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# Uncertainty of Measurement in Voting System Testing

The objective of this document is to clarify the use of the term “uncertainty” in the voting system testing process.  Uncertainty of measurement can be found in the National Institute of Standards and Technology’s (NIST) Handbook 150 and the U.S. Election Assistance Commission’s (EAC) laboratory accreditation and voting system testing and certification programs.  The inclusion of a discussion on uncertainty is often a challenge with respect to information technology (IT) systems.  Thus, this document is intended to describe how it should be viewed in the near term, but recognize it may evolve over time.

## Introduction

The reason the term “uncertainty” is used is to reinforce the concept of consciously considering the confidence and assurance that the results from the testing produce accurate test results (i.e. voting systems should pass if they conform to the VVSG and fail if they do not conform). Additionally, uncertainty addresses the issue of whether or not the voting system is actually correct and *free of errors* if they pass all the VSTL tests.  Uncertainty is a very complex concept in information technology.  It can typically be viewed as the sum of multiple variables and factors and could have significant impact on the test results.

Conformance testing in information technology typically uses a concept called falsification testing, where one forces the implementation that claims conformance to a specification to execute various combinations of legal and illegal inputs, and the resulting output is compared to the "expected results." These inputs and expected results are constructed by the test developer upon a detailed examination and analysis of the specification. Despite the time and expense to develop these tests, the test developer can never cover all the possibilities allowed by the specification. Falsification testing can only prove that a given implementation is not conformant (and thus, not correct); one can never prove, or be certain, of the correctness of an implementation that passes all the constructed tests.

## Research Efforts in Measuring Uncertainty in IT

Program verification, in which mathematical claims about the behavior of a program are stated and proved, has been attempted. In theory, program verification techniques could prove that a particular program *must* behave correctly on all possible inputs. However, despite considerable research effort during the last three decades, there is nothing to suggest that this approach has led, or will lead, to a practical solution.  Program verification has had limited success because even relatively simple programs are hard to prove correct.

Thus, attention has shifted to a second, newer, research area, which involves "statistical" or "probabilistic" measures of correctness of programs. Under this approach, a program isn't *proven* correct, but instead is shown to be very likely (say 99.99% likely) to be correct. Techniques developed using this approach would be applicable to the testing of more complex programs (like voting systems) than currently is the case with formal proof techniques. Some research has been done at NIST to try to quantify the uncertainty in IT testing.  One approach attempted to examine the probability that an implementation is correct given that it passes all the constructed tests. However, to date, neither this nor any other research has resulted in any concrete mechanism to quantitatively measure the uncertainty of the result of conformance testing.

**Conclusion**

As indicated above, quantitative techniques to assess uncertainty in IT have not produced fruitful results to date. However, it is incumbent on an EAC accredited voting system test laboratory (VSTL) to construct test campaigns that provide confidence in the test result. Qualitative assessments of uncertainty can be accomplished by the VSTLs to help instill confidence in the test result and to enhance repeatability in the testing process. NIST Handbook 150 addresses some of these.

Laboratory audits, which help to ensure VSTLs' compliance to EAC and NIST/NVLAP documents, help to enhance uncertainty by making sure the appropriate structure and personnel are in place for effective testing. Other qualitative factors that can influence uncertainty include:

- Ensuring that appropriate training is in place for all testing staff.
- The retention of records of original observations, derived data and sufficient information to establish an audit trail, staff records and a copy of each test report issued, for a defined period. This enables the test to be repeated under conditions as close as possible to the original.
- The development of, and adherence to, an effective Test Plan.
- Appropriate and effective validation of test methods.
- Traceability from each test case back to individual requirements in the VVSG.
- Choosing comprehensive sets of test data, including data for expected, as well as unexpected, conditions.
- Performing sufficient volume and stress testing.
- Thoroughly inspecting the results of each test.
- The development of an effective Test Report, which ensures traceability from the test data to the conclusions in the Test Report.

Although quantitative measures to assess uncertainty in testing voting systems are currently beyond the state of the art, the VSTLs shall address uncertainty using qualitative measures. The above non-exhaustive list may be used for this purpose.