



*Master Class*

**V&V**

# Verification & Validation of Models and Analyses

Class-room or in-house training  
Available in English or in French  
2 day course

Tutors : **Jean François IMBERT**  
**Philippe PASQUET**

A close-up photograph of a spiral-bound notebook and a pen resting on a desk. The spiral binding is on the left, and the pen is on the right.

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# Verification & Validation of Models and Analyses

## *2 day Master Class*

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### Overview

Engineering simulation plays an increasing role in industry's search for competitiveness and technology based innovation at any stage of the design, qualification and certification of their products. Key decisions and product qualification/certification increasingly rely on virtual tests and digital simulation, creating a major paradigm shift in which the objective of physical tests is progressively moving from a demonstration of compliance to a reference for analysis validation. This trend in industry is shown through adoption of new terms such as « realistic simulation » and « virtual testing ». This situation creates new responsibility for the engineer to guarantee the required confidence level.

This new approach requires secured processes for the verification and validation of models and analyses bringing evidence of their predictive capability. In particular, programme managers now require formal evidence on "simulation fit for purpose" on which they can build confidence and take decisions. In addition, the increasing situation for extended enterprise creates new constraints to guarantee safe and robust analysis processes. At the same time, and due to the economic pressure, V&V activities are frequently seen as an additional cost that can easily be reduced and even fully cut, thus underestimating the induced risks. In addition, V&V is not easy to implement because of the diversity of involved persons: managers, simulation experts, test specialists, software developers and quality controllers, software vendors...

### Course objectives and benefits

This Master Class is especially dedicated to V&V methodologies for numerical simulation in Engineering.

Participants will:

- Develop their knowledge in V&V including fundamental concepts, most recent methodologies and contents of existing standards.
- Understand essential links between the product validation/certification and simulation V&V.
- Learn how to plan and prioritize simulation V&V including physical tests programmes.
- Understand validation test issues and improve synergy between virtual and physical tests in the context of validation.
- Learn how to build business cases allowing for justification of V&V plans.
- Understand simulation V&V organisation and management issues and best practises
- Learn how to implement reporting to bring visibility and confidence to all managers concerned with simulation outcomes.
- Be able to adapt or tailor the course methodologies to their specific industrial context, and further improve their V&V processes and plans.

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## Who should attend?

- Primarily, engineers and senior analysts in charge of simulation activities or preparing to take new responsibility in the management of simulation, especially with regard to V&V responsibility
  - Managers in charge of engineering simulation teams and willing to improve their knowledge in V&V and in the relevant processes
  - And also programme/project managers who need to make critical decisions based on engineering simulation results and wish to increase their understanding and visibility of the required V&V activities
- Participants should have a few years of experience in engineering simulation for the design and development of industrial products.

## Course context

All industry sectors confronted with numerical simulation V&V are concerned with this course. It is established on the solid knowledge of the tutors and the vision they have developed from their rich industrial experience, mainly within the aerospace and nuclear energy sectors and is primarily illustrated by FEA/Structure Analysis examples. The course is therefore of greatest interest to engineers involved in this technical domain, but will also appeal to engineers from other simulation domains because most of the V&V methodologies which are presented are generic in nature.

The course is neutral and independent of any particular software solution.

We limit the number of participants to a small group to facilitate dialog and exchanges between participants.

## Tutors

This course is tutored by Jean-Francois IMBERT and Philippe PASQUET, high-level simulation professionals both benefiting from a long academic and industrial experience gained from leading companies. Their skills extend from numerical methods to solving industrial problems, especially in aerospace and nuclear area, and to analysis management. V&V is one their key expertise, reason for which they have been asked for help by major European companies. They are recognized as ones of the leading figures in the engineering analysis community in France.

- **Jean-Francois IMBERT** has 40+ years experience in Structures Engineering, CAE/ numerical simulation, mostly in the aeronautical and aerospace sectors where he exercised both operational, expert and management responsibilities. All along his career, he ensured the development and implementation of innovative numerical simulation capabilities in industrial contexts, mostly in Structure Analysis. In his successive responsibilities, he accumulated a unique and broad experience in simulation management and the multiple features of V&V, including validation tests and analysis /test synergy. Furthermore he has a long practice of engineering education both in academic institutions and professional seminars.

- With 40+ years of dense experience in engineering simulation, **Philippe Pasquet** has covered the full range of technical responsibility in this domain, both with research institutes and various consulting firms and software houses: development of software, development of methods, advanced studies, team management, scientific and technical management ... Powered by his passion for pedagogy and simulation technology, he gives since many years conferences and talks at high level towards efficient use and good practices of simulation in the industry, motivating students and engineers for those fascinating engineering simulation jobs.

The course is agreed and under control of NAFEMS Education and Training Working Group (ETWG).

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New courses and dates are announced regularly – for full details visit

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# Verification & Validation of Models and Analyses

## 2 day Master Class Programme

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### 1. Introduction

1. Industrial context and stakes
2. Scope of numerical simulation in engineering
3. Simulation in the product lifecycle

### 2. Validation, qualification & certification of industrial products

1. Fundamentals on product V&V, qualification and certification
2. Validation in Systems Engineering, hierarchical validation approach
3. Introduction to new technologies and TRL
4. Regulations and certification in aeronautics

### 3. V&V and simulation management

1. Present context: PLM, SDM, CAD/CAE...
2. Introduction to simulation capability management
3. Simulation V&V and competence management
4. Scope and complexity of simulation management

### 4. V&V fundamentals and Standards

1. Fundamentals
  - Verification
  - Validation and uncertainty quantification
  - Predictive maturity
  - V&V processes
2. Standards
  - Short history of standardization in V&V
  - Main standards: ASME, AIAA, NASA...

### 5. Code verification

1. Error typology
2. Verification of algorithms
3. Quality assurance for software: methodologies for SW development, regression tests, exact and manufactured solutions...

### 6. Verification of analyses

1. A priori verifications: formal aspects, check-lists.
2. A posteriori verifications: space and time discretization errors, improvement of results.
3. Example of verification check-list

### 7. Validation and simulation / test synergy

1. Validation process and hierarchical planning
2. Simulation / testing collaboration
  - Specificities and difficulties of validation tests
  - Prerequisites for successful validation tests
  - Test uncertainties
3. Accuracy assessment: deterministic and statistical validation metrics...
4. Predictive capability in the application domain: main attributes and how to assess it?
5. Industrial examples

### 8. Realistic Simulation

1. HPC infrastructure trends: new architectures.
2. New discretization techniques
3. Solver improvements, multi-physics, multi-scale, optimization...
4. Realistic visualization: issues and benefits.
5. Impact on V&V plans

### 9. Simulation Uncertainty Quantification (UQ)

1. Typology: random, epistemic uncertainties
2. Maturity of existing uncertainty quantification methodologies: Monte Carlo, Latin hypercube, response surfaces, polynomial chaos, "Lack of knowledge" theory, theory of evidence...
3. Sensitivity analysis, robustness (key parameters identification...)
4. Academic and industrial examples, methodologies and tools
5. UQ best practises

### 10. V&V Implementation strategies

1. Responsibilities of V&V process actors
2. Implementation issues and obstacles
3. Industrial justification: V&V business case, costs, benefits...
4. Best practises: planning and prioritization, reporting to programme management, organization.

### 11. Simulation V&V in the nuclear energy

**sector:** regulations, V&V processes

### 12. Course outcomes and conclusion

*This programme can be tailored as in-house sessions or classroom sessions, in English or in French.*

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