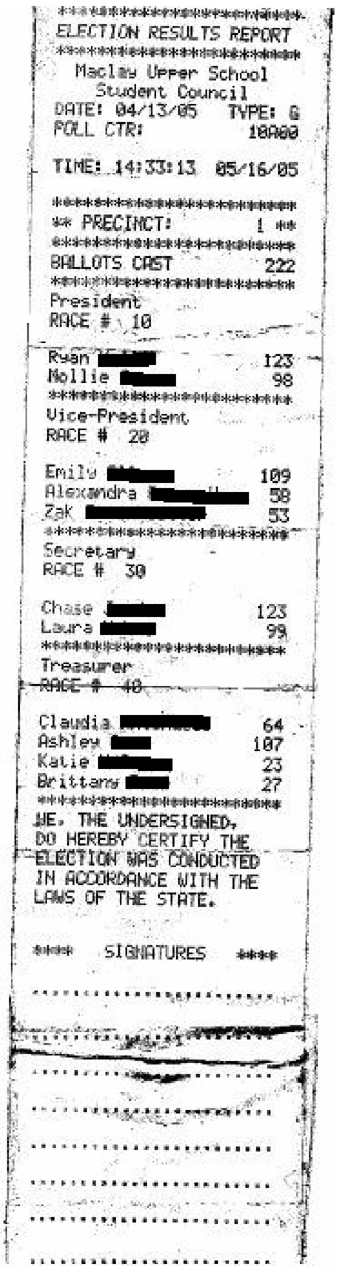
Chase [redacted] 123
Laura [redacted] 99
*************************
Treasurer
RACE # 40

Claudia [redacted] 64
Ashley [redacted] 107
Katie [redacted] 23
Brittany [redacted] 27
*************************
WE, THE UNDERSIGNED,
DO HEREBY CERTIFY THE
ELECTION WAS CONDUCTED
IN ACCORDANCE WITH THE
LAWS OF THE STATE.

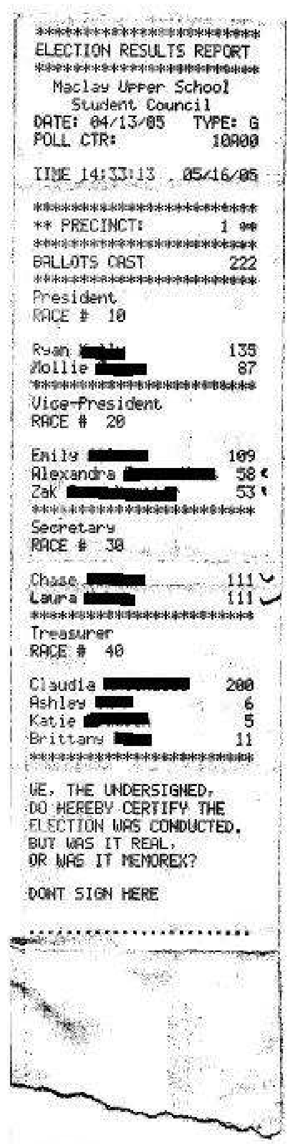
**** SIGNATURES ****

(Surnames of high school students redacted)

The following images show the original optical scan report side-by-side with reports that were produced by modifying the program code on the memory cards. On all memory cards, the vote data remains identical in this particular exploit. Only the reporting mechanism was modified to give false results.



ELECTION RESULTS REPORT
Maclay Upper School
Student Council
DATE: 04/13/05 TYPE: G
POLL CTR: 10A00
TIME: 14:33:13 05/16/05
** PRECINCT: 1 **
BALLOTS CAST 222
President
RACE # 10
Ryan [redacted] 123
Mollie [redacted] 98
Vice-President
RACE # 20
Emily [redacted] 109
Alexandra [redacted] 58
Zak [redacted] 53
Secretary
RACE # 30
Chase [redacted] 123
Laura [redacted] 99
Treasurer
RACE # 40
Claudia [redacted] 64
Ashley [redacted] 107
Katie [redacted] 23
Brittany [redacted] 27
WE, THE UNDERSIGNED,
DO HEREBY CERTIFY THE
ELECTION WAS CONDUCTED
IN ACCORDANCE WITH THE
LAWS OF THE STATE.
**** SIGNATURES ****



ELECTION RESULTS REPORT
Maclay Upper School
Student Council
DATE: 04/13/05 TYPE: G
POLL CTR: 10A00
TIME 14:33:13 05/16/05
** PRECINCT: 1 **
BALLOTS CAST 222
President
RACE # 10
Ryan [redacted] 135
Mollie [redacted] 87
Vice-President
RACE # 20
Emily [redacted] 109
Alexandra [redacted] 58
Zak [redacted] 53
Secretary
RACE # 30
Chase [redacted] 111
Laura [redacted] 111
Treasurer
RACE # 40
Claudia [redacted] 200
Ashley [redacted] 6
Katie [redacted] 5
Brittany [redacted] 11
WE, THE UNDERSIGNED,
DO HEREBY CERTIFY THE
ELECTION WAS CONDUCTED.
BUT WAS IT REAL,
OR WAS IT MEMOREX?
DONT SIGN HERE

ELECTION RESULTS REPORT
Maclay Upper School
Student Council
DATE: 04/13/05 TYPE: G
POLL CTR: 10A00
TIME: 14:33:13 05/16/05
** PRECINCT: 1 **
BALLOTS CAST 222
President
RACE # 10
Ryan [redacted] 102
Mollie [redacted] 120
Vice-President
RACE # 20
Emily [redacted] 109
Alexandra [redacted] 53
Zak [redacted] 58
Secretary
RACE # 30
Chase [redacted] 123
Laura [redacted] 99
Treasurer
RACE # 40
Claudia [redacted] 57
Ashley [redacted] 56
Katie [redacted] 54
Brittany [redacted] 55
WE, THE UNDERSIGNED,
DO HEREBY CERTIFY THE
ELECTION WAS CONDUCTED.
BUT WAS IT REAL,
OR WAS IT MEMOREX?
DONT SIGN HERE

**Original poll tape** **Tampered memory card 1** **Tampered memory card 2**

(Surnames of high school students redacted)

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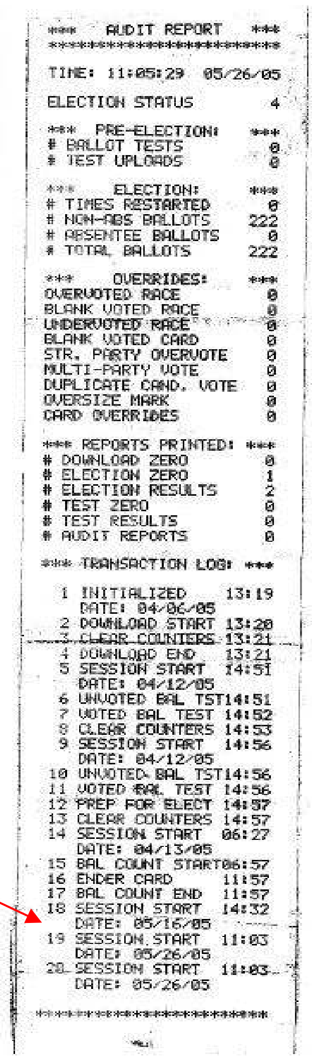
Note that the run date and time on all reports are the same. The original report was run in Leon County on May 16, when the author was not present. However, the reports from the tampered memory cards, which also state run time to be May 16, were actually run on morning of May 26, when the author conducted the proof of concept test. These reports demonstrate that report data, including the date and other information, are easily altered on optical scan reports.

**Optical scan audit report**



```
***   AUDIT REPORT   ***
*************************

TIME: 11:05:29  05/26/05

ELECTION STATUS        4

***  PRE-ELECTION:   ***
# BALLOT TESTS         0
# TEST UPLOADS         0

***     ELECTION:    ***
# TIMES RESTARTED      0
# NON-ABS BALLOTS    222
# ABSENTEE BALLOTS     0
# TOTAL BALLOTS      222

***     OVERRIDES:   ***
OVERVOTED RACE         0
BLANK VOTED RACE       0
UNDERVOTED RACE        0
BLANK VOTED CARD       0
STR. PARTY OVERVOTE    0
MULTI-PARTY VOTE       0
DUPLICATE CAND. VOTE   0
OVERSIZE MARK          0
CARD OVERRIDES         0

*** REPORTS PRINTED: ***
# DOWNLOAD ZERO        0
# ELECTION ZERO        1
# ELECTION RESULTS     2
# TEST ZERO            0
# TEST RESULTS         0
# AUDIT REPORTS        0

*** TRANSACTION LOG: ***

 1 INITIALIZED    13:19
   DATE: 04/06/05
 2 DOWNLOAD START 13:20
 3 CLEAR COUNTERS 13:21
 4 DOWNLOAD END   13:21
 5 SESSION START  14:51
   DATE: 04/12/05
 6 UNVOTED BAL TST14:51
 7 VOTED BAL TEST 14:52
 8 CLEAR COUNTERS 14:53
 9 SESSION START  14:56
   DATE: 04/12/05
10 UNVOTED BAL TST14:56
11 VOTED BAL TEST 14:56
12 PREP FOR ELECT 14:57
13 CLEAR COUNTERS 14:57
14 SESSION START  06:27
   DATE: 04/13/05
15 BAL COUNT START06:57
16 ENDER CARD     11:57
17 BAL COUNT END  11:57
18 SESSION START  14:32
   DATE: 05/16/05
19 SESSION START  11:03
   DATE: 05/26/05
20 SESSION START  11:03
   DATE: 05/26/05

*************************
```

The tampering took place between audit log events 18 and 19

Above is the Diebold "audit report" for the optical scan machine, printed on May 26. This audit log is printed from the optical scan firmware, not from the executable on the memory card. No changes were made on this report. Note that it shows no error messages. The memory card this report purports to be auditing was tampered with on an airplane at an earlier date in May, but nothing in the audit log reflects the actual timing of memory card events.

No anomalies appeared on the audit report because none of the changes made by the author affected any of the Diebold audit log information.

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## Manipulation through integer overflows

Currently, many programmers have become accustomed to higher level programming languages, which give warnings and guidance to adjust integer overflow problems. The problem defined below will be familiar to programmers who have worked in earlier environments and/or with lower level programming languages. Please note that only 16 bit integers (2 byte) are used instead of longer integers, which are the default in today's environment.

In a publicly available memo from Guy Lancaster, sent January 18, 2001 2:41 PM, subject "Memory card checksum errors (was: 2000 November Election)",[23] there is discussion about the checksum structure protecting the votes against corruption.

ELECTION ZERO REPORT

Maclay Upper School
Student Council
DATE: 04/13/05 TYPE: G
POLL CTR: 10000

TIME: 12:31:23 05/26/05

** PRECINCT: 1 **

BALLOTS CAST 0

President
RACE # 10

Ryan [redacted] 65511
Mollie [redacted] 25

Vice-President
RACE # 20

Emily [redacted] 0
Alexandra [redacted] 0
Zak [redacted] 0

Secretary
RACE # 30

Chase [redacted] 0
Laura [redacted] 0

Treasurer
RACE # 40

Claudia [redacted] 0
Ashley [redacted] 0
Katie [redacted] 0
Brittany [redacted] 0

WE, THE UNDERSIGNED,
DO HEREBY CERTIFY THE
ELECTION WAS CONDUCTED
IN ACCORDANCE WITH THE
LAWS OF THE STATE.

**** SIGNATURES ****

It is clear that the checksum algorithm used was chosen to be the simplest possible one, because it has been chosen to protect the votes against random corruption of the data instead of intentional tampering.

This finding led the author to create an exploit with the idea of inserting votes that will cancel each other out when added.

By the way: There were no error messages during start-up with this card, nor did any error messages appear afterward.

(Surnames of high school students redacted)

The "zero report" above demonstrates an unmodified optical scan report with a pre-stuffed ballot box. This produced no error message. Note that with the numbers artificially changed, the report behaves as though nothing is wrong. For the example above, the votes were changed but the reporting program was not tampered with. Thus, the reader can see the pre-stuffed votes. Were the author to use this exploit in a less transparent way, he would also manipulate the report program such that no matter how many votes were preloaded, the zero report would always report "0."

Pre-stuffing the ballot box with votes 65511 and 25 is essentially the same as if one candidate had -25 votes and the other +25 votes at the start. Naturally, the choice of -25 and +25 was arbitrary and different figures could have been used.

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If one wants to create a false zero report using the methodology previously described, while pre-stuffing the ballot box, there appear to be no safeguards to catch the manipulation; however, the author has not yet had the opportunity to test a full election sequence (including scanning election ballots) with a prestuffed ballot box, exploiting integer overflows.

While far from comprehensive, the implications of the integer overflow experiment are:

- There is no integer overflow testing and/or no testing of the sum-of-parts against the totals

- In conjunction with a modified reporting program to produce a zero total report which will always contain only zeroes, the ability to effectively redistribute the votes between the candidates (as close to the source as possible), while maintaining a complete illusion of integrity. This attack can be targeted and therefore adjusted with pre-known demographics of specific locations.

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# Further considerations

When the firmware turns control over to Accu-Basic, the user is not notified, nor is the user notified when control returns to the firmware. The Accu-Basic program on the memory card not only has control over the printer as output media, but also enables interaction with the user over the LCD display, and “YES” and “NO” the buttons located underneath the LCD.

## The implications of this are:

1) Conditional behavior of malicious code can be based on user input
2) The user can be made to believe that his activities are real, while they are not, by programming the memory card so that it will not return control back to firmware.

For example: Screen messages at the end of the election could make the user believe he is closing the election and transmitting results, while he is not. Below, the author tested control over user interface:


The author programmed the memory card to produce this message on the optical scan machine LCD display in place of the real one, startling Leon County Information Technology Officer

## Logic & Accuracy tests:

Election officials have been led to believe that these systems are accurate if they pass a “logic and accuracy test” before and/or after the election. Diebold voting machines are tested in “test mode” which uses a different part of the program than that used on election day, reducing the value of the logic and accuracy test. However, even if the machines *were* tested in “election mode,” because there is no verification of what is inside the card, and because this design provides the ability to implement conditional logic, including date and time-sensitive triggers, by altering the executable program in the memory card, and therefore L&A tests appear to be an inadequate way to test the system for tampering.

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# Conclusions

The Accu-Vote Precinct Count Optical Scan system inherits numerous attack vectors from flexibility to modify over security design.

Operational procedures required to secure the system would put un-sustainable burden in perimeter defense, training of the personnel and supervision among the other layers of security.

# Recommendations

1. Further evaluation should be performed on the 1.96.x and 2.0.x versions of the Diebold optical scan system to determine whether they do or do not have the same fundamentally insecure architecture. A similar examination should also be performed on the Diebold touch-screens, including the TS-R4 and TS-R6 versions, the TSx version, and the new “VVPAT” version, along with any other component of the accumulation process for any of these systems.

2. Because memory cards have been given a pre-eminent position in the Diebold voting system studied, they should be deemed to contain critical data and should be considered to be a public document. Of course, they should be retained for 22 months in federal elections, as required by U.S. federal election law.

3. Memory cards or, in the event they are not available, the voting systems themselves, should be examined for all jurisdictions using any Diebold voting system which relies on this type of architecture. If manipulation is done properly, there will be no telltale anomalies in the reports printed for the public. In areas like Volusia County, (24)(25)(26) and Brevard County (27)(28) Florida, where significant anomalies have appeared related to vote tabulation, memory cards, or poll tapes, the memory cards should be certainly inspected by someone experienced in forensics.

4. The architecture of other manufacturers should be examined for similar vulnerabilities. Priority should be set for this examination according to the significance of the vendor.

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# Footnotes

(1) When more clarity as to the true meaning of the term is needed, refer to U.S. Federal Standard 1037C entitled "Telecommunications: Glossary of Telecommunication Terms," issued by the General Services Administration pursuant to the Federal Property and Administrative Services Act of 1949, as amended.. http://www.its.bldrdoc.gov/fs-1037/fs-1037c.htm

(2) "Defense in Depth" can be found from *http://nsa1.www.conxion.com/support/guides/sd-1.pdf*

(3) Interview of Guy Lancaster by Bev Harris, Feb. 4, 2003.

(4) Guy Lancaster a key programmer of Diebold optical scan system: Guy Lancaster resume, and information from the annual corporate information in the Canadian Survey of Industrials, which lists design of the ES-2000 in 1988, under Lancaster

(5) Two other Diebold optical scan versions have also been certified: version 1.96.4, and Central Count Accu-Vote OS 2.0.12. Source: National Association of State Election Directors (NASED) Web site, NASED Qualified Voting Systems 12/05/03 - Current (as of May 19, 2005): http://www.nased.org/ITA%20Information/NASEDQualifiedVotingSystems12.03to6.05.pdf

(6) Release notes for Diebold Precinct-Based Optical Scan version 1.96.4 as obtained from the state of California (http://www.bbvdocs.org/diebold/OS-releasenotes.pdf)

(7) Diebold optical scan 1.94 User's Guide Rev. 2 (http://www.bbvdocs.org/diebold/manuals/AVOS_Precinct_Count_1_94_Users_Guide_Rev_ 2.pdf)

(8) Diebold memo: Date Fri, 26 Mar 1999, from Ian S. Piper, Subject: "128kb Memory Card One Pass Copy" See Appendix A.

(9) CROPSCAN, Inc.: http://www.cropscan.com

(10) Diebold AccuVote compiler source code (Original source, Diebold FTP site files found by the founder of Black Box Voting, Bev Harris, on Jan. 23, 2003.) These files can be found online by search engine. The makefile is not needed, but may also be found on the Internet through search engines.)

(11) Unfinished AccuBasic programming manual, original source, Diebold FTP site files found by Harris on Jan. 23, 2003, in a Guy Lancaster (glanca) folder. (http://www.bbvdocs.org/diebold/ab-manual.pdf)

(12) AccuBasic source code files (also referred to as abasic, abobasic, and some permutations named 'abc'). Original source, Diebold FTP site files found by Harris on Jan. 23, 2003. These files appear on the web sporadically, and may be found on search engines.

(13) Pre-compiled AccuBasic files (also referred to as abasic, abobasic). Original source, Diebold FTP site files found by Harris on Jan. 23, 2003. These files appear on the web sporadically, and may be found on search engines.

(14) Internal memos among Diebold programmers. The exact origin of this set of memos is not known yet. The memos were leaked to Harris on Sept. 5, 2003, and from there were propagated around the Internet. Diebold acknowledged ownership of the memos in litigation with the Online Policy Group.

(15) AccuVote-OS 1.94 Precinct Count User's Manual, Revision 2.0, July 18, 2002, page 14, which fails to list the executable program as an item stored in the memory card. (http://www.bbvforums.org/forums/messages/2197/2276.html)

(16) A publicly available Diebold memo from Guy Lancaster to Steve Ricke, dated 18 Nov 1999 17:28:23, subject "Re: Report Failure" (full text included Appendix B)

(17) 1990 Federal Election Commission Standards, Chapter 5, specifically, but not limited to, articles 5.1, 5.3 and 5.5 (http://www.bbvforums.org/forums/messages/2197/2383.html)

(18) Unfinished AccuBasic programming manual, original source, Diebold FTP site files found by Bev Harris on Jan. 23, 2003, in a Guy Lancaster (glanca) folder. (http://www.bbvdocs.org/diebold/ab-manual.pdf)

(19) The Visual Basic Script attack on GEMS was first performed in Washington D.C. at the National Press Club, Sept. 22, 2004, as reported in CNET News, 22 Sept. 2004: "E-voting critics report new flaws." Thompson tweaked the script to give it more flexibility (i.e. such that it could perform alterations simply by entering a candidate's name and the number of votes you desire to manipulate), and performed this hack on Feb. 14 and May 2, 2005 in Leon County.

(20) Leon County Information Officer Thomas James, when he saw Dr. Thompson's GEMS hack on Feb. 14 and May 2, initially said that the poll tapes and memory card would cause him to detect the hack. Also refer to this Diebold document: http://www.diebold.com/dieboldes/response7.pdf

(21) Hex editor XVI32, version 2.51, by Christian Maas, freeware (http://www.chmaas.handshake.de/delphi/freeware/xvi32/xvi32.htm)

(22) The compiler has been publicly available for several years. It was on the Diebold FTP site found by Harris. Refer to Interview of Guy Lancaster by Bev Harris, Feb. 4, 2003; also, was released by Harris on the Internet on June 16, 2003 on four Web sites; was released again on July 8 by the Scoop.nz Web site These files appear on the web sporadically, and may be found on search engines.

(23) Diebold memo from Guy Lancaster, sent January 18, 2001 2:41 PM, subject "Memory card checksum errors

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(was: 2000 November Election)" Full text available in Appendix C.

(24) In Volusia County during the 2000 election, minus 16,022 votes appeared for Al Gore, and according to an internal CBS investigation (http://www.bbvdocs.org/misc/CBSreport.pdf), these votes caused the election to be erroneously called for George W. Bush. The documentation contained in the Diebold memos indicates that this was due to a memory card replacement, though no one explains how minus 16,022 votes appeared on a (now missing, according to the memo) memory card for a precinct with only a few hundred voters.

(25) Document received in Nov. 2, 2004 Black Box Voting public records request from Volusia County. Diebold representative Mark Earley requests an explanation as to why 57 extra memory cards were needed, allegedly due to an unusually high occurrence of memory card corruption. He points out that Volusia County claims more corrupted memory cards than all the counties in the state of Florida, combined.

(26) Poll tape analysis by Black Box Voting, with records obtained from Volusia County showed anomalies on 57 reports. Some of the reports were missing the zero tape, some were missing poll worker signatures, and several showed that multiple copies of the memory card for that precinct had been created.

(27) In Brevard County, Florida, an unexplained anomaly caused a 4,000-vote error in the 2000 general election. Report: "CBS News Coverage of Election Night 2000" (http://www.bbvdocs.org/misc/CBSreport.pdf)

(28) In Brevard County, officials repeatedly withheld logs and poll tapes from the Nov. 2, 2004 Black Box Voting public records request, and then deemed the records (including the results reports) to be proprietary and unavailable due to security concerns.

# Acknowledgements

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## List of Appendices:

Appendix A: Diebold memo about memory cards used
Appendix B: Diebold memo about checksums
Appendix C: Diebold memo with more information about checksums
Appendix D: Sample program
Appendix E: List of locations that use Diebold voting systems

# Appendix A

**To**: **"Request for Change Report" <rcr@dieboldes.com>**
**Subject**: **128KB Memory Card One Pass Copy**
**From**: **"Ian S. Piper" <ian@dieboldes.com>**
Date: Fri, 26 Mar 1999 12:45:06 -0600

We need to have a 128KB memory card copy routine that only requires the user to insert the source card once and the destination card once.

As you may have already heard, EPSON has stopped producing the memory cards we use in the Accu-Vote. No need to panic. We have stocked up on 32KB cards and 128KB cards for the short term, and we have found an alternate supplier, Centennial Technologies. One of the drawbacks to Centennial's card is that it only comes in the 128KB flavor or higher (we can't use higher). One of the drawbacks to only supplying 128KB cards is the fact that to copy a 128KB card on an Accu-Vote, you must insert the source card four times and the destination card four times (it copies in pages of 32KB). For customers to swallow the fact that in the future they will only be able to get 128KB cards, we will have to provide a more convenient copying solution.

Ian

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# Appendix B

**Re: Report Failure**
**To: Steve Ricke <steve@gesn.com>**
**Subject**: **Re: Report Failure**
**From**: **Guy Lancaster <**glanca@gesn.com**>**
Date: Thu, 18 Nov 1999 17:28:23 -0600
Cc: Support <support@gesn.com>
Organization: Global Election Systems Inc.
**References: <000901bf31ea$7b91bc40$1e03a8c0@globalelection.com>**

**128KB Memory Card One Pass Copy**

The 1.94w firmware does not keep a checksum on the Accu-Basic report program stored on the memory card. It sounds like that area has been corrupted on these but without a checksum, the Accu-Vote doesn't recognize the fact and report the error until a report is attempted. The audit report is generated by programming on the ROMs and therefore is not affected by memory card corruptions. Memory card duplication will duplicate corrupted data perfectly.

Treat these like other cases of memory card corruption. They still have valid election and count data and could continue to be used normally except for printing results and therefore compare to getting a TEXT CHECK ERROR.

What is causing these and other corruptions is still unresolved and the investigation continues...

Guy

BTW: All that I mean by corruption is that data has been changed in an incorrect way. This does not necessarily indicate a problem with the memory card itself, only with the data stored on it.

These cards are still capable of printing audit reports and performing supervisor functions but are no longer able to print any sort of TOTALS report.

If the offending card is redownloaded it will work reliably.

During one instance Bill Vandenburg of Atkins gave a service call to a precinct which had not created a ZERO TOTALS REPORT. He made a card to card copy and the second card had the same malfunction. The tabulator worked fine after he used a previously programmed spare card.

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# Appendix C

**RE: Memory card checksum errors (was: 2000 November Election)**

**To**: <**support@gesn.com**>
**Subject**: **RE: Memory card checksum errors (was: 2000 November Election)**
**From**: **"John McLaurin" <jmglobal@earthlink.net>**
Date: Thu, 18 Jan 2001 14:56:15 -0500
Importance: Normal

-----Original Message-----
**From:** owner-support@gesn.com [mailto:owner-support@gesn.com]**On Behalf Of** Guy Lancaster
**Sent:** Thursday, January 18, 2001 2:41 PM
**To:** Support
**Subject:** Memory card checksum errors (was: 2000 November Election)

This is an overview on what memory card checksum errors are. Exactly what causes them is a separate question.

The memory card is very simply a programmable memory device with a battery backup. The Accu-Vote accesses this memory directly. If something goes wrong when the Accu-Vote is writing new data to the memory card or if the Accu-Vote crashes (as computers have been known to do) and writes to random memory locations, then the data on the memory card may be corrupted (nasty word I know but it fits). All this means is that the data is modified in an unintentional manner. This could also happen without an Accu-Vote through static discharge or some types of radiation (i.e. old airport scanners, cosmic rays???).

There are several mechanisms that we could use to detect this. We use the simplest of these which is to treat the data as a series of numbers and store totals of sets of those numbers as separate data known as checksums. If the data has been modified without updating the checksums, then the checksums will fail to add up.

The Accu-Vote keeps three different types of checksums for three different classes of data. These are text, counters, and precinct. The text checksums cover all the titles and names that are used mostly just for printing reports. Since the text data does not affect the other operations, we check it only occasionally and we allow most operations to continue after a warning.

The counters and precinct data are considered critical and the Accu-Vote is largely inoperable when these checksums fail. We do support the option to clear the counters if only they have been affected and then counting may be restarted. However there is no way to recover from corruption of the precinct data other than to clear and re-download the memory card.

All checksums are validated upon insertion of a memory card or at power on. Thus this is the most common time to detect problems. However the counter and precinct checksums are validated every time a new ballot is scanned. If an error is detected, counting is aborted.

Now to Lana's questions. The above should answer everything other than why erroneous data managed to upload. I see two possible explanations. One is that the data was corrupted after the checksums were validated. In this case the errors would show the next time the checksums were checked. The

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other possibility is the miniscule chance that the erroneous data managed to add up to the correct checksum.  The checksums are stored as totals ranging from 0 to 65535 so the chance of this happening are less than 60,000 to 1 just based on that.  Other factors add to this to make it extremely unlikely. However in this case the card would not later show checksum errors.

So John, can you satisfy Lana's request from this?  I can't without more details.

Guy

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# Appendix D

This sample is provided for educational purposes only.

```
F "aaAaPa'ZERO TOTAL REPORT'BfLAdPa'TEST ZERO REPORT'BfLAePa'TES"
F "T RESULTS REPORT'BfLAbPa'ELECTION ZERO REPORT'BfLAcPa'ELECTIO"
F "N RESULTS REPORT'E?Na'WHICH REPORT\nIS WANTED?'BgGBhLLAiBfLAf"
F "OaaI=QaaT'!HIJACKED!'XbWfy'*'Xb'THIS MACHINE IS NOW'Xb'EXECUT"
F "ING UNAUHTORIZED'Xb'CODE. THIS PROGRAM IS'Xb'ON MEMORY CARD W"
F "HICH'Xb'IS THE BALLOT BOX.'Xb''Xb'WILL YOU CERTIFY THIS?'Xb''"
F "Xb'****    SIGNATURES    ****'Xb''XbWfy'.'XbWfk'\n'E?Na'ARE WE "
F "HAVING\nFUN YET?'OabLLLAgT'PRINTING REPORT'OaaI=QaaXb'********"
F "******************'Xb'ELECTION RESULTS REPORT'Xb'**************"
F "************'Xb''Xb'THIS COULD BE ANYTHING'Xb''Xb'WE, THE UNDE"
F "RSIGNED,'Xb'DO HEREBY CERTIFY THE'Xb'ELECTION WAS CONDUCTED.''"
F "Xb'BUT WAS IT REAL,'Xb'OR WAS IT MEMOREX?'Xb''Xb'DONT SIGN HE"
F "RE'Xb''Xb'..........................'XbWfk'\n'E?Na'  NEED ANOTH"
F "ER\n      COPY?'OabLLLAhT'PRINTING REPORT'OaaI=QaaXb'**********"
F "****************'Xb'ELECTION RESULTS REPORT'Xb'*****************"
F "**********'Xb''Xb'AND THIS SOMETHING ELSE'Xb''Xb'WE, THE UNDER"
F "SIGNED,'Xb'DO HEREBY CERTIFY THE'Xb'ELECTION WAS CONDUCTED.'X"
F "b'BUT WAS IT REAL,'Xb'OR WAS IT MEMOREX?'Xb''Xb'DONT SIGN HER"
F "E'Xb''Xb'..........................'XbWfk'\n'E?Na'  NEED ANOTHE"
F "R\n      COPY?'OabLLL"
```

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```
REM Sample.abs - Copyright (c) 2005 Blackboxvoting, Inc
REM            - All right reserved, except as otherwise permitted by
REM            - written agreement. This sample is provided for
REM            - for educational purposes only.


PROC ZERO_TOTAL_REPORT
        REM This routine will print zero totals report on download
        $what = "ZERO TOTAL REPORT"
        CALL LABEL_REPORT
ENDPROC

PROC TEST_ZERO_REPORT
        REM This will produce zero totals report in L&A testing
        REM Edit here if you want the test to differ from the real
        $what = "TEST ZERO REPORT"
        CALL LABEL_REPORT
ENDPROC

PROC TEST_RESULTS_REPORT
        REM This will produce results report in l&a testing
        REM Edit here if you want the test to differ from the real
        $what = "TEST RESULTS REPORT"
        CALL LABEL_REPORT
ENDPROC

PROC ELECTION_ZERO_REPORT
        REM This routine will print official zero total report before
        REM the polls are opened
        $what = "ELECTION ZERO REPORT"
        CALL LABEL_REPORT
ENDPROC

PROC ELECTION_RESULTS_REPORT
        REM This routine will print official results report after the
        REM polls are closed
        $what = "ELECTION RESULTS REPORT"
        IF NOT PROMPT("WHICH REPORT|IS WANTED?") THEN
                CALL print_results
        ELSE
                CALL print_nesults
        ENDIF
ENDPROC

PROC AUDIT_REPORT
        CALL LABEL_REPORT
ENDPROC

PROC LABEL_REPORT
        %finished = 0
        WHILE %finished = 0
                DISPLAY "!HIJACKED!"
                PRINT FILL(24,"*")
                PRINT "THIS MACHINE IS NOW"
                PRINT "EXECUTING UNAUHTORIZED"
                PRINT "CODE. THIS PROGRAM IS"
                PRINT "ON MEMORY CARD WHICH"
                PRINT "IS THE BALLOT BOX."
                PRINT
                PRINT "WILL YOU CERTIFY THIS?"
                PRINT
                PRINT "****   SIGNATURES   ****"
                PRINT
                PRINT FILL(24,".")
                PRINT FILL(10,"|")
                IF NOT PROMPT("ARE WE HAVING|FUN YET?") THEN
                        %finished = 1
                ENDIF
        ENDWHILE
ENDPROC

PROC print_results
        DISPLAY "PRINTING REPORT"
        %finished = 0
        WHILE %finished = 0
                PRINT "************************"
```

```
            PRINT "ELECTION RESULTS REPORT"
            PRINT "************************"
            PRINT
            PRINT "THIS COULD BE ANYTHING"
            PRINT
            PRINT "WE, THE UNDERSIGNED,"
            PRINT "DO HEREBY CERTIFY THE"
            PRINT "ELECTION WAS CONDUCTED."
            PRINT "BUT WAS IT REAL,"
            PRINT "OR WAS IT MEMOREX?"
            PRINT
            PRINT "DONT SIGN HERE"
            PRINT
            PRINT "........................"
            PRINT FILL(10,"|")
            IF NOT PROMPT("  NEED ANOTHER|     COPY?") THEN
                    %finished = 1
            ENDIF
        ENDWHILE
ENDPROC

PROC print_nesults
        DISPLAY "PRINTING REPORT"
        %finished = 0
        WHILE %finished = 0
            PRINT "************************"
            PRINT "ELECTION RESULTS REPORT"
            PRINT "************************"
            PRINT
            PRINT "AND THIS SOMETHING ELSE"
            PRINT
            PRINT "WE, THE UNDERSIGNED,"
            PRINT "DO HEREBY CERTIFY THE"
            PRINT "ELECTION WAS CONDUCTED."
            PRINT "BUT WAS IT REAL,"
            PRINT "OR WAS IT MEMOREX?"
            PRINT
            PRINT "DONT SIGN HERE"
            PRINT
            PRINT "........................"
            PRINT FILL(10,"|")
            IF NOT PROMPT("  NEED ANOTHER|     COPY?") THEN
                    %finished = 1
            ENDIF
        ENDWHILE
ENDPROC
```

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# Appendix E
# List of Diebold Locations

A detailed list of U.S. counties and townships, and Canadian provinces, that use Diebold voting systems can be found at http://www.blackboxvoting.org/diebold/locations.pdf

Here is a summary of the locations where Diebold voting systems are found. Most are optical scan systems. The touch-screen counties, marked on the document linked above, also use optical scan machines for absentee votes.

**Alaska –** State of Alaska, 27 counties (some rural counties may not have population to use machines)
**Arizona –** State of Arizona, 15 counties
**California** – 17 counties
**Colorado –** 24 counties and municipalities
**Florida –** 30 counties
**Georgia** – 159 counties
**Iowa** – 8 counties
**Illinois –** 8 counties
**Indiana** – 10 counties
**Kansas –** 28 counties
**Kentucky –** 1 county
**Maryland** – 23 counties
**Massachusetts –** 135 cities and towns
**Maine** – 26 cities and towns
**Michigan –** 177 cities and townships
**Minnesota –** 29 counties, townships and cities
**Mississippi** – 82 counties (recent statewide purchasing decision)
**Missouri** – 33 counties
**North Carolina** – 22 counties
**Nebraska –** 2 counties
**New Hampshire** – 50 towns
**New Mexico –** 1 county (may have switched to another vendor)
**Nevada –** 1 county (may have switched to another vendor)
**Ohio –** 88 counties (recent statewide purchasing decision)
**South Carolina** – 6 counties
**Tennessee** – 4 counties
**Texas** – 4 counties
**Utah** – 29 counties
**Virginia –** 37 counties
**Vermont** – 21 towns
**Washington** – 4 counties
**Wisconsin** – 103 counties, cities, towns and villages
**Wyoming** – 2 counties
**Puerto Rico**
**Canada** – 90 locations
***Total at this time***: **U.S.** = 33 states, 1,207 locations – **Canada -** 90 locations – total 1,297 locations

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# Diebold TSx Evaluation

## SECURITY ALERT: May 22, 2006
## Supplemental report, additional observations

**Unredacted on July 2, 2006 by Black Box Voting**

A Black Box Voting Project

Prepared by: Harri Hursti

On behalf of Black Box Voting, Inc.

**Purpose of this document**

This document captures some miscellaneous supplementary observations for further study. These items should be considered either not properly studied, or just starting points without any real study done and without known significance, if any. In some cases it is unknown if the item discussed has been only existed in the development phase and been disabled or removed before release version.

**1. Flash memory erasure:**

There seems to be a memory card-triggered feature to erase the contents of flash memory. This destructive function was started in the TS6 with the file EraseFFX.bsq, and was carried over to the TSx when the file ErasePSM.stl is found on the memory card. This feature was not tested in Emery County and should be examined further.

**2. Further study needed on macros:**

TS6 and TSx machines have as build-in feature new kind of macro capabilities. This capability is simplistic Windows Window Manager Message recording and play function. Presumably the feature has been designed for automation of volume testing, if this is the case it is important to understand that this approach bypasses part of the system and therefore is by no means equal to end-to-end testing. There are number of concerns, including but not limited, around this feature functionality warranting further studies.

- The files are stored on the removable memory card as unprotected plain-text files. There are no protection mechanisms against modifications to these files
- Are the WM_message filters adequate
- Is the processing function secure against buffer overflow / boundary overflow attacks
- the message parameters passed back to windows checked, is there proper exception handling in place

Creation and access to the macros is available on poll worker level access, under circumstances even without any smart card authentification.

On the preliminary testing following issues were identified :

- macro is not contained in the user interface logic. Because of this macro can access settings changing the telephone number / ip address and initiate call
- Two machines, with completely identical software release numbers had different behavior with the same macro. Machine A just had a software crash and become unstable, while machine B produced an error message on the system log and contained the error while still ending to experience loss of software functionalities. There were other examples of different, but reproducible, software behaviors between machines with both modified and unmodified macros.

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- File handle processing seems to be flawed and interrupted by exception macro processing produced open file handles
- There seems to be user interface race conditions, which can not be triggered by human interaction with the machine, but are revealed by no delay playback of the human actions

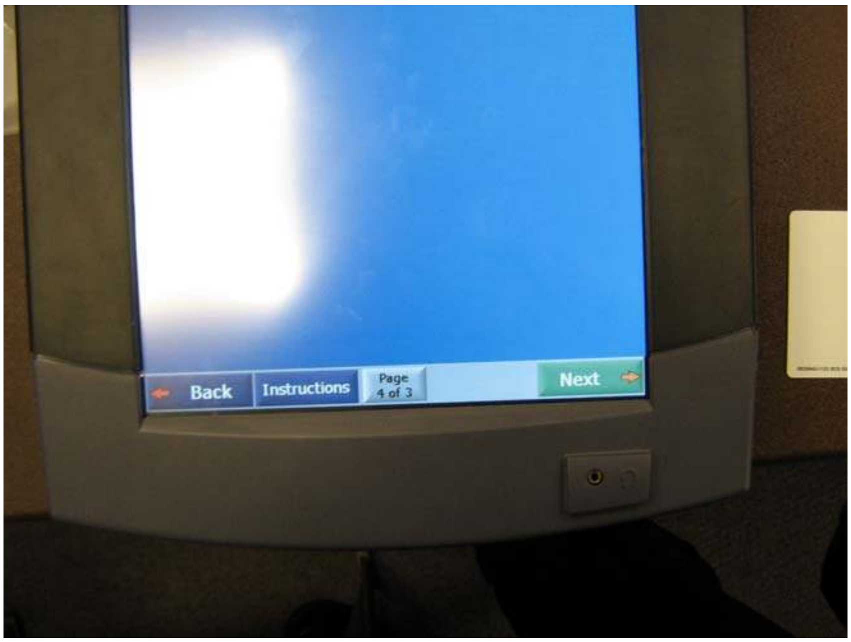


Fig. 8 – Macro skips to "Page 4 of 3" of 3 page ballot and stops without error message while macro is still active

**3. Back door**

The TS6 is likely to have an additional back door for accessing windows, though this could not tested in Emery County – also it is unknown if any of this in any form has been carried over to TSx. Further source code analysis of the well-known "CVS.TAR" file[2], which contains source code for the TS6 and has been widely used in touch-screen system security studies, has revealed this feature.

The fact that this backdoor has not been published before underlines the fact that source code reviews performed this far have been not conclusive.

The start-up program for the ballot station is looking for existence of file Explorer.glb on the memory card. The file itself can be empty, because the found file based on the name alone is a trigger for alternative execution of general purpose file management utility program instead of the ballot station, therefore enabling access to Operating System. This back door has also been documented in the publicly available memos:

> Re: Tippacanoe, IN - Upgrading AVTS
>
> * To: <support@dieboldes.com>
> * Subject: Re: Tippacanoe, IN - Upgrading AVTS
> * From: "Talbot Iredale" <tiredale@dieboldes.com>
> * Date: Tue, 8 Oct 2002 10:38:37 -0700
> * References:
>
> <GOEFLGCGEKJOLBNCMPEIOELOCCAA.jeffhintz@dieboldes.com>
>
> To access the OS in WinCE 3.0 create a file called "Explorer.glb" on the pcmica card, insert the card into the unit and turn the unit on. The unit will then display the desktop rather than run Ballot Station. You can then go to the windows directory and select "control" and then "network" to set the ip address.
>
> The other option is the setup a DHCP server on the Windows machine which will automatically configure the network card.
>
> Tab

**4. Automatic deletion of files, including election file-extension files:**

In case the memory card is full, the system will, without any interaction with user start to delete files from the card to free up memory. This deletion will also take out files with election file extensions from the election subdirectory. There is no way to verify which logic the system follows when choosing for the files to be deleted.

**5. Memory card test file merits further study:**

From the publicly available documentation there is reference to memory card testing with 16-bit "gray-code algorith" using file:

COUNTUP.DAT

This functionality should be studied,. Vulnerabilities are unknown.

**6. Other file names should be examined:**

The following references were found from the publicly available documentation :

DIAG.BIN
DIAG.NB0

No testing was done with these files, it is unknown what, if any, functionalities are involved.

**7. Outdated OpenSSL version**

The OpenSSL used in the TSx BallotStation 4.6.4 software is an outdated version 0.9.7e, dated 25/10 1994, which is known to contain some security vulnerabilities. At the time of the writing, most current versions are 0.9.7j and 0.9.8b.

**8. Certificate will expire**

The Cyptographic certificate of TSx has an expiration date of 31/1 2009. Installation / replacement process for renewed certificate was not studied.

**9. Piggyback connectors under modem**

The modem is implemented on the motherboard as piggyback module. However, there are two sets of connectors underneath this modem built for two different kinds of piggybacks. It is unknown what the other piggybacks enable.

**11. Memory discrepancies:**

Emery County Clerk Bruce Funk noticed that some of his machines, which were marked with a yellow stick-on dot and had serial numbers in the 201000-223000 range, had screen messages indicating critically low available memory storage at the time of the delivery. Whereas machines in the 230000-255000 range had memory storage of 22-27 MB, the machines in the earlier serial number blocks had memory storage of 4-8 MB.

Funk was told by Diebold representatives[1] in a tape recorded meeting Mar. 27, 2006 that there were no differences between the programs installed on the machines, that none of the machines were used, and that there were no extra programs on the machines.

It was noted during this study that some machines contained test election data. Deleting this data did not free up a significant amount of memory. After this study, Diebold has explained that this lack of memory is due to the presence of extra fonts installed on some machines. No study was done to find out the reason for varying free memory sizes.

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| Serial Number | Available memory | Serial Number | Available memory |
|---|---|---|---|
| 201492 | 7 MB (17% free) | 245521 | 26 MB (59% free) |
| 203638 | 6 MB (14% free) | 244533 | 24 MB (54% free) |
| 210639 | 8 MB (17% free) | 245397 | 25 MB (57% free) |
| 211883 | 7 MB (16% free) | 245506 | 26 MB (60% free) |
| 216349 | 8 MB (19% free) | 248120 | 26 MB (59% free) |
| 219632 | 7 MB (17% free) | 248250 | 25 MB (58% free) |
| 220005 | 4 MB (10% free) | 248347 | 25 MB (57% free) |
| 223158 | 11 MB (25% free) | 248469 | 26 MB (58% free) |
| 230354 | 22 MB (51% free) | 249309 | 25 MB (57% free) |
| 232637 | 24 MB (55% free) | 249448 | 27 MB (62% free) |
| 237382 | 26 MB (59% free) | 251787 | 27 MB (60% free) |
| 243050 | 24 MB (55% free) | 254449 | 23 MB (52% free) |
| 244076 | 26 MB (59% free) | 254546 | 25 MB (56% free) |
| 244282 | 25 MB (58% free) | 254706 | 25 MB (57% free) |
| 244401 | 28 MB (63% free) | 255073 | 25 MB (58% free) |
| 244486 | 26 MB (58% free) | | |

Fig. 9 – Serial numbers: Variations in memory storage available

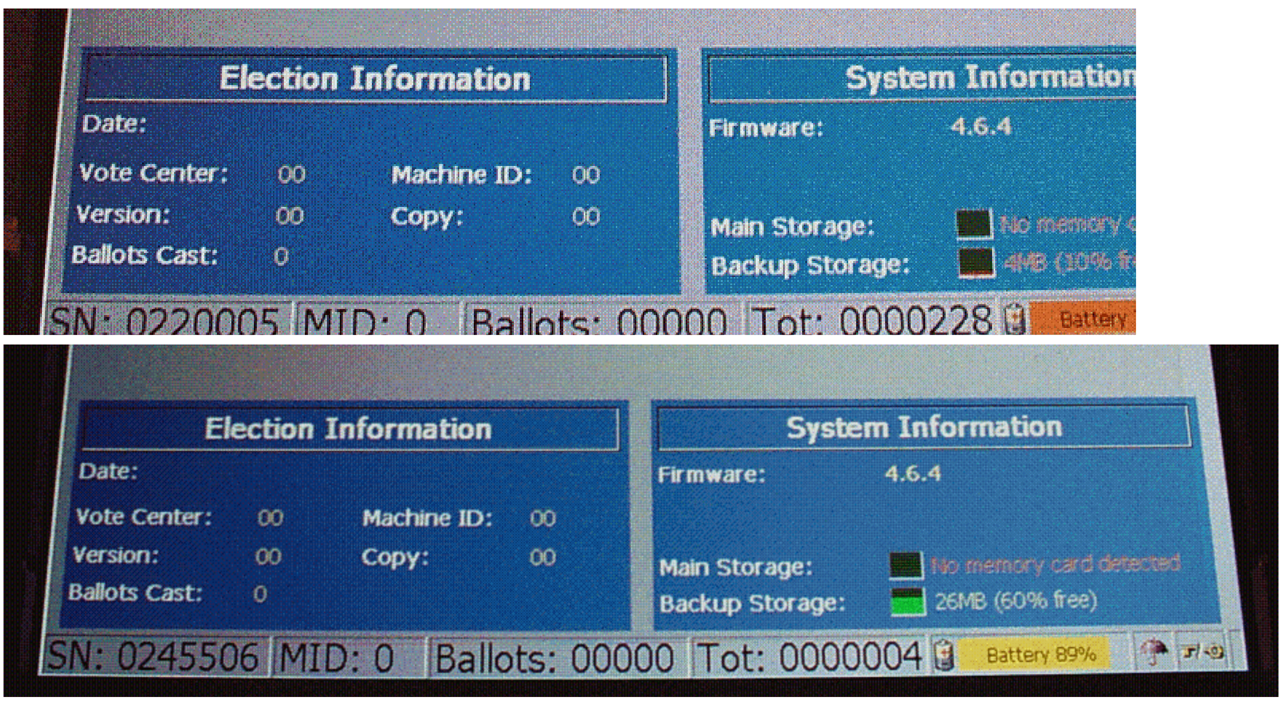


Fig. 10 – Screen shots: Variations in memory storage available

## 12. Electrical hazards:

The electrical sockets on the TSx are not properly fitted to the case. Every unit examined revealed problems with sockets popping out or falling out, sometimes by simply moving the machine or through light contact with the cord. Because many polling places lack sufficient wall outlets to plug in all the machines, these machines are typically daisy-chained together

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(one machine plugged to the next) with a single machine plugged in to the wall. The improperly designed socket design presents potentially an electrical hazard to poll workers and voters.

Fig. 11 – Exposed 110 volt wiring and socket falling out


**13. VVPAT – Voter Verifiable Paper Audit Trail:** The printer mechanism for the TSx machines examined in Emery County does not sufficiently guide the paper, producing frequent paper jams.

Fig. 12 – Paper jam in progress

In addition, a design decision to place a brown door over the paper which the voter is supposed to verify leads to questions about the usefulness of the VVPAT. Unless the door is lifted up it obstructs view of the paper representation of the voter's vote. If the system is to be used to verify a paper trail, it should have instructions printed prominently on the casing instructing voters to lift the brown door to see the paper trail.

Fig. 13 – Brown door blocking view of voter verifiable paper trail

The lens used to view the VVPAT tends to obstruct the viewing of the paper representation of the vote.

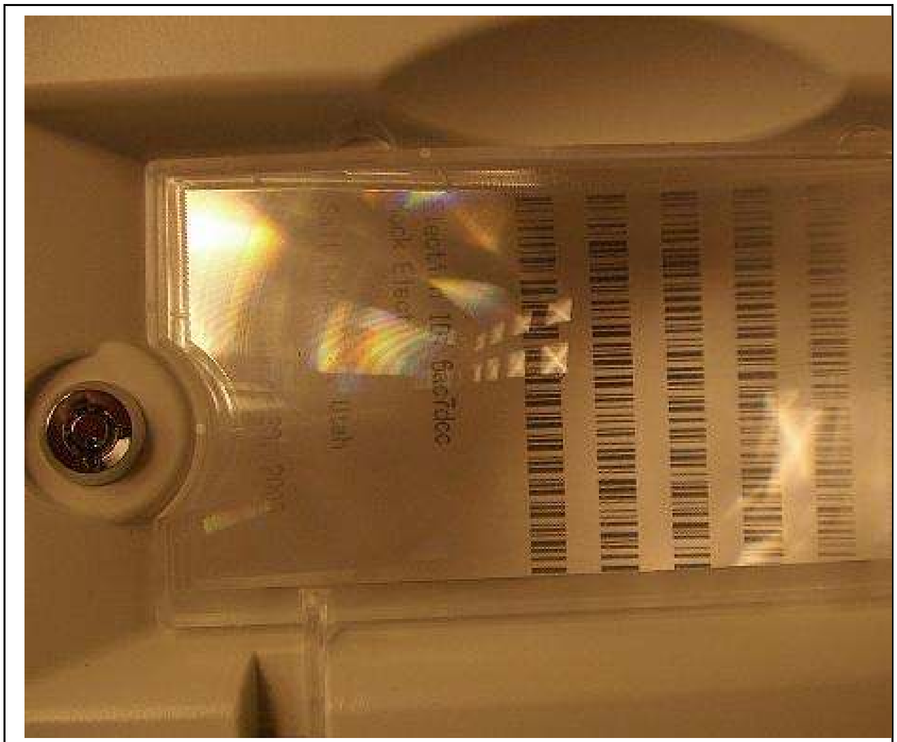

Fig. 14 – Print is too small so magnifying lens is provided but the lens distorts.

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The voter can lift the lens, but the print is very small and the bottom of the paper record of the vote does not display fully.

Fig. 15 – Print is small; lower part of paper trail tends not to scroll up into full view.

## Conclusions and Recommendations

FOOTNOTES

[1] Tape recorded Emery County meeting with state elections director, county commissioners and Diebold attorneys, March 27, 2006

[2] Files found by Bev Harris on Diebold FTP site Jan. 23, 2003

ACKNOWLEDGEMENTS

The citizenry owes an immense debt of gratitude to Bruce Funk, the Emery County Clerk for Emery County, Utah who, upon noticing anomalies in the Diebold TSx machines delivered to his county, requested an independent evaluation of this voting system.

Appreciation is expressed to Kalle Kaukonen for providing his perspective on this report.

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# Diebold TSx Evaluation

## SECURITY ALERT: May 11, 2006
## Critical Security Issues with Diebold TSx

Unredacted – Released July 2, 2006 by Black Box Voting

A Black Box Voting Project
Prepared by: Harri Hursti

On behalf of Black Box Voting, Inc.
A nonprofit, nonpartisan, 501c(3) consumer protection group for elections

**Executive Summary**

Due to the nature of this report it is distributed in two different versions. Details of the attack are only in the restricted distribution version considered to be confidential.

This document describes several security issues with the Diebold electronic voting terminals TSx and TS6. These touch-pad terminals are widely used in US and Canadian elections and are among the most widely used touch pad voting systems in North America. Several vulnerabilities are described in this report. One of them, however, seems to enable a malicious person to compromise the equipment even years before actually using the exploit, possibly leaving the voting terminal incurably compromised.

These architectural defects are not in the election-processing system itself. However, they compromise the underlying platform and therefore cast a serious question over the integrity of the vote. These exploits can be used to affect the trustworthiness of the system or to selectively disenfranchise groups of voters through denial of service.

**Introduction**

The Diebold AccuVote touch-screen (Direct-Recording Electronic, or "DRE") voting terminals TS6 and TSx are used in hundreds of jurisdictions and many different states and provinces in the US and Canada, respectively. They are among the most popular DRE voting machines.

Voting terminals TS6 and TSx employ custom made hardware running with an embedded Windows CE operating system. As is true for all Windows CE systems, they require a boot loader to prepare the hardware for the launch of operating system. Both the boot loader and the operating system are custom built specifically for the unique hardware of the terminals.

The TS6 and TSx do not share the same core level architecture. For example, they have different CPUs. Furthermore, they have been designed by different engineering companies.

As part of the typical engineering process, the hardware and Windows CE customization is interwoven and performed simultaneously. Due to the heavy customization required for embedded operating systems to meet the hardware requirements and the nature of their environment of use, it is difficult to support the argument that these systems are "Commercial Off The Shelf" (COTS) operating systems like their desktop counterparts. Instead, the operating system itself is custom-built for each and every platform separately by combining the Operating System (OS) core with platform specific modifications and drivers. In the case of Windows CE, the tool to build the operating system is Microsoft Platform Builder.

Based on the tape recorded public meeting in Emery County on March 27, 2006[1], the TSx comes with at least three different revisions. There is no documentation available to as the extent the hardware revisions differ from each other, nor to which extent modifications are needed in the boot loader and/or Operating System builds. An Emery County system that was inspected and sold as new in early 2006 appears to be revision A. This machine had a PXA250 CPU and a MediaQ display controller. At least the revision A architecture has end-of-the-life-cycle components which indicate the need for re-engineering and modification to low-level design and programming. At least one version requires a different boot loader or Operating System build due to hardware changes.

**Three-layer architecture, 3 security problems**
**Each can stand alone or combine for 3-layer offense in depth**

As an oversimplification, the systems in question have three major software layers: boot loader, operating system and application program. As appropriate for current designs, the first two layers should contain all hardware specific implementations and modifications, while the application layer should access the hardware – the touch pad, memory card, the network etc. – only via services and functions provided by the operating system and therefore be independent of the hardware design. Whether the architecture in question follows these basic guidelines is unknown.

Based on publicly available documentation, source code excerpts and testing performed with the system, there seem to be several backdoors to the system which are unacceptable from a security point of view. These backdoors exist in each of these three layers and they allow the system to be modified in extremely flexible ways without even basic levels of security involved.

Different files carry various subsets of the following features: Signature check, mode check and integrity check. None of these can be considered security features against tampering. For example, the integrity check is 32-bit CRC. This check can be equated to a very crude spell-checker. It is effective against accidental typing errors but not deliberate attacks.

In the worst case scenario, the architectural weaknesses incorporated in these voting terminals allow a sophisticated attacker to develop an "offense in depth" approach in which each compromised layer will also become the guardian against clean-up efforts in the other layers. This kind of deep attack is extremely persistent and it is noteworthy that the layers can conceal the contamination very effectively should the attacker wish that. A quite natural strategy in these types of situations is to penetrate, modify and make everything look normal.

Well documented viral attacks exist in similar systems deploying interception and falsification of hash-code calculations used to verify integrity in the higher application levels to avoid detection. The three-level attack is the worst possible attack. However, each layer

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can also be used to deploy a stand-alone attack. The TSx systems examined appear to offer opportunities for the three-level attack as well as the stand-alone attacks.

Unlike the desktop versions of Windows, the embedded versions of Windows CE 3.x and 4.x versions used in the Diebold system (which are both noncurrent versions) have very limited security features against a user with access below the application level. Because of the lesser security available in Windows CE, access to the standard Windows Explorer application grants users access to replace and modify files almost without restriction. This enables a hostile attacker to severely alter the system functionality and/or add new software (and hidden processes) to the system.

In addition to altering individual files, the TSx and TS6 systems also present opportunities to change the Operating System itself. This provides possibilities for hiding the attack and/or altering the application's behavior without any changes to the application itself. A major contributor to this is the ability to change the Operating System functions and libraries any application software relies on at a deep level.

It is important to understand that these attacks are permanent in nature, surviving through the election cycles. Therefore, the contamination can happen at any point of the device's life cycle and remain active and undetected from the point of contamination on through multiple election cycles and even software upgrade cycles.

Here is a rough analogy:

- The application can be imagined as written instructions on a paper. If it is possible to replace these instructions, as it indeed seems, then the attacker can do whatever he wishes as long as the instructions are used.

- The operating system is the man reading the instructions. If he can be brainwashed according to the wishes of the attacker, then even correct instructions on the paper solve nothing. The man can decide to selectively do something different than the instructions. New paper instructions come and go, and the attacker can decide which instructions to follow because the operating system itself is under his control.

- The boot loader is the supreme entity that creates the man, the world and everything in it. In addition to creating, the boot loader also defines what is allowed in the world and delegates part of that responsibility to the operating system. If the attacker can replace the boot loader, trying to change the paper instructions or the man reading them does not work. The supreme entity will always have the power to replace the man with his own favorite, or perhaps he just modifies the man’s eyes and ears: Every time the man sees yellow, the supreme being makes him think he is seeing brown. The supreme entity can give the man two heads and a secret magic word to trigger switching the heads.

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In the world of the Diebold touch-screen voting terminals, all of these attacks look possible. The instructions (applications and files) can be changed. The man reading the files (Windows CE Operating System and the libraries) can be changed. Or the supreme entity (boot loader) can be changed, giving total control over the operating system and the files even if they are "clean software."

**1) Boot loader reflashing**

The prime responsibility of the boot loader is to set up the system hardware, ready it for launch of the operating system, and then launch it. In the development phase of the system, additional features for debugging and flexible software testing cycles are often needed. It is the standard practice to remove these features from the release versions, even when security is not a concern at all.

Most importantly, the Diebold boot loader for both TS6 and TSx releases seems to contain the full capability to reflash itself and the operating system. (Reflashing refers to the capability to reprogram the flash memory which acts as the permanent storage media for the platform in question.) Additionally, there seem to be a number of other development features not as easily accessible, including boot monitor and diagnostics.

Furthermore, the boot loader seems to be network aware and supporting modified boot orders between permanent on-board memory, removable media and the network. This document and the testing done focus on use of removable storage, a standard PCMCIA (Personal Computer Memory Card International Association) memory card, as the delivery mechanism of the new boot loader, operating system and applications. An examination of the motherboard indicates that other delivery mechanisms also exist and these will be discussed briefly as well.

In the boot-up process after the primary hardware initialization phase is complete, the boot loader will, in the case of existence of standard memory card in the PCMCIA slot, mount it as a standard windows file system.

In the case of the TS6, the boot loader will look for the existence of any file with 8.3 filename:

FBOOT.NB0
FBOOT.BIN (possibly not implemented)

and in the case of the TSx :

EBOOT.NB0
EBOOT.BIN (possibly not implemented)

If these files can be found, those files will start to be processed based simply on the fact that the filename was right ("trusting the filename"). If the files pass rudimentary integrity and a

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file mode checks as they easily should, the boot loader will automatically read the file and write that to the machine as a new boot loader. This process is destructive for the pre-existing boot loader and there seem to be no fail-safe mechanisms. The reprogramming starts automatically without any interaction with the user. Due to the highly destructive nature of this attack, this process was not tested in Emery County. These observations are based on analysis of the documentation available.

Due to the fact that the boot loader is the primary mechanism for its own reprogramming, if the boot loader is suspected to be compromised with a deep attack, using the boot loader itself to install a known clean version of a boot loader is no longer a viable option as a recovery path to clean the system.

At the time of this writing, existence of a safe recovery path for the TS6 from any suspected boot loader compromise is unknown. Based on an examination of the motherboard, the TSx appears to have a hardware-level interface which can facilitate initial programming of the boot loader. This interface is accessible with a JTAG-type of connector, enabling the auxiliary system to take over CPU level control of the motherboard.

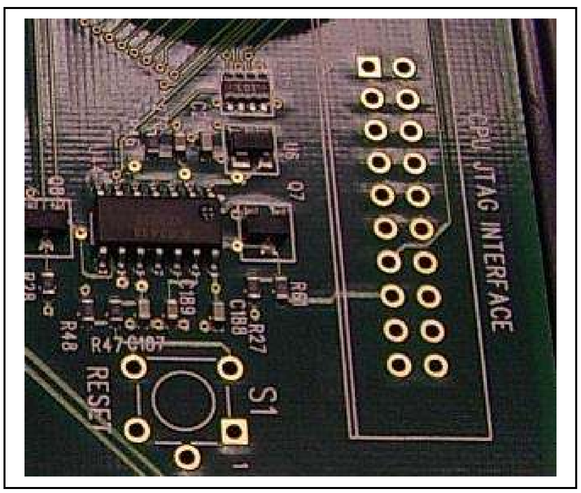


Fig. 1 – JTAG interface on TSx motherboard

At the time of this writing it seems reasonable to assume that this mechanism will enable the auxiliary system to prevent starting untrustworthy code execution onboard, allowing reprogramming of the flash memory to provide a safe recovery path.

It is unknown if this mechanism can be used to retrieve data for forensic studies from a system suspected of contamination, because the reprogramming operation is destructive and prevents any other forensic studies.

Unfortunately, the same mechanism used to provide a safe recovery path can be employed just as easily for a delivery mechanism for malicious code to the system. Due to the very

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nature of the process, no software-based security mechanism can provide a remedy against this type of attack.

**2) Operating system reflashing**

After processing of the new boot loader files, the boot loader will continue without any additional soft boot. This means that the programming code being executed can be temporarily different than the code in storage media, until the next reboot. At the reboot all traces of this temporary discrepancy will be erased.

Next, image files for new operating systems are searched. Unlike a standard desktop computer operating system, in embedded systems it is customary to deliver the whole runtime-ready operating system as one single image file. The boot loader will look for the following files:

NK.BIN (tested in live system)
NK.NB0 (possibly not implemented)
NK0.BIN (possibly not implemented)

As in the previous case, the file processing is launched based on the correct file name alone. The NK.BIN file is assumed to contain the WinCE.NET image. The file will be processed from the memory card without user interaction, overwriting the previous content and therefore destructive for future forensic studies.

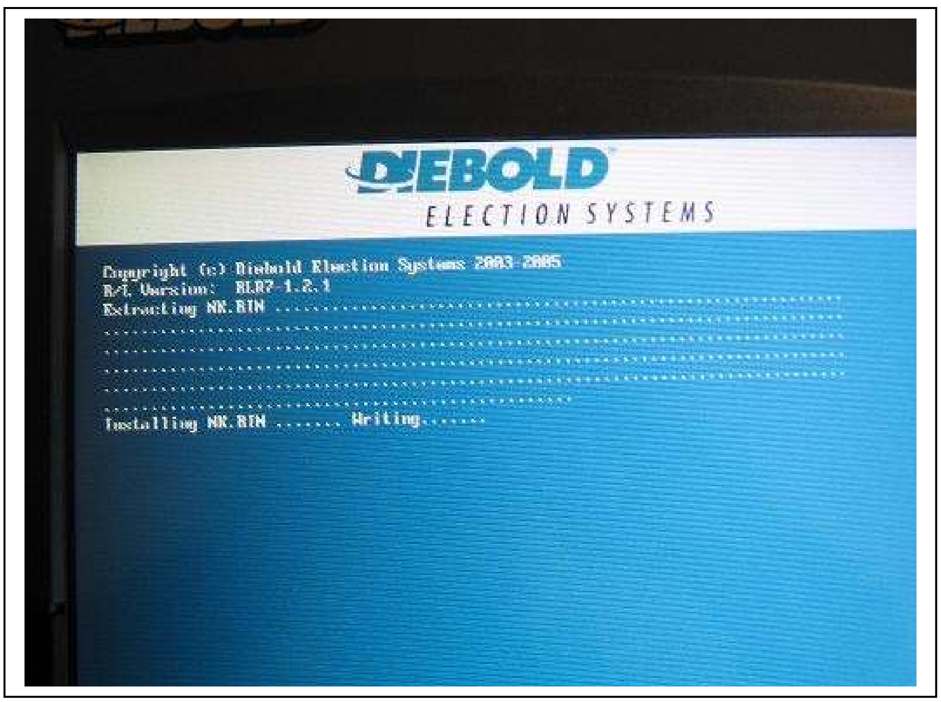



Fig. 2 – Photo taken during replacement of the Windows CE operating system on TSx machine

There are no cryptographic signatures or other security related measures involved. Replacement of the Windows CE operating system file is performed without even the most basic level of source, authentication or compatibility testing, allowing even code that is impossible to execute to be installed.

The valid NK.BIN file is a standard output from the Microsoft Platform Builder product.

Other mechanisms exist in addition to the PCMCIA card for replacement of the Windows CE operating system. Network awareness also enables a configuration where the Windows CE image will be downloaded from a remote network device. While not the focus of this document, the protocol seems to be standard and lacking implementation of security features.

**3) Selective file replacement**

The Diebold touch-screen voting application is called "Ballot Station."

After the boot loader has launched the Windows CE operating system, the start-up phase of the Ballot Station application begins with a custom-made start-up program. Before starting the existing Ballot Station application, the memory card is searched for existence of any files with an *.INS extension. All files matching this criteria will be processed sequentially. The INS file is a Diebold proprietary format batch overwrite install file, which can encapsulate multiple files to be replaced in the system.

This install procedure does check the internal version number of the file and magic number (double word length constant) as a measure to pre-qualify the file for processing. Unlike in previous phases, the file also contains a description field and a public version number to be displayed to a user in dialog for acceptance of the batch. Whereas the operating system will be replaced automatically with no questions asked of the user, the INS file will request user approval before installing the files.

No system log entries will be produced when INS files are processed, not even when rejected or invalid files are getting processed.

## Additional concerns

**4) Removable non-secured casing -** All of the above attacks are persistent in nature. The attacks can be deployed any time during the life cycle of the machine. It is safe to assume that a sophisticated attacker can install an election-independent core of the attack engine into the machine years ahead, delivering election-specific instructions to the engine by various easy delivery mechanisms available to, for example, any voter.

Operational procedures to lock and seal the machines before sending the machines to the homes of poll workers (as is customary in many jurisdictions) are in most cases not adequate. The TSx casing is affixed with simple standard phillips screws. When unscrewed, the back end of the casing comes off with the locked bay doors configured such that seals remain intact. When the casing is open, access to PCMCIA slots is unrestricted.

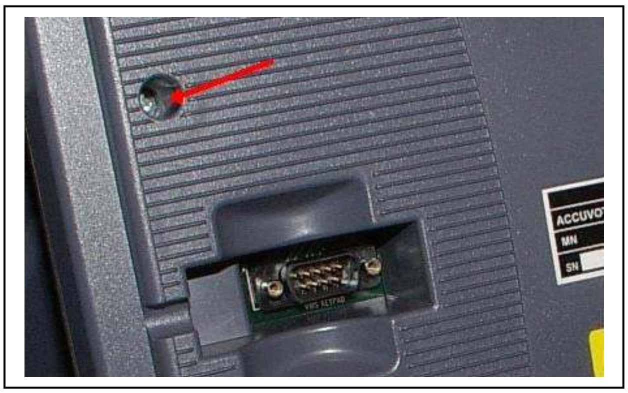


Fig. 3 – Casing is removed quickly and easily with a Phillips-head screw driver.
At the time of this writing, removing and replacing the casing leaves no telltale signs.

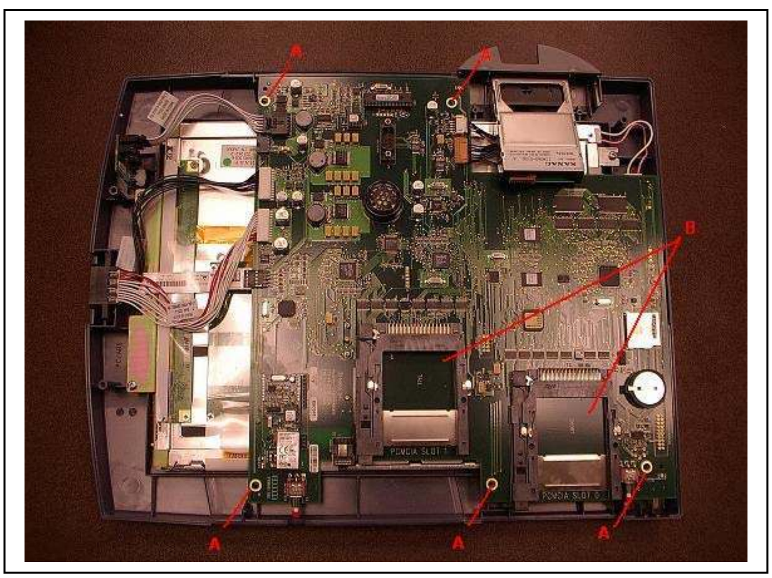



Fig. 4 - Diebold TSx motherboard
**A** = Phillips head screw holes **B** = PCMCIA card slots

### 5) Hidden SD slot

The TSx unit also comes with a hidden MMC/SD – a standard slot (Multimedia Card / Secure Data). These types of removable memory cards are standard components in many home consumer electronic devices, and the standard card has grown from its original purpose to a flexible general purpose interface, which can hold vast amounts of data in the gigabyte range, and also facilitate other types of peripheral functionalities, like networking. The slot is designed with enough room to facilitate other types of  SD cards besides simple memory cards. The SD slot is always active and once the casing is open it is accessible. The presence of  the SD card is undetectable when the case is closed.

It is unknown what support drivers are installed with Diebold-provided operating systems, but since additional support features can be added, a sophisticated attacker can, for example, introduce wireless capabilities to facilitate attack even if the system was not originally configured for wireless communication.

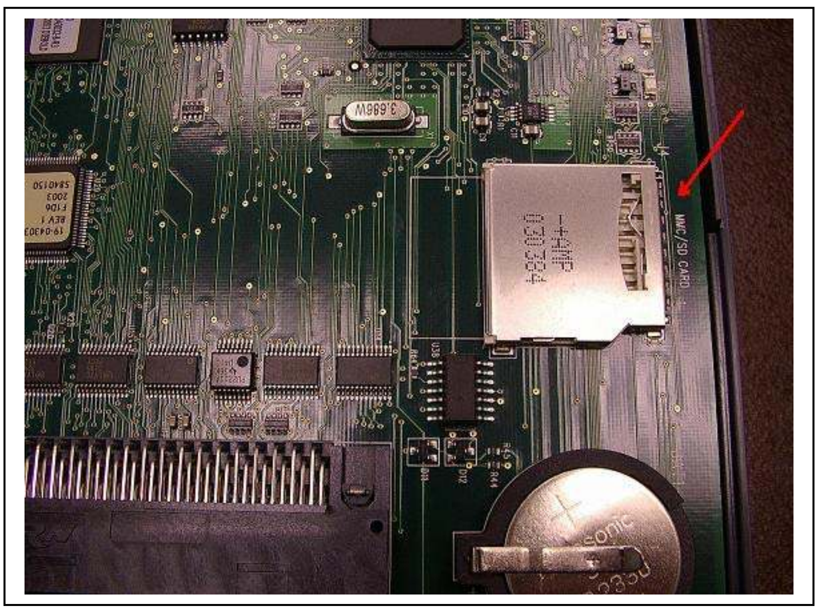
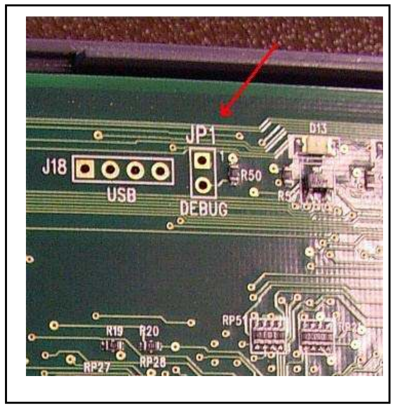



Fig. 5 – SD card slot on Diebold TSx motherboard

### 6) Jumper-enabled additional features

The motherboard also has jumpers to enable otherwise disabled software features. Based on the documentation, the Diebold standard implementation has debug features built in but disabled in the absence of having the jumper connected. Again, these features enable various simple attack vectors against the system.

Fig. 6 – "Debug" Jumper on motherboard




## 7) Software controlled voter accessible hidden button

The TSx also has an unmarked button hidden in the casing. On the circuit board, this switch is labeled "battery test". The switch is physically similar to many reset buttons, necessitating application of substantial force to press the button, requiring it to be depressed by about 1/5 - 1/6 inch in order to activate the switch. This switch is also software accessible. It is completely accessible for all voters in the standard voting booth configuration. The logic behind the button is unknown, but for an attacker it presents yet another way to interact with the machine, and an exceptionally convenient button switch for an attack designed to be triggered by a voter.


Fig. 6 – Voter-accessible hidden button – Exterior view

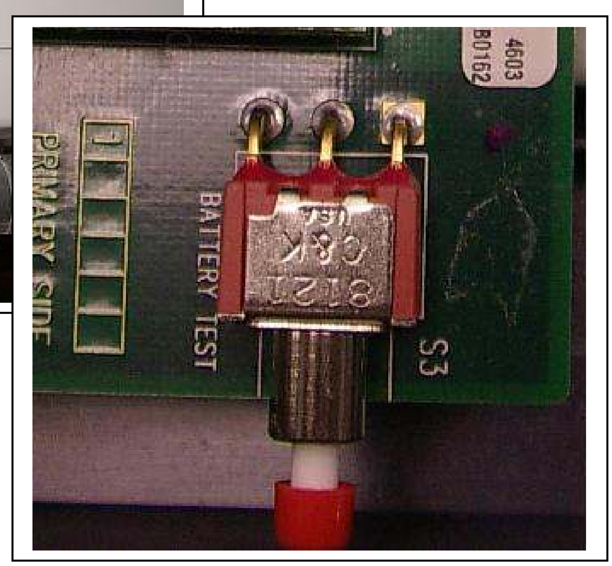



Fig. 7 – Voter-accessible hidden button – Interior view

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## Conclusions and Recommendations

Because there is no way of having chain of custody or audit trail for machines, the machines need to be reflashed with a known good version (assessing the risks potentially inherited). Ideally this should be done by the proper governmental authorities rather than being outsourced.

After that, extensive chain of custody management has to be established to make sure that machines do not get recontaminated. Less than five minutes is required for contamination.

The bootloader needs to be re-engineered.

The cases need to be properly and permanently sealed.

Further study is warranted around these issues and others in the May 15, 2006 Supplemental Report for the Emery County TSx study.

While these flaws in design are not in the vote-processing system itself, they seriously compromise election security. It would be helpful to learn how existing oversight processes have failed to identify this threat.

FOOTNOTES

[1] Tape recorded Emery County meeting with state elections director, county commissioners and Diebold attorneys, March 27, 2006

[2] Files found by Bev Harris on Diebold FTP site Jan. 23, 2003.

ACKNOWLEDGEMENTS

The citizenry owes an immense debt of gratitude to Bruce Funk, the Emery County Clerk for Emery County, Utah who, upon noticing anomalies in the Diebold TSx machines delivered to his county, requested an independent evaluation of this voting system.

Appreciation is expressed to Kalle Kaukonen for providing his perspective on this report.

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