Declaration of Daniel P. Lopresti, Ph.D
Regarding the Malfunction/Breakdown Rates of Direct Recording Electronic ("DRE") Voting Systems

I, Daniel P. Lopresti, declare under penalty of perjury and state as follows:

Summary of Qualifications

1. I am an Associate Professor in the Department of Computer Science & Engineering at Lehigh University in Bethlehem, PA where I have taught since 2003. My first position after completing graduate school was as an Assistant Professor in the Computer Science Department at Brown University in Providence, RI. I then spent 11 years working in industry, first as a research scientist at the Matsushita Information Technology Laboratory in Princeton, NJ and later as member of the technical Staff at Bell Labs, Lucent Technologies in Murray Hill, NJ.

2. I earned my Ph.D. in Computer Science, M.A. in Electrical Engineering and Computer Science, and M.S.E. in Electrical Engineering and Computer Science at Princeton University. I received an A.B. in Mathematics and Engineering Science at Dartmouth College.

3. At Lehigh University, I am the co-director of the Pattern Recognition Research Lab. I recently received a National Science Foundation grant to study electronic voting systems ("Following the Paper Trail: Reliable Processing of Voting Records for Trustworthy Elections"), and I have written a number of scholarly articles in that field. I have authored over 100

publications in journals and refereed conference proceedings on a wide range of topic; I also hold 21 U.S. Patents. I have served on dozens of conference program committees and as editor for six international conference proceedings, and I am currently an Associate Editor for IEEE Transactions on Pattern Analysis and Machine Intelligence and the International Journal of Document Analysis and Recognition.

<u>Expertise Regarding DRE Malfunctions</u>

4. Since 2006, I have been examining issues concerning electronic voting in Pennsylvania and around the country. In the course of my study, I have reviewed numerous scientific papers and other published documents on the security, reliability, and accuracy of electronic voting systems. I organized a panel discussion at Lehigh University in April 2006 which brought together noted experts from around the state to examine the risks associated with such systems. I have lectured publicly about the inherent vulnerability of direct-recording electronic ("DRE") voting machines and the need for voter verified paper records. I have offered testimony at a Northhampton County Council meeting in March 2006, spoken with voting officials in Bucks County many times, including in September 2006 and March 2008, and traveled to Harrisburg to meet with state officials to voice my concerns in July 2006. I have also attended professional conferences on Electronic Voting Technology in Boston and San Jose, in 2007 and 2008 respectively. I am currently

teaching an upper-level course called "Special Topics in Electronic Voting Systems," and, in the past two years, I have supervised seven independent study research efforts relating to electronic voting systems.

5. I have also closely examined two DRE voting machines – the Danaher 1242 full face and the Sequoia AVC Advantage full face – including dismantling these machines and studying their design, construction and operation. The Danaher 1242 is in use in six counties, and the Sequoia AVC Advantage is in use in two counties in the Commonwealth of Pennsylvania. I am also familiar with the operation and record of reliability for the other four DRE models in use in Pennsylvania: the Premier (formerly Diebold) AccuVote TSx; the ES&S iVotronic; the Hart InterCivic eSlate; and the Sequoia Edge. I have reviewed many articles and certification reports that evaluate these machines and their operation and I have studied the certification procedures and reports for DRE machines in Pennsylvania and elsewhere.

6. I am also familiar with certain federal standards used by the Federal Election Commission for expressing reliability in voting-related computer software and hardware. One such standard is known as Mean Time Between Failures ("MTBF"); it expresses the mean amount of hours that a computer is expected to operate without failing, and still be minimally acceptable for use in voting. MTBF is a federal advisory standard that all electronic voting machine manufacturers must meet for their electronic voting machines to be certified

for use in the Commonwealth of Pennsylvania. I have also seen the MTBF standard used in a volume test to assess the Diebold AccuVote TSx, a DRE voting machine. The Premier (formerly Diebold) AccuVote TSx is used in 16 counties in the Commonwealth of Pennsylvania.

DRE Malfunctions

7. DRE machines, like all computers, are comprised of both hardware and software. Hardware refers to the physical components of the machine – its mechanical and electronic parts, wiring, buttons, dials, screens, printing apparatus, etc. Software refers to the sequence of instructions that powers the computational aspects of the device; it is comprised of code written in various computer languages.

8. DRE machines, like all computers, fail or breakdown both because of hardware and software breakage or malfunction. A common example of hardware failure is where a wheel or reel on a printer fails to turn or to feed through paper properly, resulting in a "printer jam." A common example of a software failure is where, because of an error in the program logic, a certain computation is not completed correctly, causing the machine to get "stuck," or frozen, in a state and become unresponsive to user inputs, or to generate incorrect or unintelligible outputs. The possibilities for hardware and software failures are virtually limitless but, to a certainty, every computer

suffers from them from time to time, and some intervention – whether a repair, re-booting, resetting, or other action – is generally required before the computer becomes operational and its functioning is again trustworthy.

9. The Secretary of State of the Commonwealth of Pennsylvania has issued a Directive which states that, if all of the voting machines in a particular voting precinct fail and are out of service during the same time period, the election officials in that precinct may distribute emergency paper ballots for use by voters (the "100% rule"). As a professor of Computer Science, and someone deeply familiar with the both the DRE voting machines in use in Pennsylvania, and computers and computer failures generally, it is my opinion that the Secretary of State's Directive contains a fundamental misunderstanding of how computer failures happen, as well as the impact of the 100% rule in practical circumstances where election officials are expecting to rely upon computer hardware and software to conduct an election.

10. Most of the voting precincts that I am familiar with in Pennsylvania have two or three voting machines operative and available for voting. My conclusions presume that this number of machines per precinct is fairly typical, and that this allocation is appropriate under state standards for numbers of voters per precinct and the asserted capacity of the DRE machines now in use in the Commonwealth.

11. As a threshold matter, it is important to recognize that there have been circumstances where all of the DRE machines in a particular voting precinct in the Commonwealth have failed or are inoperative for any number of reasons during the same period; there were reports of this occurring in the 2008 Presidential Primary. Given the complexity and delicacy of these machines, this can certainly occur, and it has. In those cases where *all* machines in a precinct are inoperative at the same time, under the current Directive, paper ballots will be made available and people will be allowed to vote.

12. The problem with the 100% rule is that it completely discounts both the possibility and the negative impact of fewer than all of the machines failing and being out of service at the same time – which, statistically, is far more likely to occur than a simultaneous failure of all machines at once. In those cases where fewer than all machines fail at once, the 100% rule means that a precinct must function at lower voting capacity than the Commonwealth or local officials previously deemed appropriate. Put another way, the 100% rule only provides assistance in the most extreme, and unlikely, cases of a catastrophic precinct-wide failure of all machines – and it provides no assistance in the far-more-likely circumstance that a breakdown of fewer than all available machines occurs, creating delays in voting and potentially leading voters to abandon their voting effort.

13. In addition, the rate at which DRE voting machines fail – either for hardware or software reasons – is an issue of significant concern and there is little empirical testing to demonstrate the reliability of this machinery. The only reported volume test of DREs (i.e., test of multiple DRE machines under election-like conditions) that I am aware of occurred in 2005 and involved 96 Diebold (now Premier) AccuVote TSx machines. The test, which was conducted by independent computer science researchers lead by Matt Bishop, Ph.D., showed that the machines tested had failure rates over *10 times greater* than the minimally-acceptable failure standards of MTBF for electronic voting machines.[1] Looking solely at software failures, which the researchers deemed "more problematic" than hardware failures, the test showed failure rates *approximately six and a half times greater* than minimally-acceptable federal standard of MTBF for electronic voting machines.[2]

14. Thus, the 2005 Bishop et al. study demonstrates significant problems: *first*, it reports failure rates that far exceed what the federal government deems minimally acceptable for voting machines; *secon*d, it reached these finding *after* the State of California had certified those machines for use in elections there (the machines were subsequently decertified), thereby raising questions about the certification procedures, at least in that state; and *third*, it appears to

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[1] 2005 Voluntary Voting System Guidelines (Volume II, Version 1.0), United States Election Assistance Commission, pg. 71. http://vote.nist.gov/VVSG2005Vol2.pdf

[2] [BGJ+05] "Analysis of Volume Testing of the AccuVote Tsx / AccuView," Matt Bishop, Loretta Guarino, David Jefferson, and David Wagner, October 2005. http://www.sos.ca.gov/elections/voting_systems/vstaab_volume_test_report.pdf.

be the only study that attempts to document failure rates for DRE voting machines by volume testing. Put another way, there is little available scientific data establishing reliability of DRE voting machines over extended periods corresponding to the length of real elections, and what data is available reveals troubling rates of failure.

15. Using the 205 Bishop et al. study, and some other information published by Michael Shamos, Ph.D., I have performed certain calculations to show the probability of DRE machine breakdowns in precincts with different numbers of machines, all based on the available data. Bishop, et al. and Shamos[3] estimate the mean time between failures (MTBF) for DRE electronic voting systems to be as little as 25 hours. As Shamos notes, the federal standard specifies a minimum MTBF of 163 hours.[4] Before considering failure rates at all, it is important to specify what kinds of failure "count" as failures for purposes of the analysis. Bishop, et al. report two types of failures in their study: printer jams and software problems. I have decided not to count printer jams as "failures" for the purposes of my analysis, first, because it is reasonable to assume that printer jams can be fixed in some cases by poll workers; and second, because the type of VVPAT (voter verified paper audit

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[3] [S07] "Voting as an Engineering Problem," Michael Shamos, The Bridge (National Academy of Engineering), vol. 37, no. 2, 2007. http://www.nae.edu/nae/bridgecom.nsf/weblinks/MKEZ-744MD8

[4] 2005 Voluntary Voting System Guidelines (Volume II, Version 1.0), United States Election Assistance Commission, pg. 71. http://vote.nist.gov/VVSG2005Vol2.pdf

trail) employed by the Diebold (now Premier) AccuVote TSx examined in the 2005 Bishop et al. study is not used in Pennsylvania.

16. Hence, my focus will be solely on the rate of occurrence of *software* problems observed by Bishop, et al. and their impact on the availability of the DRE system. I assume that once a software problem has arisen, the safest recourse is to take the machine in question out of service for the rest of the day so that the cause of the problem can be fully investigated and attempts can be made to recover any votes that are recorded in the machine. Attempting to solve such problems by rebooting the machine and "hoping for the best" is ill-advised.

17. MTBF can be converted into the probability that a given DRE will fail sometime during the election day. Bishop, et al. and Shamos place the estimates for this failure rate at between 10% and 20%. From this value, we can determine the expected number of machine failures that will be experienced by Pennsylvania precincts. The impact of these failure rates is a function of the number of machines available in each precinct.

18. The table below illustrates the situation when there is a 10% chance that a given machine will fail on election day – the more conservative estimate. If there are two machines in a precinct, there is an 18% probability that the precinct will be operating at 50% of its capacity by the end of the day. If there

are three machines in a precinct, there is a 24% probability that the precinct will be operating at 67% of capacity by the end of the day.

	Machines per Precinct									
	2 Machines		3 Machines		4 Machines		5 Machines		6 Machines	
Failures	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.
0	0.81	1.00	0.73	1.00	0.66	1.00	0.59	1.00	0.53	1.00
1	0.18	0.50	0.24	0.67	0.29	0.75	0.33	0.80	0.35	0.83
2	0.01	0.00	0.03	0.33	0.05	0.50	0.07	0.60	0.10	0.67
3			0.00	0.00	0.00	0.25	0.01	0.40	0.01	0.50
4					0.00	0.00	0.00	0.20	0.00	0.33
5							0.00	0.00	0.00	0.17
6									0.00	0.00

19. The table below illustrates the case when there is a 20% chance that a given machine will fail on election day. Here, we see that if there are two machines in a precinct, there is a 32% probability that it will be operating at 50% of its capacity by the end of the day. If there are three machines, there is a 38% probability it will be operating at 67% of its capacity, and a 10% probability that it will be operating at 33% of its capacity by the end of the day.

	Machines per Precinct									
	2 Machines		3 Machines		4 Machines		5 Machines		6 Machines	
Failures	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.
0	0.64	1.00	0.51	1.00	0.41	1.00	0.33	1.00	0.26	1.00
1	0.32	0.50	0.38	0.67	0.41	0.75	0.41	0.80	0.39	0.83
2	0.04	0.00	0.10	0.33	0.15	0.50	0.20	0.60	0.25	0.67
3			0.01	0.00	0.03	0.25	0.05	0.40	0.08	0.50
4					0.00	0.00	0.01	0.20	0.02	0.33
5							0.00	0.00	0.00	0.17
6									0.00	0.00

20. This analysis demonstrates that the probability of failures of 50% or more of DRE voting machines in a particular precinct is far greater than the probability of failure of 100% of machines in any precinct, and that the probability of a

50% or more failure is sufficient to warrant consideration of a more relaxed rule allowing for the use of emergency paper ballots.

21. Finally, I have calculated failure probabilities based upon the MTBF for electronic voting machines itself, rather than on the research of Bishop et al. and the writing of Shamos. Assuming a constant failure rate system with a mean time between failure of 163 hours, the minimum as specified in the 2005 Voluntary Voting System Guidelines, I find that there is an 8% chance that a given machine will fail sometime during a 13-hour election day. The table below illustrates the impact on precincts and their capacities to handle voters with varying numbers of machines.

	Machines per Precinct									
	2 Machines		3 Machines		4 Machines		5 Machines		6 Machines	
Failures	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.	Prob.	Cap.
0	0.85	1.00	0.79	1.00	0.73	1.00	0.67	1.00	0.62	1.00
1	0.14	0.50	0.20	0.67	0.24	0.75	0.28	0.80	0.31	0.83
2	0.01	0.00	0.02	0.33	0.03	0.50	0.05	0.60	0.06	0.67
3			0.00	0.00	0.00	0.25	0.00	0.40	0.01	0.50
4					0.00	0.00	0.00	0.20	0.00	0.33
5							0.00	0.00	0.00	0.17
6									0.00	0.00

22. Note that if there are two machines in a precinct, there is a 14% probability that it will be operating at 50% of its capacity by the end of the day. If there are three machines, there is a 20% probability it will be operating at 67% of its capacity, and a 2% probability that it will be operating at 33% of its capacity by the end of the day.

Conclusion

23. As Shamos has stated: "Voting machines are among the least reliable devices on the planet."[5] In the face of the data that is available, the continuing uncertainty surrounding the performance of DREs under turnout conditions of the magnitude expected this year, and my findings, the Secretary of State's refusal to: (i) order the use of emergency paper ballots when fewer than all machines fail (for example, when 50% or more machines fails, as opposed to the 100% rule); and (ii) direct that local officials stock paper ballots in specific numbers, based upon expected turnout, cannot be justified by any scientific or statistical measure and will have serious consequences for Pennsylvania voters and their ability to cast their ballots in the upcoming elections.

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Bethlehem, Pa.

Daniel Lopresti, Ph.D.

[5] [S07] "Voting as an Engineering Problem," Michael Shamos, The Bridge (National Academy of Engineering), vol. 37, no. 2, 2007.