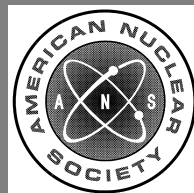


American Nuclear Society

**verification and validation of non-safety-related
scientific and engineering computer programs
for the nuclear industry**

an American National Standard



**published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA**

**American National Standard
Verification and Validation of Non-Safety-Related
Scientific and Engineering Computer Programs
for the Nuclear Industry**

Secretariat
American Nuclear Society

Prepared by the
**American Nuclear Society
Standards Committee
Working Group ANS-10.4**

Published by the
**American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA**

Approved October 28, 2008
by the
American National Standards Institute, Inc.

American National Standard

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La Grange Park, Illinois 60526 USA**

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Printed in the United States of America

Foreword

(This Foreword is not a part of American National Standard “Verification and Validation of Non-Safety-Related Scientific and Engineering Computer Programs for the Nuclear Industry,” ANSI/ANS-10.4-2008.)

The purpose of this standard is to provide guidelines for the verification and validation (V&V) of non-safety-related scientific and engineering computer programs developed for nuclear industry applications. The standard does not recommend a specific approach to program development but does recommend that V&V activities be carried out in parallel with program development. For a specific project, the project sponsor should determine the level of the V&V effort to be applied. The standard complements the following ANSI-10 standards relating to computer program development:

ANSI/ANS-10.3-1995, “Guidelines for the Documentation of Computer Programs” (withdrawn);

ANSI/ANS-10.5-2006, “Accommodating User Needs in Scientific and Engineering Computer Software Development”;

ANSI/ANS-10.2-2000, “Portability of Scientific and Engineering Software.”

In addition, an effort has been made to maintain consistency in terminology and concepts with various software standards being developed under the sponsorship of the Institute of Electrical and Electronics Engineers, Inc., and to identify areas of disagreement.

Compliance with this standard does not substitute for compliance with regulatory requirements. For example, any analysis that requires a 10 CFR Part 50 Appendix B quality assurance program would still require one whether or not it conforms with this standard.

Charles R. Martin was the working group chair for much of the development of this standard. His contributions are gratefully acknowledged.

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Verification and Validation of Non-Safety-Related Scientific and Engineering Computer Programs for the Nuclear Industry

1 Scope and objective

1.1 Scope

This standard provides guidelines for the verification and validation (V&V) of non-safety-related scientific and engineering computer programs developed for use by the nuclear industry. The scope is restricted to research and other non-safety-related, noncritical applications.

1.2 Objective

The objective of this standard is to identify activities that will improve the reliability of scientific and engineering computer programs and reduce the risk of incorrect application.

1.3 Guidance for applying this standard

The intent of this standard is to present a comprehensive set of V&V activities. These activities should be performed in parallel with the program development process. Sections 5 through 10 address the situation in which V&V is carried out in parallel with program development. Section 11 describes V&V activities that may be applied a posteriori to an existing program where V&V parallel to program development was not performed.

Since performing the complete set of V&V activities for a project may be impractical, the level of the V&V effort to be applied and whether it is to be carried out in parallel or a posteriori should be determined by the project sponsor based on such factors as the size; complexity; regulatory requirements; and American National Standards Institute/American Nuclear Society ANSI/ANS-10.5-2006, "Accommodating User Needs in Scientific and Engineering Computer Software Development," intended use of the program.

Application of this standard is expected to provide material for use in a quality assurance program. This standard does not recommend a particular approach toward quality assurance.

Questions about frequency of reviews or audits, resolution of discrepancies, or responsibility for configuration control are not within the scope of this standard.

2 Definitions

In the context of this standard, the following definitions apply.

non-safety-related: Software whose failure would not create a hazard to a facility, worker, or member of the general public.

validation: (a) The process of testing a computer program and evaluating the results to ensure compliance with specified requirements. (b) The demonstration that the verified computer program (and by inference the mathematical model) are an adequate representation of the physical phenomena.

verification: The process of evaluating the products of a software development activity to provide assurance that they meet the requirements defined for them.

Verification and validation is abbreviated throughout the standard as V&V. In addition, reference is made to the following software development, maintenance, or V&V products:

- statement of problem;
- management plan;
- requirements specification;
- design specification;
- program documentation (user's manual, technical manual, etc.);
- source code;
- integrated program;
- installation package;
- test plan;
- V&V plan;
- V&V report.

These products are briefly described in Secs. 4 through 10.

3 Introduction and overview

Computer programs are used extensively in scientific and engineering applications involving research and development activities or in the modeling of physical phenomena. Since errors in such programs may have undesirable consequences, it is important that the development of these programs exhibit a level of reliability commensurate with their significance. V&V is a systematic approach to improving reliability. Although V&V activities may be conducted on existing programs, they are most effective when carried out in parallel with program development. A parallel approach allows for early detection and correction of errors in the software requirements, design, and coding.

If a computer program is to be developed to represent a process or phenomenon occurring in nature, the usual approach is to represent this process or phenomenon in terms of a mathematical model. This model is used as the basis for program design. The design in turn is converted into a set of computer instructions.

Verification can be considered to be the proof or demonstration that the computer instructions correctly represent the design and that the design correctly represents the mathematical model. Validation, on the other hand, is the demonstration that the verified computer program (and by inference the mathematical model including uncertainties/approximations) is an adequate representation of the physical phenomena. What is considered to be adequate—and under what conditions—shall be specified in a document referred to as the requirements specification.

As defined in Sec. 2, validation consists of the testing of a computer program and the evaluation of the test results. To ensure the adequacy of validation, the testing carried out by the developer may be evaluated, supplemented, or independently performed by a separate organization responsible for V&V, or a combination of all three. The program is validated when the test results are shown to meet the criteria given in the requirements specification. Verification consists of a detailed examination of the products of each program development activity to ensure consistency with the requirement for that activity. For example, the requirements specification is verified to ensure correctness,

completeness, and consistency with the statement of problem; the design specification is verified against the requirements specification; and the source code is examined to ensure consistency with the design specification.

The criteria presented in this document depend upon the availability of a document stating the requirements that a computer program must satisfy. Because of the research basis of most scientific program development, however, it is often not possible to provide a priori a complete requirements specification. What constitutes a valid answer or appropriate algorithm is often not known until after different approaches have been tried and their results evaluated. In such cases an iterative approach is recommended that allows the requirements to be refined or respecified as results from different activities of program development become available. The final program documentation and the final V&V report shall be based on the most up-to-date representation of the program.

The V&V activities described in this standard shall be carried out in accordance with the management plan. The management plan should tailor the scope of the individual activities based on the software complexity, regulatory requirements, intended use, and significance of unpredictable execution due to code defects.

The purpose of this standard is to specify the V&V activities to be performed rather than the methods used to carry them out.

It is often necessary to validate existing computer programs for which detailed documentation may not be available from the developer. A section on V&V of existing programs is included in this standard to cover this situation.

4 Overview of V&V in the program development process

In order to present criteria for V&V in software development, it is necessary to define a set of software development activities. Within each activity should be elements of configuration management that control identification, change, status, and possibly compliance overview. It is important to note, however, that neither the activities defined nor the development products

associated with them are prescribed or recommended by this standard. They are presented only as a framework for describing V&V. If a different set of activities is used, the V&V criteria presented in this standard should be evaluated and adjusted accordingly. Furthermore, the scope and effort of the V&V activities should be tailored based on the size and scope of the program development effort.

The software development process assumed for this standard consists of the following activities, some of which may be iterative:

- initiation;
- requirements definition;
- design;
- coding;
- integration and testing;
- installation;
- operation and maintenance.

Table 1 provides a summary of V&V that may occur during program development.

4.1 Initiation

The first step of program development is the initiation, sometimes referred to as “concept exploration.” During this activity, a problem is identified, and a decision is made to develop a computer program to solve the problem. The problem may be documented in a brief report called a statement of problem. The approach to be taken in developing the computer program is documented in a management plan. Note that depending on the size and complexity of the development effort, one or more plans, documents, checklists, etc., may be combined into a single document.

The management plan forms the basis for both the development and V&V efforts. It describes the organization of the project, the activities to be performed, the schedule to be followed, and the responsibilities of each participant. Aspects of the plan that affect V&V include the following:

- who will perform the V&V;
- the general V&V activities to be performed;
- the level of effort applied to each activity;
- the assignment of testing responsibilities;
- the procedures for incorporating V&V findings into program development.

V&V planning should be initiated during this phase. Details of this planning activity are presented in Sec. 4.2

4.2 Requirements definition

During this activity, the requirements that the computer program must satisfy are identified and documented in a requirements specification. This process may involve several iterations between the program developer and the sponsor, and requirements may be modified later as a better understanding of the problem is gained.

The V&V activities that may be performed during requirements definition are development of a V&V plan, verification of the requirements specification, development of preliminary test plans, and verification of the preliminary test plans.

These V&V activities are described in Sec. 5.

4.3 Design

During program design, the developer defines the logical structure, information flow, logical processing steps, data structures, and other aspects of a computer program that will satisfy the requirements specification. This information is documented in a design specification, along with descriptions of required support software, estimated storage, and other information pertinent to the program’s operating environment. In addition, program documentation is begun. This documentation, when completed, will include those documents listed in Sec. 9.2. Each of these sections may be started in this phase; description of inputs in the application shall be provided to allow for test planning.

The V&V activities that may be performed during this phase are design verification, verification of the preliminary program documentation, update of the test plan(s) to incorporate design information, and verification of the updated test plan(s). These V&V activities are described in Sec. 6.

4.4 Coding

During coding, the developer implements the program design by coding it in a programming language. The coding process is accompanied by static checks such as compilation and by preliminary checkout of the code. The program documentation may be updated to reflect

Table 1 – Sample V&V activities associated with program development

Development activity	Development product	Testing activity	V&V activity
Initiation	Statement of problem		Prepare V&V plan
	Management plan		
Requirements definition	Requirements specification		Verify requirements specification
		Develop preliminary test plan	Verify preliminary test plan
Design	Design specification		Verify design
	Preliminary program documentation		Verify preliminary program documentation
		Update test plan	Verify updated test plan
Coding	Source code		Verify source code
	Updated program documentation		Verify updated program documentation
		Finalize test plan	
		Build test database	Verify test plan and test database
Integration and testing	Integrated program		Verify program integration
		Run test plan (validation)	Verify test results
Installation	Installation package		Verify installation package
	Final program documentation		Verify final program documentation
			Prepare final V&V report
Operation and maintenance	Changes to program and documentation		Repeat above activities as necessary

additional information known about the program at this time.

The V&V activities that may be performed during the coding are source code verification,

verification of the updated program documentation, finalization of the test plan(s), development of the test database(s), and verification of the test plan(s) and test database(s). These activities are described in Sec. 7.

4.5 Integration and testing

During integration and testing, program components are combined into an overall program, testing is performed to ensure correct integration of the components, and the integrated program undergoes formal testing.

The V&V activities that may be performed during this phase are verification of the integrated program, execution of the test plan(s), and verification of the test results. These activities are described in Sec. 8.

4.6 Installation

During installation, the program is installed in its operational environment, and the program documentation is updated to completely and accurately describe the program.

The V&V activities that may be performed during this phase are verification of program installation, verification of the final program documentation, and preparation of the final V&V report. These activities are described in Sec. 9.

4.7 Operation and maintenance

During operation and maintenance, the program is employed in its operational environment and modified as necessary to correct problems and to respond to changing requirements. Depending upon the nature and extent of a given modification, some or all of the documentation associated with the program will need revision, and some or all of the development activities will need repeating.

The V&V activities that may be performed for a given modification depend upon the development products modified and the development activities repeated. Each product that is changed should undergo V&V, and the overall consistency and traceability among development products should be reverified. Section 10 discusses this aspect of V&V.

5 V&V activities during requirements definition

5.1 Preparation of V&V plan

The V&V plan sets forth the approach to be followed for conducting the V&V effort. This

approach shall comply with the management plan and respond to each requirement specified in that document. The size, complexity, regulatory requirements, and intended use of the program development effort will determine the level of detail required in the V&V plan. If appropriate, an organization's general V&V plan may be used.

The V&V plan may include the following topics:

- V&V plan description
 - identification of the program to undergo V&V,
 - scope and objectives of the V&V plan,
 - reference to the management plan and other relevant documents;
- V&V approach
 - activities to be performed during each step program development,
 - tools and techniques to be used,
 - documentation to be produced,
 - format and content of each document to be produced;
- schedule of V&V activities and milestones
 - receipt of development products,
 - performance of V&V activities,
 - delivery of V&V products;
- V&V project organization
 - staffing levels for each activity,
 - responsibilities;
- V&V project management
 - supervision and coordination of V&V activities and deliverables,
 - project controls (e.g., configuration management),
 - security measures.

An important topic under V&V documentation is the method to be used for reporting V&V results. Each V&V activity should be documented describing both the positive and negative results of the analysis or testing performed. The following information is typically included in a V&V report:

- identification of the program undergoing V&V;
- summary of V&V performed;
- development materials evaluated;
- V&V activities performed;
- tools and techniques used;
- V&V documents generated;
- security and control procedures followed;
- deviations from the V&V Plan;