What is Modeling and Simulation and Software Engineering?

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Definitions

Model:
A system of postulates, data and interfaces presented as a mathematical description of an entity or proceedings or state of affair. (Development of equations, constraints and logic rules.)

Simulation:
Exercising the model and obtaining results. (Implementation of the model)
Classification of Models

- Deterministic
- Continuous variable
- Dynamic
- Time varying
- Linear
- Real-time
- Stochastic
- Discrete variable
- Static
- Steady state
- Non-linear
- Batch
Why Simulations?

Simulations are applicable in the following situations:
1. When operating conditions change e.g. temperature, pressure, etc
2. When non-controllable factors change e.g. weather, earthquake
3. Dependence of variation of critical factors e.g. fatigue, resonance may be destructive.
4. How sensitive is one factor to the changes in another?
5. Other benefits:
   a) Useful in design
   b) Study effects of constraints
   c) Increase understanding
6. Pitfalls: An assumption, which the owner can't model or verbalise; so when two independent models clash, contradictory results arise
Tangible Benefits

- Saves manpower, material
- Useful even if not possible by other means
- Saves money with fast, consistent answers
- Could be used for education after establishing
Intangible Benefits

- Increased flexibility, accuracy, range of operation
- New results not available before
- Improved results due to standardisation
- Increased understanding
- Explicitly stated assumptions and constraints
Major Investments

- Computer
- Skill/Expertise
- Time for implementation
Third Methodology

Simulation has emerged as the Third methodology of exploring the truth. It would complement the theory and experimental methodology. Simulation will never replace them.
Complementary Approach

- Real System
  - Perform Experiments
    - Experimental Results
- Make Model
- Model System
  - Construct Approximate Theories
  - Theoretical Predictions
- Implement on Computer
  - Third Methodology
    - Simulation Results
    - Compare & Test Models, Theories
    - Feedback

Source: Allen and Tildesley
Pitfalls of Simulations

- Modelling errors at different levels
  - Scientific model of reality
  - Mathematical model
  - Discrete numerical model
  - Application program model
  - Computational model
- Input errors: Out of range inputs can give spurious results
- Precision errors: Limits in the precision
Phases of Development

- Real system to mathematical model
- Algorithm to solve mathematical model
- Implementation on a computer
- Validation
  - User with I/O
  - Model
  - Evaluations
- Simulations
Reliability tests

- Fermi solutions: Approximate results what the simulations would give. Fermi a Physicist was very good at making quick estimates of the expected output
- Sensitivity studies: Changes in outputs due to changes in inputs
- Comparing empirical results: Compare with experimental or other computational results
- Comparing with analytical results: Lower dimensional analytical results
- Checking conservation laws: Mass, energy, momentum
- Comparing with alternative numerical methods: Compare with the results from different algorithms
- Parameter studies: Look for any anomaly
- Peer review: Several people arriving at similar results
Software Engineering

- Computer Implementation & Validation
  - Requirements and Analysis
    - List of major functions to come up with software architecture
  - Design
    - Two levels of design up to individual functions
  - Construction
    - Coding
  - Testing
    - Validation and Verification
  - Maintenance (may involve several development cycles)
    - Enhancements and perfection until the software is alive

Development cycle