What is testing?

Testing is the practice of making objective judgments regarding the extent to which the system (device) meets, exceeds or fails to meet stated objectives

What the purpose of testing?

There are two fundamental purposes of testing: verifying procurement specifications and managing risk. First, testing is about verifying that what was specified is what was delivered: it verifies that the product (system) meets the functional, performance, design, and implementation requirements identified in the procurement specifications. Second, testing is about managing risk for both the acquiring agency and the system's vendor/developer/integrator. The testing program is used to identify when the work has been "completed" so that the contract can be closed, the vendor paid, and the system shifted by the agency into the warranty and maintenance phase of the project.

Why is testing important?

A good testing program is a tool for both the agency and the integrator/supplier; it typically identifies the end of the "development" phase of the project, establishes the criteria for project acceptance, and establishes the start of the warranty period.

When in the SE Life-Cycle does testing occur?

in the System Engineering "V" Model for ITS, testing is the first step in Integration and Recompostition. However, while testing is shown as **one** stage of the life cycle, it is important to understand that testing is also a **continuous process** within the life cycle. Testing begins with writing the requirements; each requirement must be written in a manner that allows it to be tested. During the design stages, testing will be a consideration as design trade-offs are evaluated for their ability to satisfy the requirements. New requirements may emerge from the designs as choices are made to satisfy the requirements within the project's constraints. Hardware components, software components, subsystems, and systems will be verified during the implementation and testing stages. Final system-level tests will be performed to accept the system and demonstrate the system's readiness for production service. However, testing activities will not end once the system is in operation; testing will continue as the operations and maintenance staff perform corrective, adaptive, and other system maintenance activities.

What methods are used to conduct testing?

There are five basic verification methods, as outlined below.

♦ **Inspection** - Inspection is the verification by physical and visual examinations of the item, reviewing descriptive documentation, and comparing the appropriate characteristics with all the referenced standards to determine compliance with the requirements.

- **Certificate of Compliance** - A Certificate of Compliance is a means of verifying compliance for items that are *standard products*. Signed certificates from vendors state that the purchased items meet procurement specifications, standards, and other requirements as defined in the purchase order. Records of tests performed to verify specifications are retained by the vendor as evidence that the requirements were met and are made available by the vendor for purchaser review.

- **Analysis** - Analysis is the verification by evaluation or simulation using mathematical representations, charts, graphs, circuit diagrams, calculation, or data reduction. This includes analysis of algorithms independent of computer implementation, analytical conclusions drawn from test data, and extension of test-produced data to untested conditions.

- **Demonstration** - Demonstration is the functional verification that a specification requirement is met by observing the qualitative results of an operation or exercise performed under specific condition. This includes content and accuracy of displays, comparison of system outputs with independently derived test cases, and system recovery from induced failure conditions.

- **Test (Formal)** - Formal testing is the verification that a specification requirement has been met by measuring, recording, or evaluating qualitative and quantitative data obtained during controlled exercises under all appropriate conditions using real and/or simulated stimulus. This includes verification of system performance, system functionality, and correct data distribution.

What is involved in a hardware test program?

In general, the hardware test program can be broken into six phases as described below.

- **Prototype testing –** Prototype testing is generally required for "new" and custom product development but may also apply to modified product depending on the nature and complexity of the modifications. This tests the electrical, electronic, and operational conformance during the early stages of product design.

- **Design Approval Testing (DAT)** – DAT is generally required for final pre-production product testing and occurs after the prototype testing. The DAT should fully demonstrate that the ITS device conforms to all of the requirements of the specifications.

- **Factory Acceptance Testing (FAT)** – FAT is typically the final phase of vendor inspection and testing that is performed prior to shipment to the installation site. The FAT should demonstrate conformance to the specifications in terms of functionality, serviceability, performance and construction (including materials).

- **Site Testing** – Site testing includes pre-installation testing, initial site acceptance testing and site integration testing. This tests for damage that may have occurred during shipment, demonstrates that the device has been properly installed and that all mechanical and electrical interfaces comply with requirements and other installed

equipment at the location, and verifies the device has been integrated with the over-all central system.

♦ **Burn-In and Observation Period Testing –** A burn-in is normally a 30 to 60 day period that a new devise is operated and monitored for proper operation. If it fails during this period, repairs or replacements are made and the test resumes. The clock may start over at day one, or it may resume at the day count the device failed. An observation period test normally begins after successful completion of the final (acceptance) test and is similar to the burn-in test except it applies to the entire system.

♦ **Final Acceptance Testing –** Final acceptance testing is the verification that all of the purchased units are functioning according to the procurement specifications after an extended period of operation. The procurement specifications should describe the time frames and requirements for final acceptance. In general, final acceptance requires that all devices be fully operational and that all deliverables (e.g., documentation, training) have been completed.

What is involved in a software test program?

In general, the software test program can be broken into three phases as described below.

♦ **Design Reviews –** There are two major design reviews: (1) the preliminary design review conducted after completion and submission of the high-level design documents and (2) the detailed design (or critical) review conducted after submission of the detailed design documents.

♦ **Development Testing –** For software, development testing includes prototype testing, unit testing, and software build integration testing. This testing is normally conducted at the software developer's facility.

♦ **Site Testing –** Site testing includes hardware/software integration testing, subsystem testing, and system testing. Some integration testing can be conducted in a development environment that has been augmented to include representative system hardware elements (an integration facility) but must be completed at the final installation site (i.e., the transportation management center) with communications connectivity to the field devices.

What is involved in a system-level test plan?

In general, the system-level test program can be broken into two phases as described below.

♦ **Subsystem Testing -** Subsystem verification testing is performed as a prelude to system testing. It is performed in the operational environment using installed system hardware and software. Testing at the subsystem level should be performed: a) when different developers, vendors, or contractors have been responsible for deliv-

ering stand-alone subsystems, b) when the complete functionality of a subsystem could not be tested at a lower level because it had not been fully integrated with the necessary communication infrastructure, or c) when it was previously impossible to connect to the field devices for the testing phase.

♦ **Systems Testing -** System verification testing is the highest test level; it is also usually the one with the fewest requirements remaining to be verified. Only those requirements relating to subsystem interactions, quantity of field devices, external interfaces, and system performance should remain to be formally verified. System acceptance testing is performed after all lower level testing has been successfully completed. It is performed in the operational environment using all available and previously installed and tested system hardware and software. The system acceptance test should include an end-to-end or operational readiness test of sufficient duration to verify all operational aspects and functionality under actual operating conditions. Formal acceptance at the subsystem or system level may trigger the start of equipment warranty periods, software licensing agreements, operations and maintenance agreements, etc. The procurement documents should clearly specify which of these are applicable, when they become effective and need to be renewed, and what the payment schedules and provisions are.

How much does a testing program cost?

The test location, test complexity, number and types of tests, and the test resources required (including test support personnel, system components involved, and test equipment) impact testing costs. Testing is expensive and represents a significant portion of the overall TMS acquisition budget, but this should not dissuade you from conducting a thorough and complete test program that verifies that each of your requirements has been met. You ultimately control testing costs by the number and specificity of your requirements. A small number of requirements with minimum detail will be less costly to verify than a large number of highly detailed requirements. While both sets of requirements may result in similar systems, the smaller, less complex set takes less time and resources to verify. There are more opportunities for a quality product at the lowest cost if the procurement documents specify only the functionality and performance characteristics to be provided, leaving the design and implementation decisions up to the contractor. However, this approach should be balanced with the agency's expectations since there may be various means by which the requirement *could* be satisfied by a vendor.

Where can I get more information about testing programs for ITS?

The documents listed below and additional training materials are available on the Federal Highway Administration's website at http://ops.fhwa.dot.gov/publications/publications.htm/.

♦ Federal Highway Administration, *Testing Programs for Transportation Management Systems – A Technical Handbook,* (Washington, DC: 2007).

♦ Federal Highway Administration, *Testing Programs for Transportation Management Systems – A Primer*, (Washington, DC: 2007).

♦ Federal Highway Administration, *Testing Programs for Transportation Management Systems – Practical Considerations*, (Washington, DC: 2007).