APPLICATIONS OF STRUCTURAL FIRE ENGINEERING

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# Principles of Verification & Validation

Lesław Kwaśniewski

*Warsaw University of Technology, Warsaw, Poland*

Cezary Bojanowski

*Argonne National Laboratory, Argonne, IL, USA*

COST TU0904 Integrated Fire Engineering and Response

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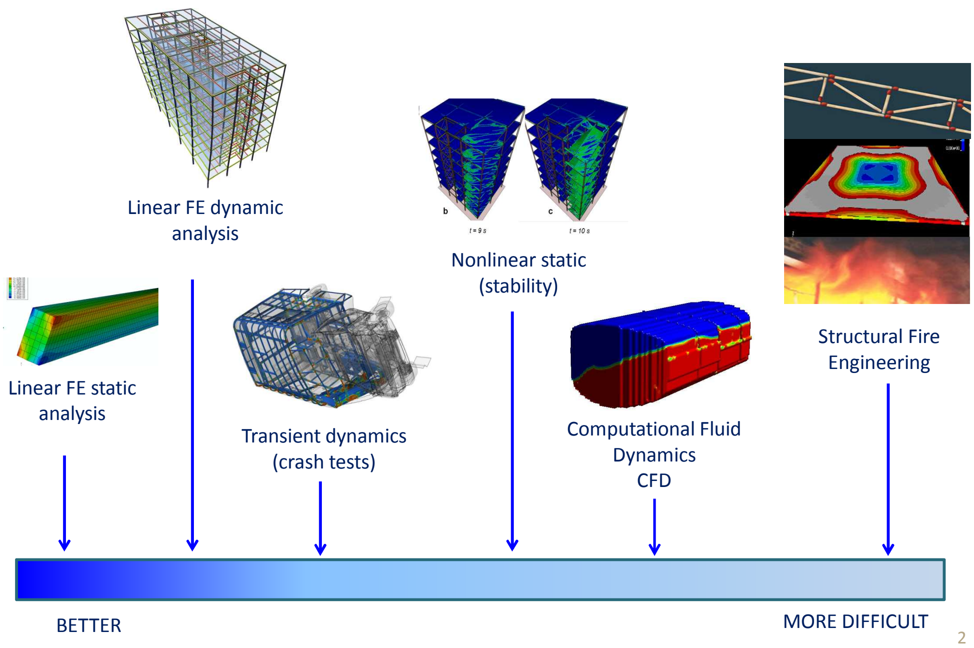
## What are the predictive capabilities of our computer simulations (Computational Science and Engineering CS&E)?



# Some facts

- Hardware development (Moore's law) - high-performance computing on multiprocessor machines

Software development – *e.g. LS-DYNA® - a finite element (FE) based simulation software - had originally 50,000 lines of code and then approached 2 million lines in little more than a decade*.

Different cost - *in the 1970s, a 20 ms crash test simulation using a 300-element vehicle model took about 30 hours of computer time at a cost equivalent to the three-year salary of a university professor.*

Different approach to computer simulations
"…for many years the Journal of Applied Mechanics shunned papers on the finite element method because it was considered of no scientific substance.

General V&V procedures applicable to Computational Science and Engineering (CS&E) or Computational Engineering and Physics (CE&P)

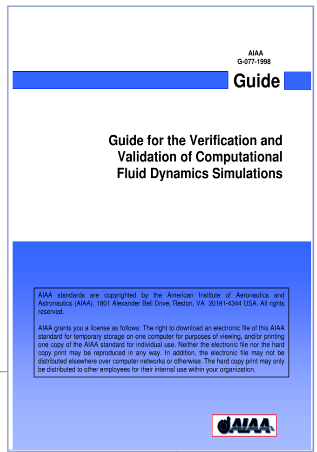
Difficulties with experimental validation in structural fire engineering





# Verification & Validation

What are the recommended procedures to improve predictive capabilities of computer simulations?




# General concepts

- Reality of interest
- Mathematical (Computational) Model
- Computer (Computational) Model
- Validation Experiments
- Verification & Validation
- Verification
  - Mesh density study
  - Benchmark problems
- Validation
  - Domains
  - Calibration
  - SRQ
  - Validation Metrics

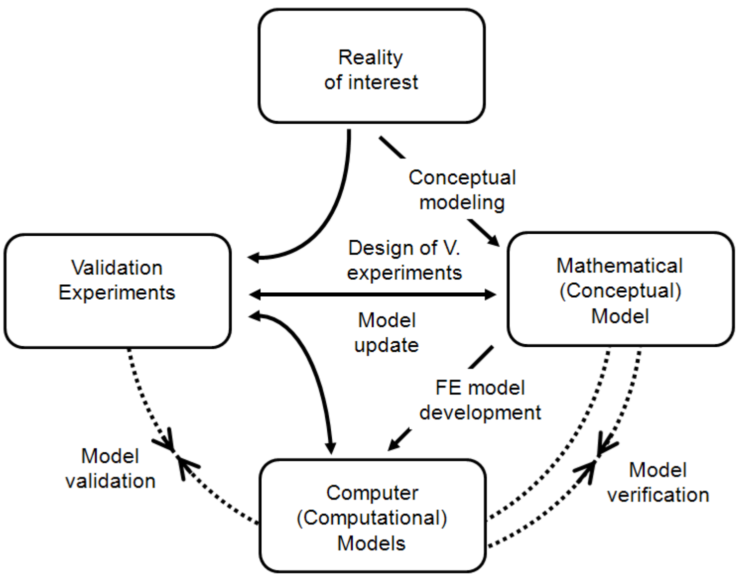
George E. P. Box

„Essentially, all models are wrong, but some are useful''

Box G.E.P., Draper N.R. (1987) Empirical model-building and response surfaces, *John Wiley & Sons*., pp. 669



# General aspects of modeling, experimentation, verification, and validation




Kwasniewski L. (2009) On practical problems with verification and validation of computational models, Archives of Civil Engineering, vol. LV, no. 3, pp. 323-346.

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# Definitions of Verification & Validation

**Verification** is supposed to deliver evidence that mathematical models are properly implemented and that the numerical solution is correct with respect to the mathematical model.

**Verification** uses comparison of computational solutions with highly accurate (analytical or numerical) **benchmark** solutions and among themselves, whereas **validation** compares the numerical solution with the experimental data.

**Verification** should precede **validation.**

Experimental **validation** is the final check to reveal possible errors and to estimate the accuracy of the simulation.

**Validation** can be practically split into three tasks:

- to detect and separate the model’s significant discrepancies,
- to remove and reduce removable and unavoidable errors,
- to evaluate uncertainties in the results.

„**Verification** deals with **mathematics**; **validation** deals with **physics**”

Roache P.J. (1998) Verification and validation in computational science and engineering, Hermosa Publishers Albuquerque, NM



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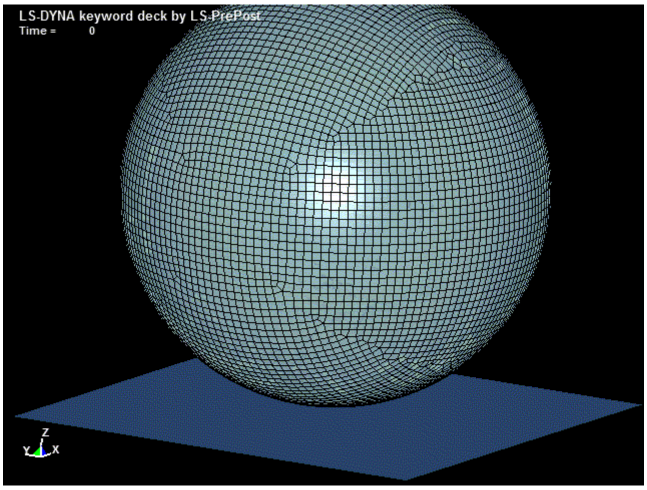
# System response quantity SRQ

Validation is based on the comparison between computational results and experimental data.

An experiment can provide much less information than the calculation.

Selection of the system response quantity (SRQ) is often limited by the experiment output.




A hollow glass ball with external radius of 25mm and the wall 1mm thick is falling under gravity from a prescribed height (2.0 m) and hits a rigid surface.

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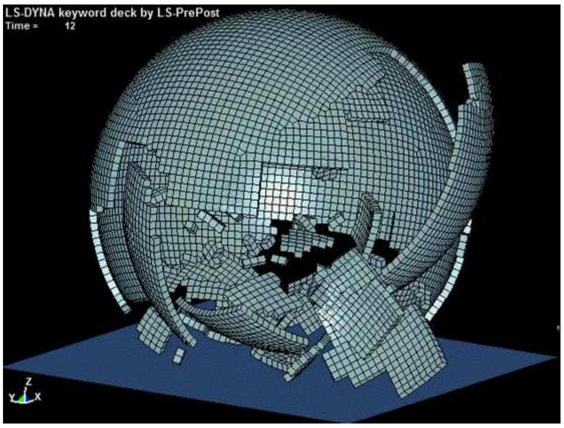
# System response quantity SRQ

Selection of SRQ:

1. Failure (1) or no failure (0)
2. Vertical z coordinate of Cenetr of Mass (static position)
3. Horizontal x y coordinates of Cenetr of Mass (static position)
4. Shape, mass, position of all pieces (static position).

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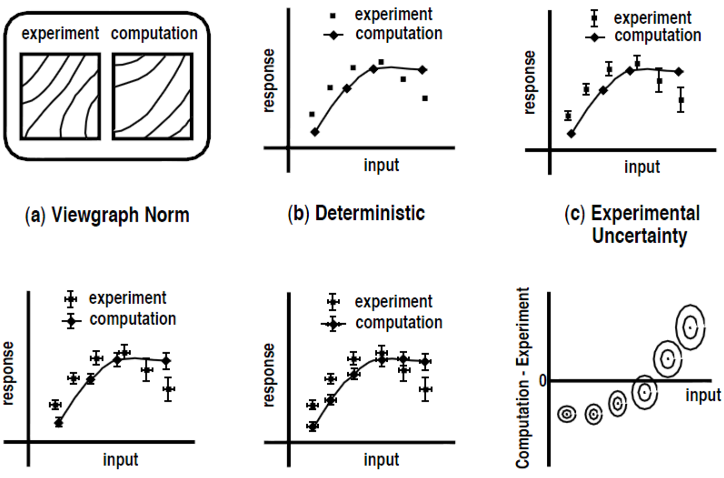
# Validation Metrics




(a) Viewgraph Norm
(b) Deterministic
(c) Experimental Uncertainty
(d) Numerical Error
(e) Nondeterministic Computation
(f) Quantitative Comparison

W.L. Oberkampf, T.G. Trucano, C. Hirsch, Verification, validation, and predictive capability in computational engineering and physics, Appl. Mech. Rev. 57 (5), 345–384, 2004.

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# Benchmark Problems

- relatively simple, easy to understand
- can show little of practical meaning
- to be used for verification of computational models not to solve an engineering problem
- all assumptions should be identified
- complete input data must be provided
- If a numerical solution is considered as a benchmark problem the mesh density is necessary
- different codes or solid vs. shell finite elements
- hierarchical approach



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Thank you for your attention!