Case Study of a Year 2000 Platform Testing Initiative

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SUMMARY & CONCLUSIONS

This paper uses the results from the testing of over 2,300 personal computers (PC's) in a multinational Fortune 500 company to examine the question of Year 2000 hardware compliance and the actual number of machines that fall into the category of "Not Compliant." The PC's tested cover a broad scope in terms of age and configuration. We perform a case study of the method and results, and present lessons learned for use in future initiatives of this type. We conclude that, contrary to popular predictions, the notions that the majority of PC's will have to be replaced or remediated through either upgrades to BIOS or commercially available software packages are **not** supported by the results of this study. Rather, we found that the vast majority of machines **are** hardware compliant and there is little need for replacement or remediation.

INTRODUCTION

The Year 2000 problem, which concerns dates in the next century not being properly recognized due to two digit year storage, has been acknowledged as a major issue by the computer industry as a whole. From this, much information has been reported by the mass media and various Year 2000 pundits on the issue and on where the problems lie with little hard data to back up their predictions. The original focus of the Year 2000 effort was legacy mainframes and COBOL code. Recently, attention has shifted to the issues related to the personal computer. The problems with mainframes generally did not affect smaller businesses and home users, but with the recognition of the problem on PC's the potential for a significantly more widespread impact is possible.

In this paper we address the issue of Year 2000 compliance as it relates to PC hardware platforms. There are several misconceptions about the Year 2000 compliance of PC hardware. The current perception propagated by the media is that the majority of personal computer hardware will not be compliant. Much of this information comes from unsupported studies, at least some of which are used by software producers to sell "solutions" to the problem. Often these studies make broad claims, such as the examples which follow.

"Anywhere from 50% to 70% of the desktop hardware of an average enterprise's installed base will not automatically roll over to the year 2000 and will run into serious hardware and software problems as a result." [1]

"In the meantime your problem is growing. Right now, a new PC is being installed. Is it Year 2000 compatible? ..... after this article was printed in Information Canada, I received more than 140 responses... 97% of the PC's tested... failed." [2]

In a study reported in [3] the results denote that 400 PC's from the Washington State Government are problematic, and, "A simple upgrade to BIOS chips can fix 120 of these PC's, ... but modifying the rest will be too costly."

"We tested pre-1997 configurations on PC hardware and software, and 93 percent of them fail [a year 2000 test]". [4]

In order to understand why our test results and conclusions differ so significantly from those predictions being made by others, it is necessary to understand the testing methods we developed to determine PC compliance and why we chose to include manual testing, in addition to the use of software packages designed to test for compliance. In the next section, we present some background information about these and other issues which is helpful in understanding our testing methods. We then describe our testing procedures and the costs associated with them and finally present our results and recommendations.

BACKGROUND

For the purposes of this paper, PC year 2000 compliance is defined as properly reading and displaying/providing dates into the next century from an *application's viewpoint*. The applications acquire the date from information provided by the clock mechanisms of the PC. For the purpose of this paper the PC hardware platform will refer to an Intel x86 or compatible processor-based computer, with a Real Time Clock (RTC), BIOS Clock, and an Operating System (OS) Clock. These three clocks, which together will determine if the PC is year 2000 compliant, are described next.

- The Real Time Clock (RTC) is the actual hardware clock used by the system. This is kept running by battery when the system is powered down.

- The BIOS Clock is a logical construct (a "software" clock) comprised of the BIOS storage for the date (i.e. two digits for the year, and either a century bit or two century bits), the roll over routines (if there are any) which allow the BIOS to properly change the century bit(s), and any routines to read from/write to the BIOS date areas.

- The Operating System (OS) Clock is another construct consisting of the clock display using a standard date call (the Date command in DOS or the Date/Time dialog box in Windows).

Relation of Clock Compliance to PC Compliance

Clearly, if none of the clocks is compliant, the PC itself will not be compliant, and if all of the clocks are compliant, the PC will be compliant. Now, clock compliance propagates upward from the RTC to the BIOS Clock to the OS Clock, so when one of these clocks is compliant those above it will also be compliant. This is true due to the logical clock structure. Thus, if the RTC is compliant, so are the other two, and therefore the PC is compliant. If the RTC is not compliant but the BIOS and OS Clocks are, we would still consider the PC to be compliant. This is because in a separate test of approximately 5,000 software packages, none were found to access the RTC directly. Therefore, even with a noncompliant RTC, from the application's standpoint the correct date will be correctly acquired from the other clocks. This leaves only one scenario to consider, i.e., the case where the BIOS is noncompliant and the OS is compliant. Since the OS Clock acquires date information from the BIOS Clock, a noncompliant BIOS will pass erroneous information to the OS Clock making the PC noncompliant.

TESTING METHOD

Testing the Clocks for Compliance

It is possible to use software packages to test the three clocks and to report the compliance of each clock. Software testing can easily and accurately determine the compliance or noncompliance of the RTC. The compliance of the BIOS Clock is more difficult to determine accurately. Different BIOS's use different routines to roll the date into the next century. Some of these routines are functional only if the computer is on. Others are only operational during startup, i.e., when the computer boots. Some BIOS's contain only one type of roll over routine; others contain both. Software testing can only test for the presence of the first type. Therefore, a BIOS Clock may be fully compliant but be erroneously reported as noncompliant by the software test because the BIOS's rollover routine can't be detected by the testing software. In these cases, the actual compliance of the BIOS can be established only by additional manual testing. Further, even if the BIOS is not fully compliant, it may be partially compliant. It is important to be able to identify this condition, because a partially compliant BIOS is easily and inexpensively remediated. It requires only that the date be correctly set manually **once** after midnight 12/31/99. Thereafter, it will retain the correct date and function as a fully compliant clock. Software testing can definitively determine OS Clock compliance or non-compliance. But, even if the OS Clock is compliant, it may not function correctly if the BIOS Clock is noncompliant. However, a partially compliant BIOS Clock will pass that partial compliance upward to the OS Clock. Therefore, in the testing methodology we developed, we wanted to be sure that we would correctly identify both complete and partial BIOS Clock compliance.

Testing Methodology

The logical flow of the testing methodology we developed and used to certify PC hardware compliance for the year 2000 is illustrated in Figure 1. The flowchart also describes how the results of the software and manual testing were interpreted to determine to which category each PC was assigned. The methodology is a two phase testing approach, software based and manual*. The first phase, the software testing, utilizes an inexpensive tool that checks the basic operation of the three clocks while the computer is on and reports them back in a clear, concise manner. The software test rates each clock as either compliant (good) or not compliant (bad).

The second step, manual testing consists of two parts. The first involves setting the system date to just prior to 1/1/2000 and powering down the computer while the system rolls the date. The computer is then powered up and the date checked to see if it correctly rolled to 1/1/2000. This test checks for BIOS routines that run only at boot time and set the century information as appropriate. This test allows us to identify as fully compliant a BIOS Clock which software testing erroneously reported as noncompliant. If this test is successful, no further manual testing is required. If this test is failed, the BIOS is not fully compliant but may be partially compliant. The second half of the manual procedure tests for this case. The testing involves the setting of the clock to 1/1/2000 and rebooting. The date is then checked again to see if the century information is retained.

Based on the test results, each PC was assigned to one of three categories and an identifying colored sticker was placed on it. The categories and sticker colors are as follows:

- Fully Compliant (Green) - These machines are compliant. Most of these machines had a bad RTC, but they had

* A completely manual test for compliance is possible and is described in the Appendix. Because of the large number of machines involved in this study, software testing was used to eliminate the need for some of the manual testing.

Figure 1 - Hardware Certification Process Flow

compliant BIOS and OS Clocks. As noted above, the RTC was not found to be accessed directly by applications so we permitted these machines to be labeled compliant if the RTC was the only problem. It was found through a vendor investigation that compliant RTC chips only started being used by the major manufacturers in mid 1997 or after.

- Partially Compliant (Yellow) - These machines require that a manual date change be performed **once** after the year 2000. The BIOS's handle dates into the next century, but the roll over routines are either incorrect or missing.

- Noncompliant (Red) - These machines do not roll over into the year 2000 at all. The date must be set **every** time the machine is rebooted. These machines need a BIOS upgrade, software patch, or other remediation to function completely in the year 2000.

Cost of Testing

The methodology was developed and written instructions were prepared by a centralized team, then distributed along with training to all of the company's major sites world-wide. The development work represented approximately 120 to 140 man-hours of effort in terms of time to investigate the technical aspects of the problem and the actual development and writing of the methodology. In addition, another 100 man-hours total were spent in training the various site coordinators on the process. (Note: This time includes both the site coordinator and instructor time.) In total 2,328 PC's were tested at a rate time of approximately 12 PC's per man-hour, representing a total of about 194 man-hours spent testing. Thus the project involved not more than 450 man-hours of effort.

RESULTS

Of the machines tested, the majority were later 486 or higher machines. Most of the remaining machines were early 486 and 386 machines, with a couple of even older systems. The number of computers falling into each of the categories from our testing is summarized in the Table 1.

These numbers show that, contrary to many of the statements made about PC platform hardware compliance, the majority of machines **are** compliant. Note: We found the number of **non-compliant RTC's** to be about 90%. This suggests the possibility that some of the media and software vendors predicting 90% noncompliance might be using RTC compliance alone as a metric for overall PC compliance. Since we have found through investigation and testing that the RTC itself does not affect platform compliance as a whole, use of this number alone as a metric is clearly inappropriate.

The numbers above show that the vast majority, approximately 79%, of PC's are compliant. These machines will not have any problems from the platform/applications standpoint with the year 2000. In addition, if there is a mechanism in place to either automatically (using a Network Time Protocol (NTP) or another automatic date update) or manually (we placed yellow stickers on user machines as a reminder in our project) update the date, then yellow machines can also be counted as compliant, bring the percentage of compliant machines up to approximately 95%. By classifying partially compliant (yellow stickered) machines as compliant, a salvage of approximately 16% is obtained via a **one-time** command typed into the machine.

Even the noncompliant (red category) machines will still be functional to some extent, although they will not update automatically and they would need a date change on every reboot. If the machines are networked, NTP can be used to keep these machines updated. If they are standalone machines, they can still be utilized for non-date operations, such as word processing or terminal emulation. These machines should not be used for any business critical applications, but a careful remapping of machines to users could leverage the current holdings so that the completely compliant machines were placed in business critical areas and the other machines were placed in less critical support roles.

DECISIONS RESULTING FROM TESTING

Our decision regarding the completely non-compliant PC's (red category) was to replace them with new machines. Due to the time and effort to obtain a BIOS patch (if available) and the age of these machines, it was determined not to be cost effective to upgrade these machines. All of the machines in that category were systems based on early 486 processors or lower. The majority of these machines had been scheduled to be upgraded anyway by the year 2000, so the actual number of machines that need changes because of the year 2000 is fairly low.

The machines that fell into the partially compliant (yellow) category were determined to be acceptable for use across the company after the year 2000 with an appropriate warning (in our case the yellow sticker.) All of these machines had 486 processors or lower, although some of them were later 486's.

	Compliant (Green)	**Partially Compliant (Yellow)**	**Noncompliant (Red)**	**Total**
Number of Machines	1837 (78.9%)	384 (16.47%)	107 (4.6%)	2328 (100%)

Table 1 : Summary of Test Results

RECOMMENDATIONS

The results of this study indicate that it is not necessary to budget for wholesale replacement of machines. If a given organization has primarily 486 and Pentium class machines, there will be few, if any, replacements necessary. With some careful planning, the machines being categorized as red can be moved to non-date-critical applications, thereby generating greater cost savings. For smaller organizations with significant numbers of older machines, it is necessary to weigh the cost of upgrading against the cost of testing and remediating. Pre-486 machines may not even have BIOS upgrades available, and they are likely to no longer be supported by their vendors.

From lessons learned in our testing initiative, there are several points that bear consideration for future projects of this nature:

- Testing machines with Pentium level or higher processors is not necessary. In our testing, all Pentium class machines were categorized as green.

- Older machines in the pre-486 range may not be worth testing and remediating. We attempted remediation on a few machines, and the cost was approximately 2-3 man-hours per machine to find and implement a patch.

- The currently available testing tools do not test the rollover routines at startup, so these must be checked manually to eliminate erroneous reports of noncompliant BIOS Clocks.

- The Real Time Clock has little direct affect on application time handling, and therefore should not be included in year 2000 platform analysis.

- Hardware vendor-supplied tools for checking the year 2000 on their own machines are of no value, as they can define compliance any way they want and these tools only need to reflect **their** definition of compliance, not necessarily your company's.

- Year 2000 software "fixes" are primarily TSR's (terminate and stay resident) that capture date calls or set the clock every reboot. There is little if any value to these products and better remediation solutions exist.

- Hardware vendor information on testing is unreliable. After many vendor visits, it was discovered that most vendors had assumed that their machines were compliant and did not actually do any testing.

As with any information technology project of this type, the cost/benefit ratio must be weighed carefully. A conservative organization may want to replace all pre-Pentium class machines to insure compliance, whereas a small company might allow partially compliant machines and possibly even noncompliant machines (with further testing of in-use functionality on those specific machines) to be used. The primary lesson learned through our testing, that should be taken into account in project planning, is the fact that the scope of the problem for PC platforms is **not** as widespread or costly as is often claimed, and the impact should be minimal in comparison to other year 2000 issues. With the limited resources available to remediate the problem on time, the personnel that would be testing and remediating PC hardware would be more beneficial working on other aspects of the year 2000 problem.

APPENDIX

The flowchart in Figure 2 shows the testing sequence for a fully manual test of PC Year 2000 compliance.

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BIOGRAPHIES

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Julia V. Bukowski (S'70, M'79, SM'85) is an associate professor of Electrical and Computer Engineering at Villanova University. Her research interests include hardware, software and network reliability. She has been engaged in a variety of research projects involving reliability modeling, software design, and software testing. She has published numerous technical articles and has been a guest editor of a special issue of the *IEEE Transactions on Reliability.* She was a Visiting Associate Professor and Fulbright Senior Lecturer at the Techion Israel Institute of Technology. She has been elected to Eta Kappa Nu and Sigma Xi and was the recipient of the IEEE Centennial Young Engineers Award from the Reliability Society.

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Figure 2 - Fully Manual Hardware Certification Process Flow