VERIFICATION, VALIDATION AND ACCREDITATION

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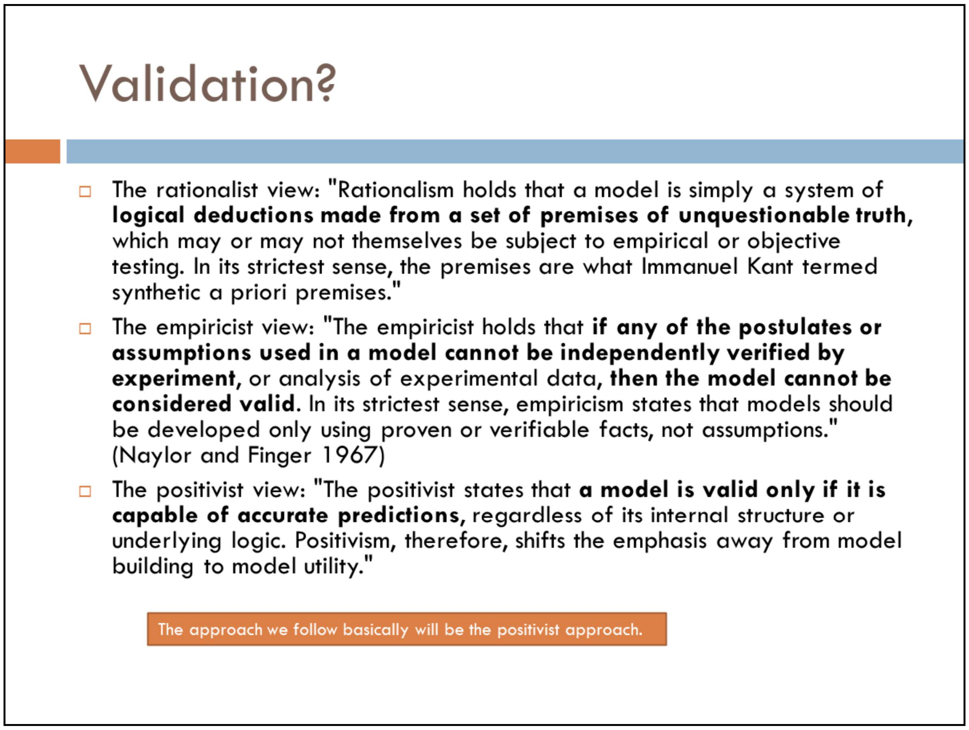
We will reviewe now Validation, Verification and Accreditation processes. This processes will be conducted from the beginning of the simulation project to assure that all the steeps will be done correctly.

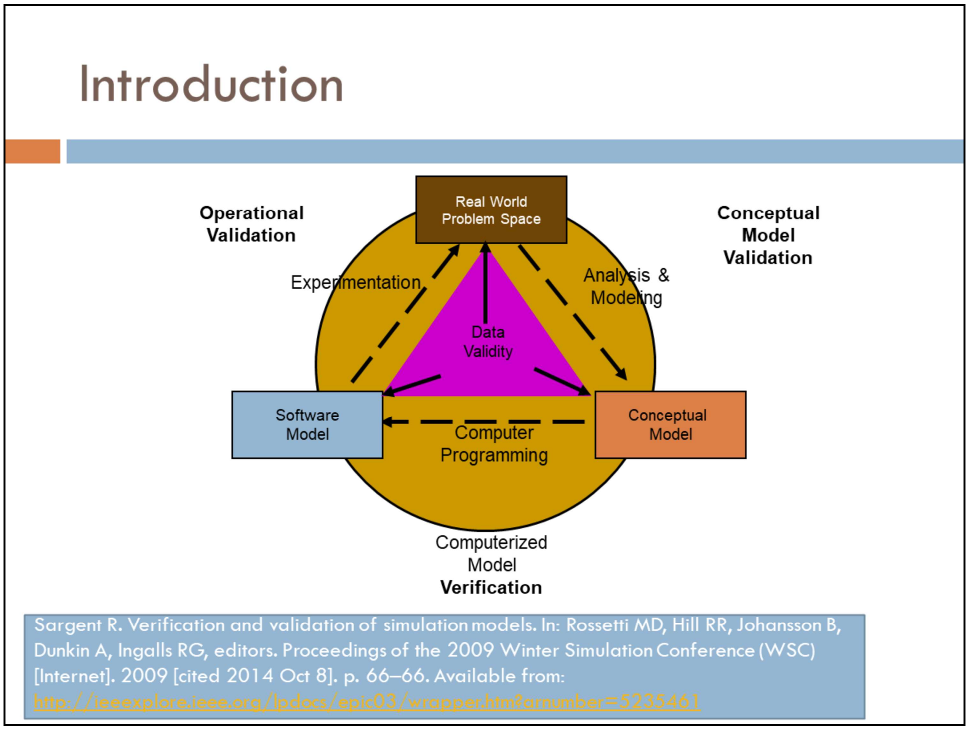


But what is Validation?. Well it depends on what is the scientific framework we will use. On this slide we present three of the main paradigms we can follow to understand what is a validation.

The first approach can be the rationalist view:. On this approach a model is simply a system of **logical deductions made from a set of premises of unquestionable truth**, which may or may not themselves be subject to empirical or objective testing. In its strictest sense, the premises are what Immanuel Kant termed synthetic a priori premises.

On the empiricist view **if any of the postulates or assumptions used in a model cannot be independently verified by experiment**, or analysis of experimental data, **then the model cannot be considered valid**. In its strictest sense, empiricism states that models should be developed only using proven or verifiable facts, not assumptions. This is the approach, presented on Naylor and Finger on 1967.

Finally, the positivist view: that states that **a model is valid only if it is capable of accurate predictions**, regardless of its internal structure or underlying logic. Positivism, therefore, shifts the emphasis away from model building to model utility. Often on simulation we will follow the positivist approach.



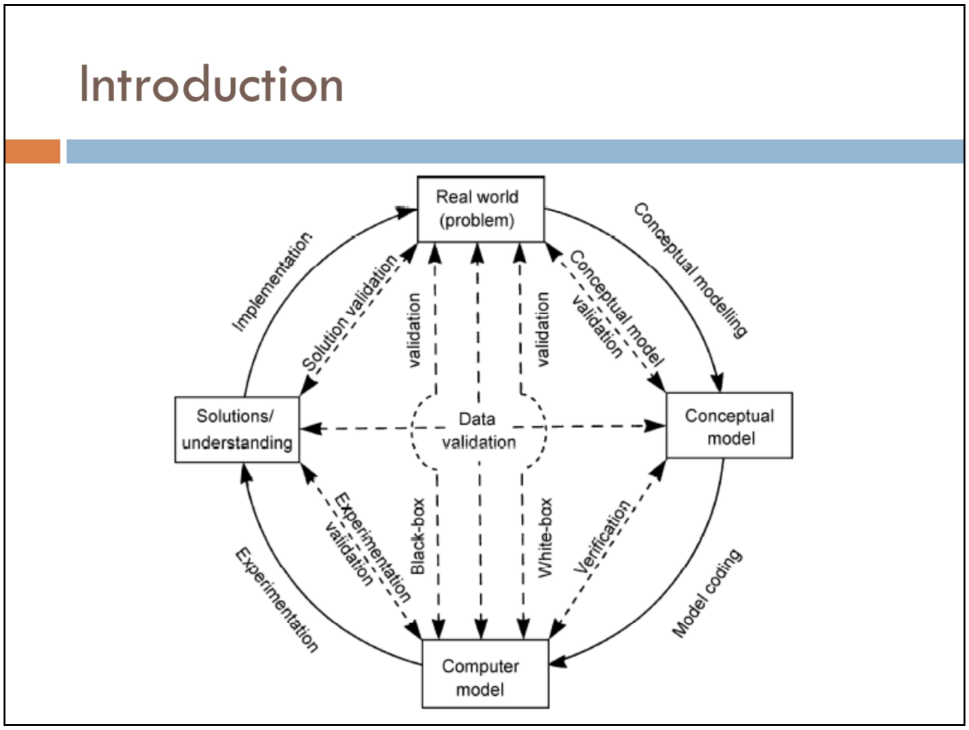
This is the simplified process to define a simulation model, we will start with a real system that is the object of our analysis. From it we will generate a conceptual model, through the Analysis and modelling process. From this conceptual model, represented in a formal language, like Specification and Description Language, SDL, DEVS, or Petri nets, among others, we will perform a codification, that allows to obtain a Computer program that represents this model. From this program, we will be able to conduct a set of experiments that provide us with the answers.

The transformation between each of these representations of the system presents a potential for error. Conceptual model validation is conducted to ensure that the creation of the conceptual model captured all the important aspects of the real system. It also insures the proper balance and interactions between objects in the conceptual model.

Computerized model verification is performed to ensure that the software model is an accurate representation of the conceptual model. The creation of software is a very error prone activity and it is likely that the ideas so carefully crafted in the conceptual model were not accurately captured in software.

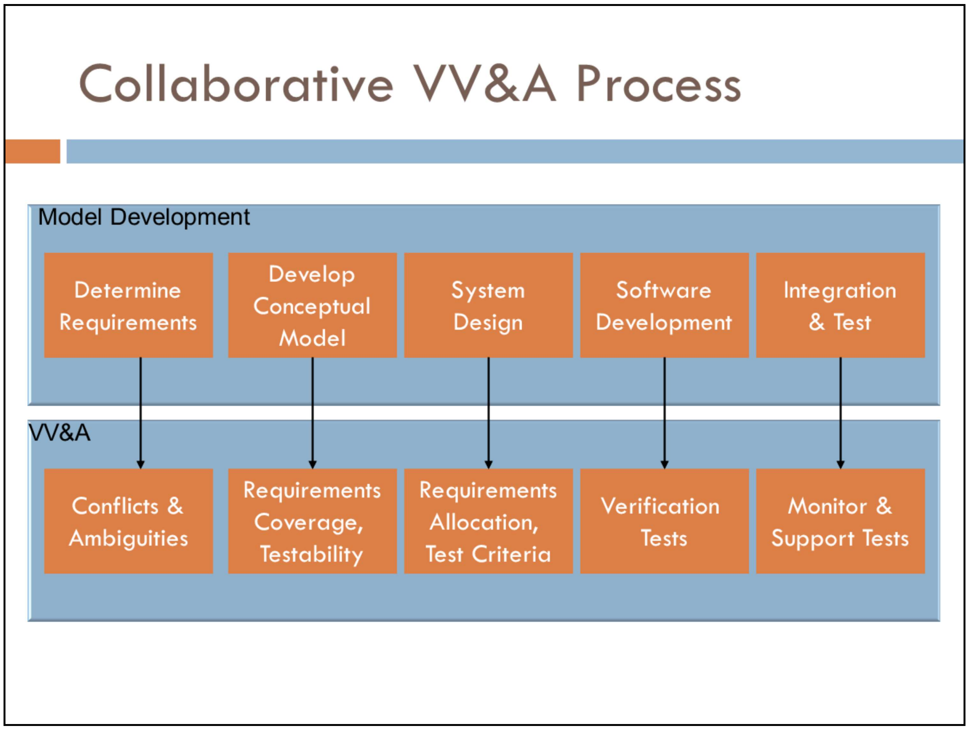
Operational validation is conducted to compare the software model to the real system. This is the final check to see that the final product does behave in a fashion that is similar and representative of the real world.

Notice that in the middle of all the process we see the Validation of the Data, that will be continuously done.



On this second process we add the Solutions understanding as a separate steep on the process. This element allows to introduce a key element in the Industry 4.0 paradigm, where the simulation models, the digital twins, must be continuously validated against the real system to assure that the assumptions are still correct.

This validation process is named the Solution Validation, and basically takes care regarding if the solutions provided with the simulation models, fits with the results we observe on the system, once we implement on it the proposed solutions provided by the simulation model.



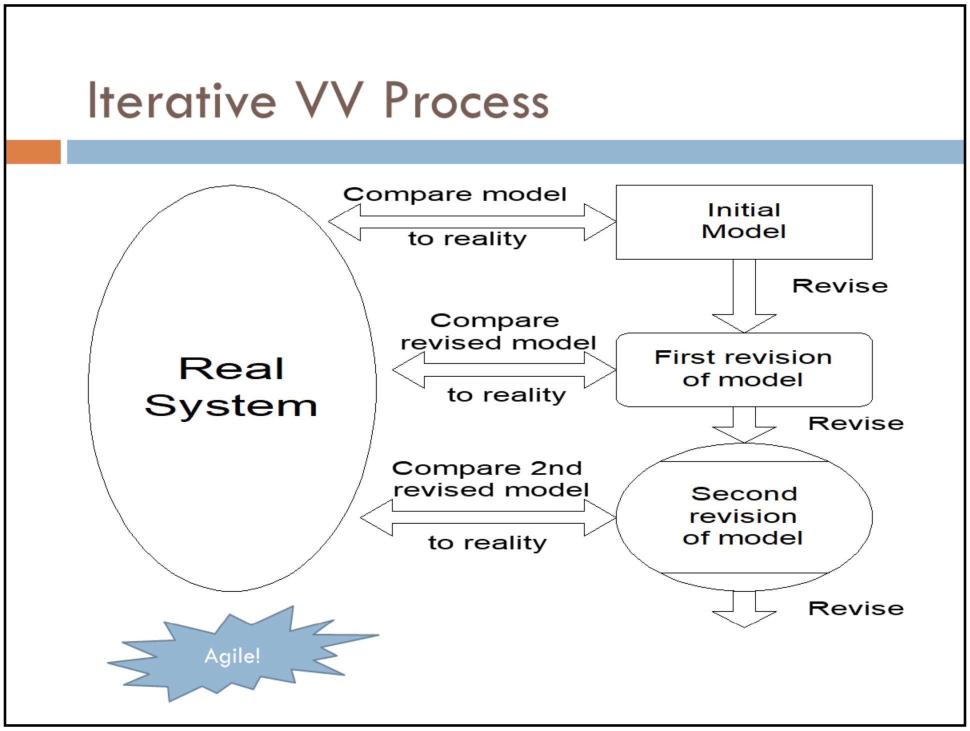
For each step in the development of a simulation system there is a corresponding activity in the Validation Verification and Accreditation process. This clearly demonstrates that Validation Verification and Accreditation process begins at the beginning of a program and that it is a cooperative and open activity.

When the requirements are being determined for the model, the Validation Verification and Accreditation team should look for ambiguities and conflicts within these requirements.

During the conceptual modeling phase, the Validation Verification and Accreditation process team will check the testability of the requirements and will ensure that the tests completely cover the model capabilities.

During system design the Validation Verification and Accreditation team will allocate specific requirements to specific tests and will establish the criteria for passing those tests.

During software development the Validation Verification and Accreditation team will conduct verification tests on the products. This continues through system integration which is supported by the Validation Verification and Accreditation team.



The process, as you notice is iterative, this imply that first we will start with a model that is useless, but very simple, covering the needed elements to be able to start. This first Initial model usually is not going to solve the issues we want to address; however, we can continue in a second revision of the model, that approximates us to the needed detail in order to solve the proposed problem,

This iterative process will continue until we find a model that is enough for our needs. At this point we will finish.

As you notice this schema fits well with the Agile methodology.

Aspects to consider

- **Agreement:**
  - between the modeller and the client (approach used to validate, experiments, information and documentation to use).
  - Control if other possible actors exists that must be included on the agreement.

There are important aspect to consider in the modeling process.

First it that the model itself is an agreement between the modeler and the client. This approach will be used to perform the validation, to define the experiments, to define the information and the documentation to use and generate, etc.

Also, it is needed to assure that all te main actors are included on the agreement, take time to assure that other possible actors that must be included on the agreement are not discarded.

To achieve the agreement

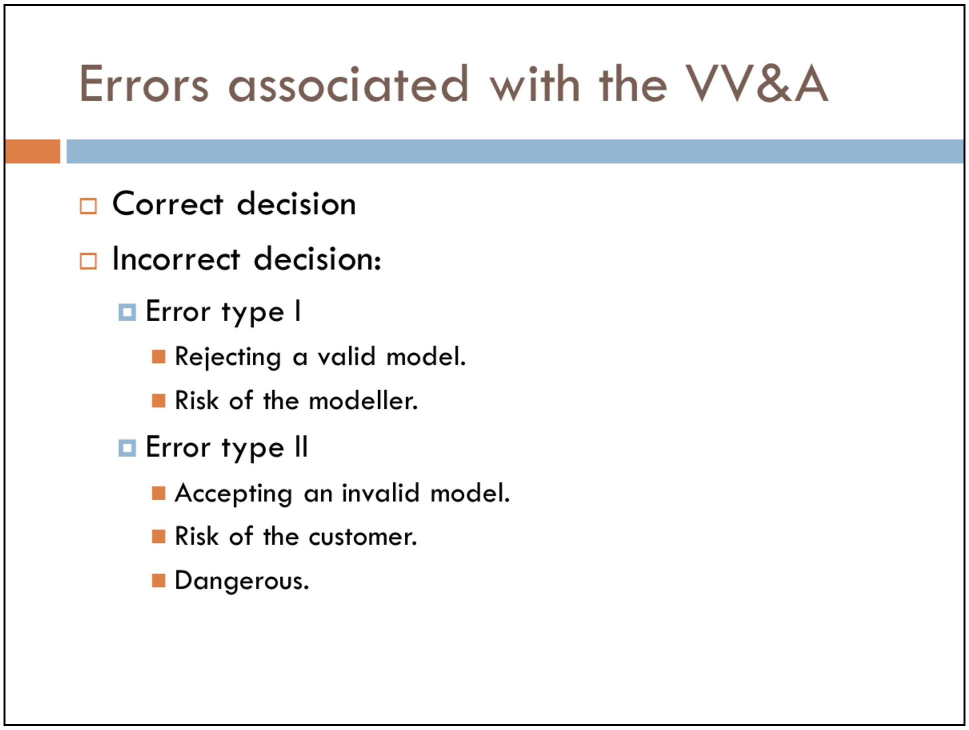
- **Purpose** of the model: A model is developed with a specific objective.
- **Validity** of the model: range of precision, can only prove that a model is false, you must do test.
- **Iterations** of the model, before reaching a satisfactory model.
- Is needed to separate the VV&A processes?
  - Development of the model: team one
  - Validation, Verification and Accreditation: team two. IV&V (**Independent** validation and verification team), usually for large projects. (Sargent, Law).

To achieve the agreement it is needed to define clearly the Purpose of the model, notice that always a model is developed with a specific objective, hence what is the goal that rules your model definition?

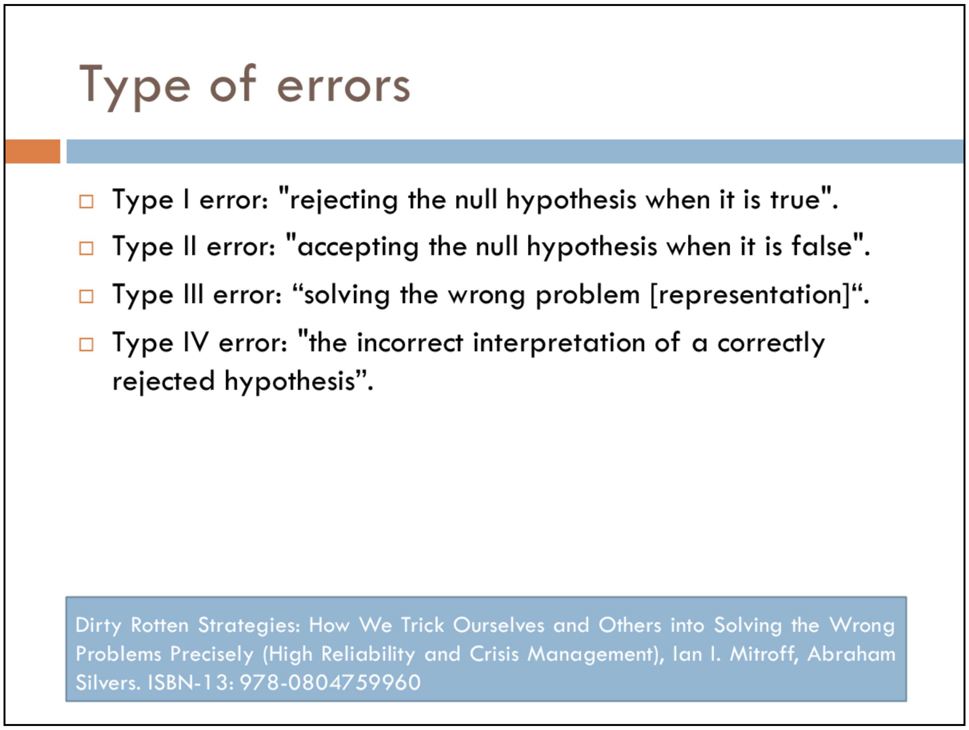
Is needed to discuss regarding how to assure the model Validity, this implies to determine the range of precision. Also, remember that we can only prove that a model is false, hence you must do several tests in order to increase the confidence on the model

Also think about the iterative process you are going to follow. This Iterations of the model, before reaching a satisfactory model can be almost infinite if the model is complex and the Validity condition of the model is not meet. Hence it is needed to discuss regarding this situation or to stablish a maximum number or iterations.

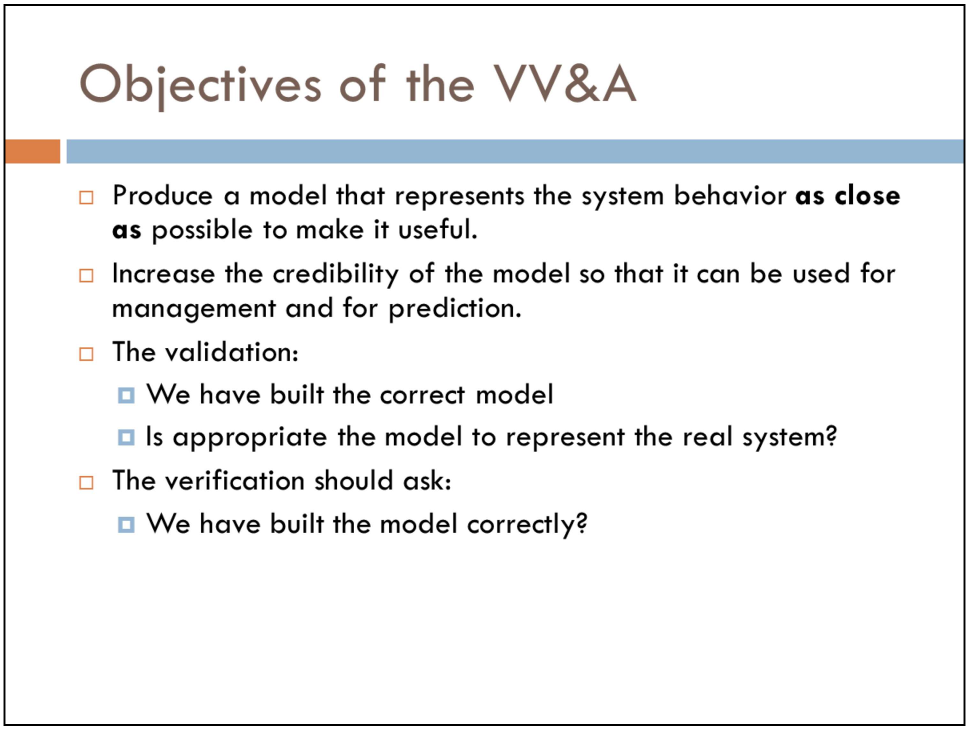
Regarding the Validation, Verification and Accreditation process, often is needed to separate the teams involved in each aspect. The development of the model will be conducted by one team, while the Validation, Verification and Accreditation by other independent team. This second scenery usually is required for large projects and is named Independent Validation Verification and Accreditation.



Regarding the errors that one can expect to find during the Validation and Verification process, one expect to find the usual statistical errors, like Error type one, that implies rejecting a valid model, representing a risk of the modeler. And error type two, implying accepting an invalid model, becoming a risk of the customer, and obviously being more dangerous.



But we can consider other errors, here you can review other errors we can find in the process of conducting a simulation model.



With all this elements in mind, the goals of Validation and Verification is to produce a model that represents the system behavior **as close as** possible to make it useful. To do so we will increase the credibility of the model with the goal that the stakeholders agree that it can be used for management and for prediction, this last steep is named the Accreditations, someone believes on the model accuracy to make previsions.

Hence, the validation wants to answer

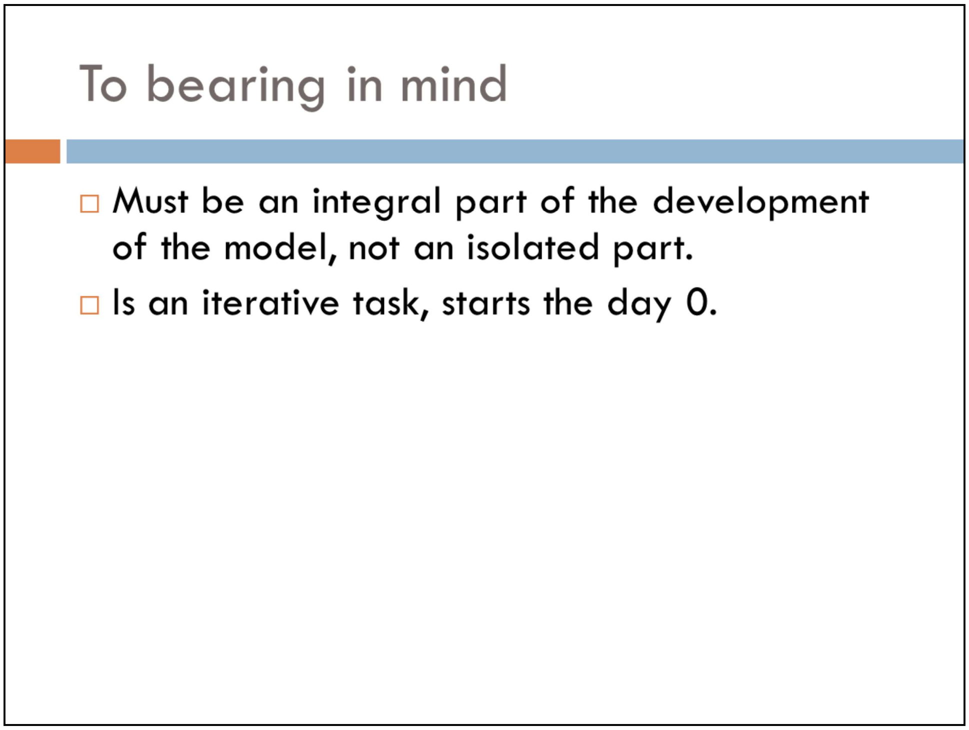
the question :we have built the correct model?, or Is appropriate the model to represent the real system?

On the other hand, Verification try to answer if, we have built the model correctly? This second question is a common one in computer science and sometimes is related to debugging an application.

Accreditation

- Is the final goal of a simulation model.
- Implies that the Stakeholders believe on the model and use it to make previsions, that can be applied to the system, implementation.

Also, notice that all the process of defining a model, hence performing the Validation and Verification is because we want to us it to make previsions or to understand how the system behave. I both cases, Stakeholders must believe on the model, otherwise, the model will become useless. If Stakeholders believe on the model, then, based on the knowledge of the model or in its prevision, they may decide to implement some actions on the system, this means modify the system following some model suggestions. At this point, later we can apply a System validation.

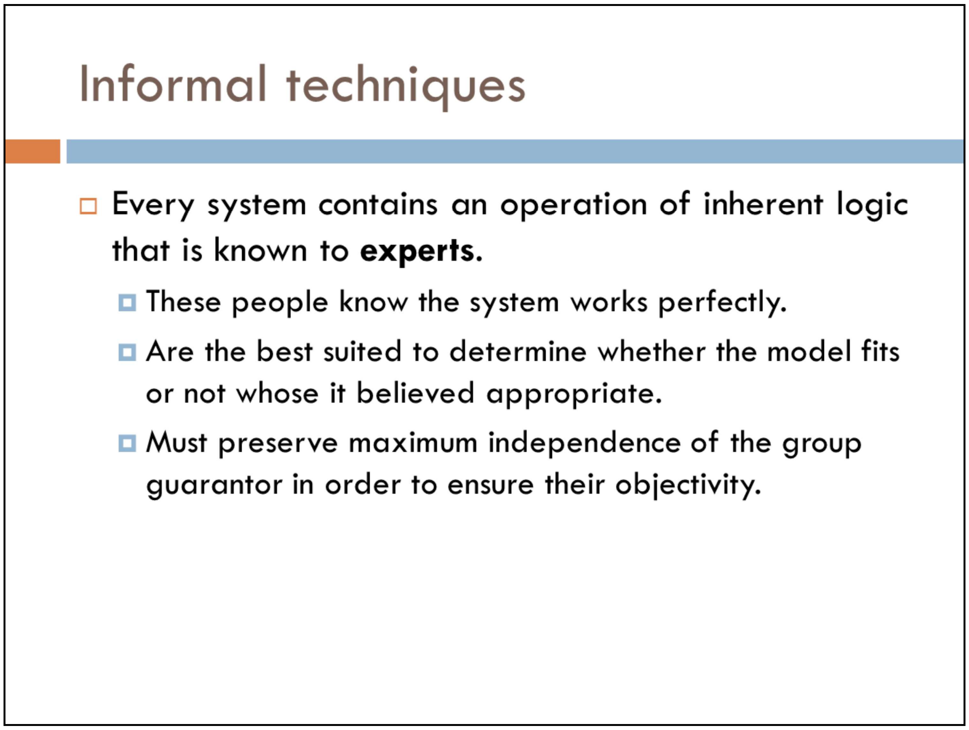


At this point we want to remark again that the Validation and Verification are integral parts of the development of the model, not an isolated part, that must be done from the beginning, starting at day 0. without this accreditation will fail.

Techniques of VV&A

- Informal techniques
- Formal techniques
- Static techniques
- Dynamic techniques

The techniques that one can use to perform the Validation and Verification can be diverse, but can be classified mainly in this four categories, Informal techniques, Formal techniques, Static techniques and Dynamic techniques.



Informal techniques are based on the idea that the experts understand the inherent logic of the system, hence we ask about its behavior to them.

The experts are those who are suited to determine if the model fits, or not, with the operation assumptions they have.

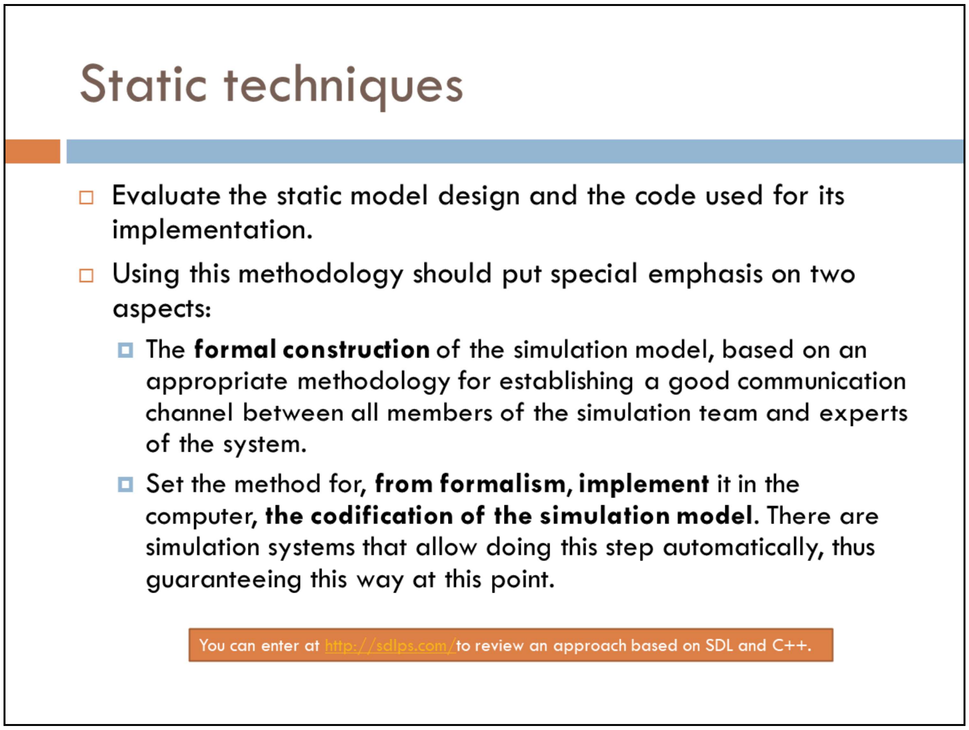
At this point is crucial that this group of experts have the maximum independence regarding the model implications. Otherwise its opinions can influence the Validation process.

Formal techniques

- For example, the **calculation of the predicates** guarantees completely the correctness of the model.
- However these techniques tend to over-complicate the understanding of the model and tend to be complicating to implement for some complex models.

Other technique that one can apply are the formal techniques, as an example based on the calculus of predicates, that will guarantee the complete correctness of the model, based on the logical definitions of the requirements.

These techniques are complex and difficult, and needs time, hence it is needed to apply this techniques only for those areas of the model where is critical to assure that al is correct, otherwise we will spend too much time on this process.



Theses techniques are based on the model definition and also, on the codification of this model through a specific tool or generic codifying language, like C++.

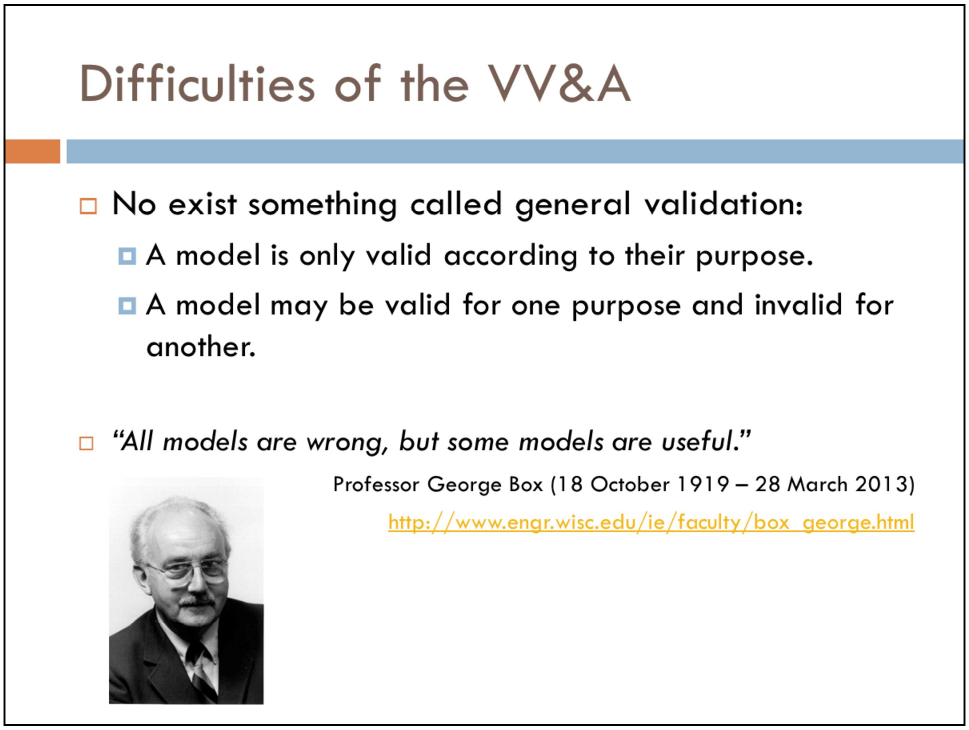
We will put emphasis on two aspects, the formal construction of the simulation model, that will be based on an appropriate methodology, as an example using a formal language lik Specification and Description Language (SDL, DEVS or Petri nets, among others, with the goal of establishing a good communication channel between all members of the simulation team, and experts of the system.

Then when the inspection of the model implies an agreement that the model represents all the assumptions we want to introduce on the analysis, we must define a method for, from formalism, implement it in the computer, the codification of the simulation model. To simplify this steep, that must be later Verified, think that some errors can be introduced here due to the manual codification of the models, there are simulation systems that allow doing this step automatically, thus guaranteeing this way at this point. This systems, like SDLPS allows to assure that the codification has been correctly done and the execution is reproducing exactly the model represented formally, in the case of SDLPS following SDL formalism.

Dynamic techniques

- Analyze the **results** provided by the simulator.
- Used common statistical techniques to assess whether the data that the simulator provides conform to reality or not.

Finally, dynamic techniques are the more commonly used techniques, we will analyze the results provided by the simulator. Here one can use common statistical techniques to assess whether the data that the simulator provides conform to reality or not, comparing as an example the output with historical data.



Some difficulty that must be considered in the Validation process are that there is no something named general validation, this means that a model is only valid according to their purpose, or similarly, that a model may be valid for one purpose and invalid for another.

A great cite to express this issue has been done by Professor George Box who states that "All models are wrong, but some models are useful."

Difficulties of the VV&A

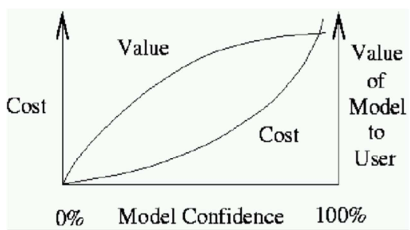
- It is possible that a “real world” does not exist to compare with the model:
  - Often the models are created to evaluate alternatives exist.
- What is the “real world”?:
  - Different roles have different visions of the system. The interpretations and therefore the real world vary.

Other difficulties that one must consider is that the “real world” maybe does not exist, because models often are created to evaluate alternatives, hence some of the alternatives we generate maybe does not exist on the real world.

Also, it is needed to understand that the concept “real world” depends on the perceptions of individuals, hence if the model is complex and includes some tacit knowledge of the experts, maybe there is not a single real world, the different visions of the experts may differ.

Difficulties of the VV&A

- Often the system data are not adequate:
  - Maybe the data don't exist.
  - You might not represent all possibilities.
- The time:
  - No time to validate and verify everything.



Sargent R.

Also, mention that maybe the system data is not adequate, maybe the data event do not exist, or maybe this data cannot represent all the possibilities that later will be defined on the simulation model.

Also is needed to mention that there is no time no validate everything. See the chart the value we will obtain doing more validations is going to stabilize asymptotically, while the cost needed to perform more validations tends to grow exponentially.

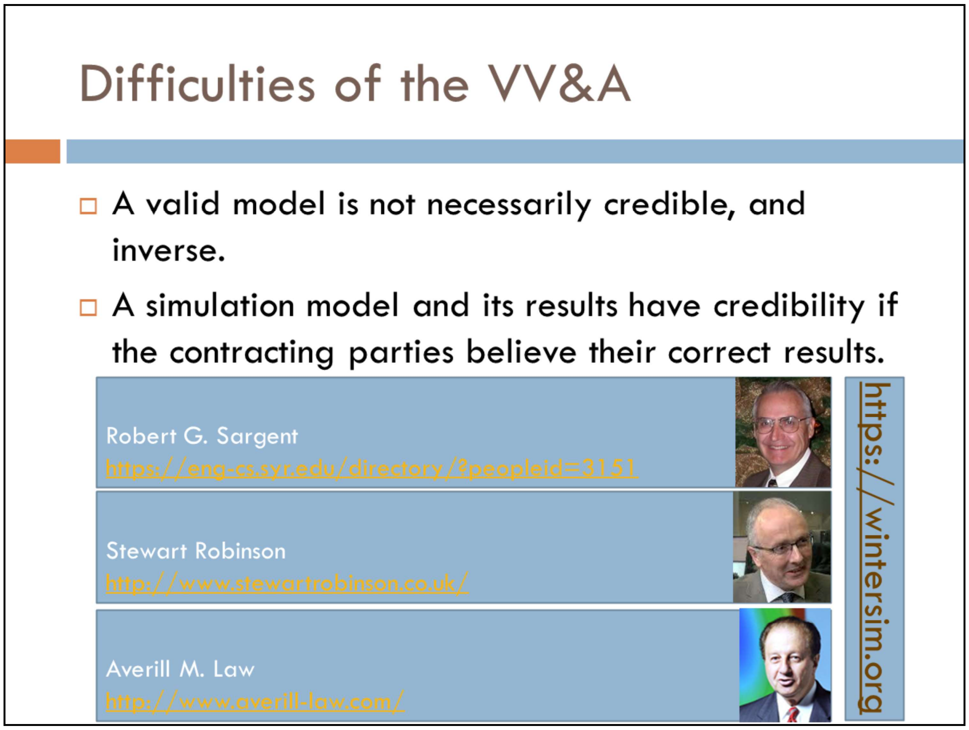
Difficulties of the VV&A

- Only can **demonstrate** that the model is **wrong**:
  - As more tests are done which can not demonstrate that the model is incorrect, the confidence interval of the model grows.
  - The objective of V&V is to increase this confidence interval.

The logic of scientific research (1935), Karl Popper

Also remember that we can only assure that a model is wrong, more test done increases the confidence on the model, but does not assure the model validity, hence the goal of Validation and Verification is to increase this confidence on the model.

A quite interesting book to read concerning this is “The logic of scientific research” by Karl Raimund Popper.



Finally, remark that again that “a valid model is not necessarily credible, and inverse.” and that “A simulation model and its results have credibility if the contracting parties believe their correct results.”

Here you have three key authors related to validation and Verification in the frame of simulation. In the web of wintersim, you can download full papers of them and review the current trend of the discipline.