

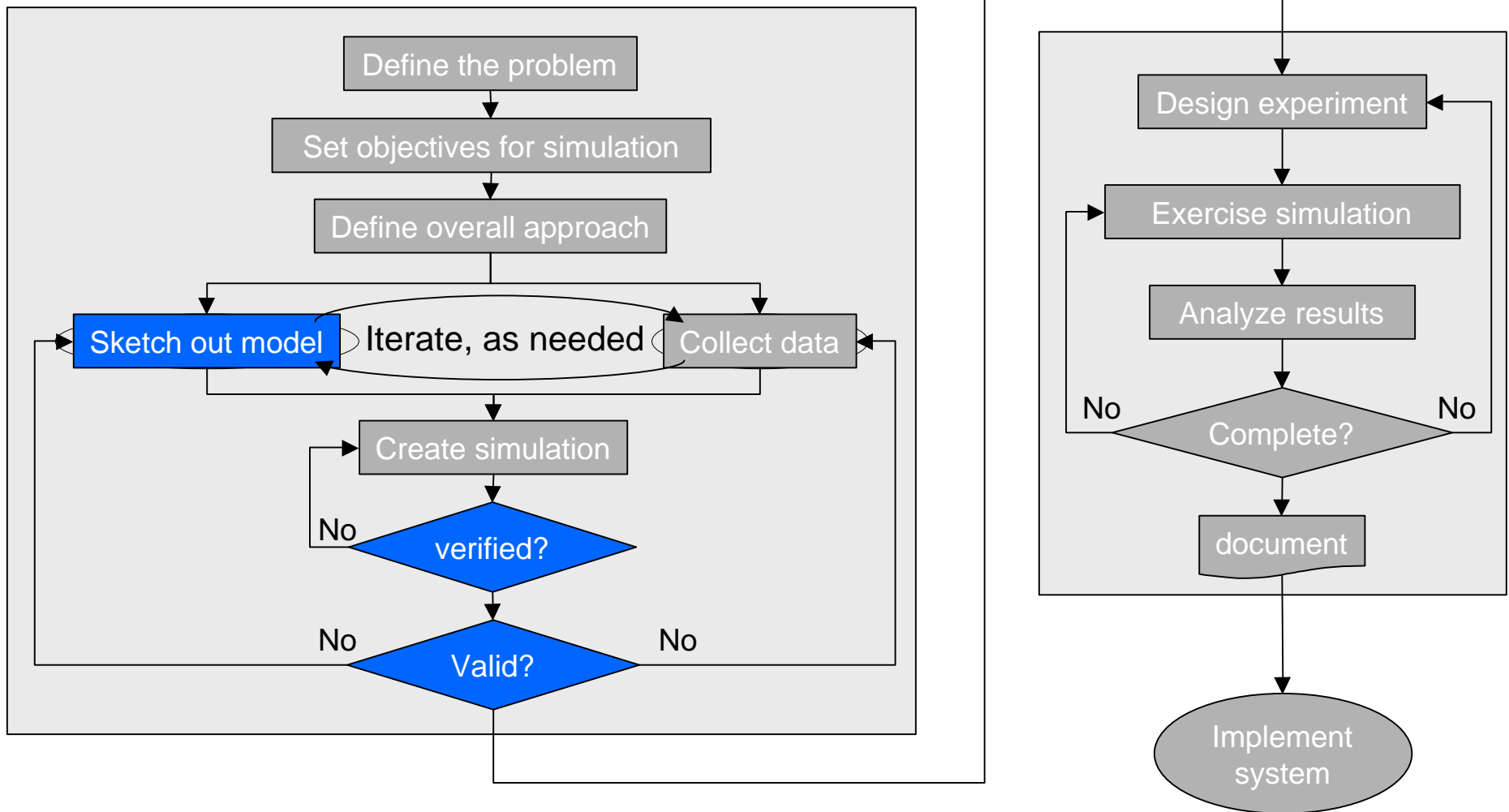
**EE/CpE 345**

**Modeling and Simulation**

**Spring 2003**

**Class 10**

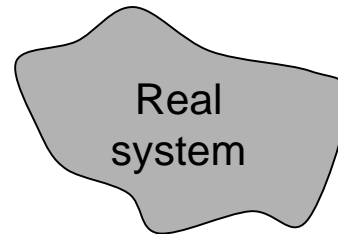
# Steps in a simulation study



# Verification and Validation of Simulation Models

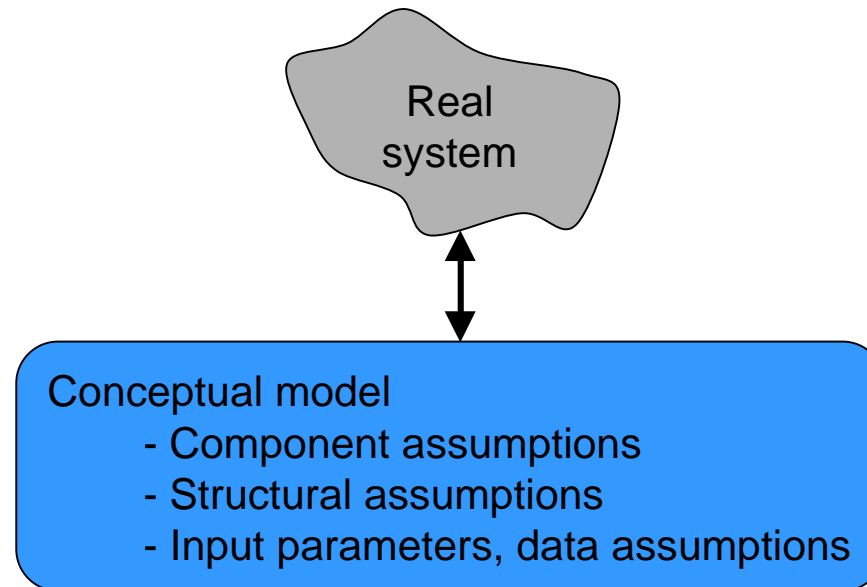
- Model
  - Building the model
  - Verification of the model - is the model built **correctly**?
  - Validation of the model - was the **correct** model built?
    - Face validity
    - Model assumptions
    - Input-output transformation
    - Is the model a reliable and credible representation of the real system?
      - Reliability -> user issue
      - Credibility -> manager issue
- Simulation
  - Verification of the simulation model - is the simulation a correct implementation of the model intended?

# Model Building, Verification, and Validation



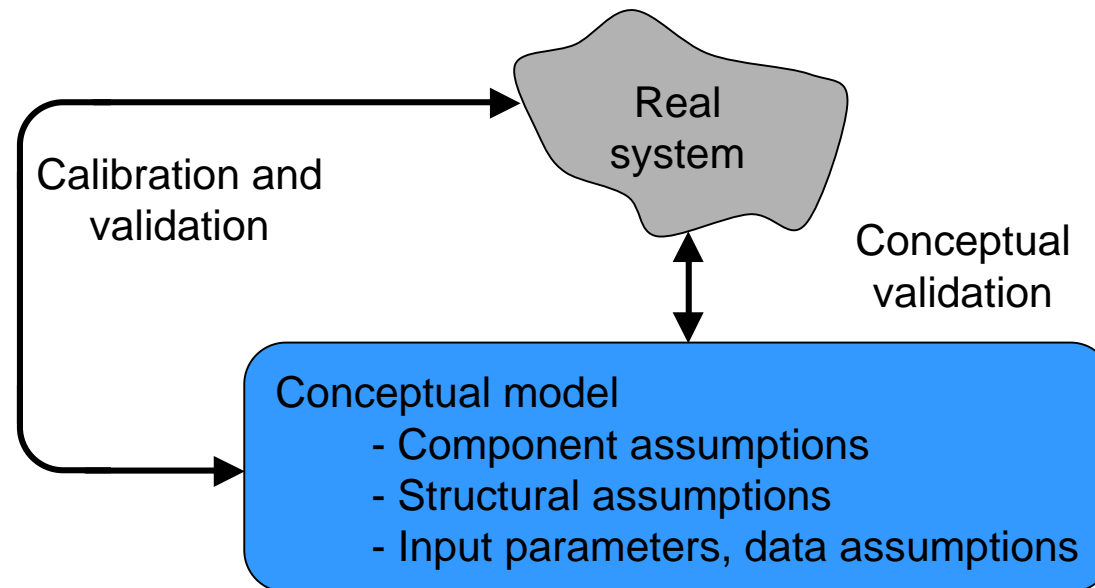
1. Observe and understand the real system's operation and behavior

# Model Building, Verification, and Validation



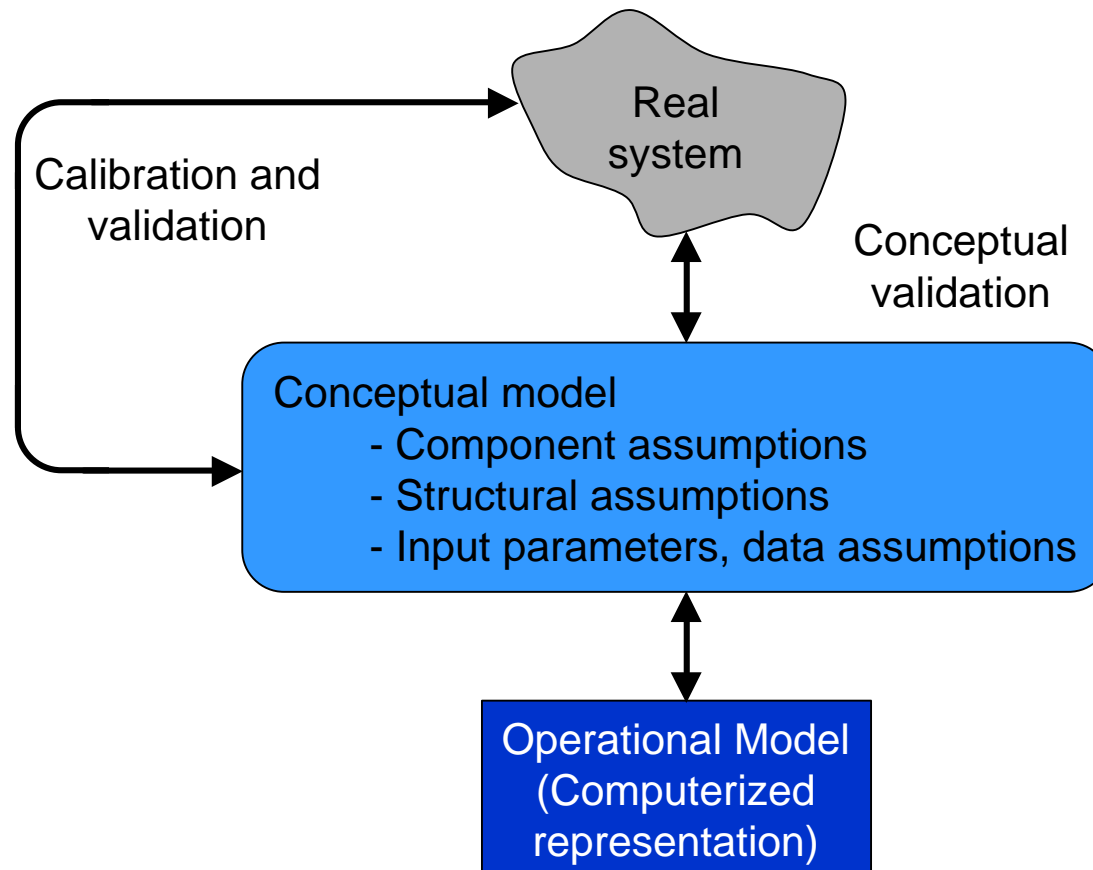
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2. Create a conceptual model

# Model Building, Verification, and Validation



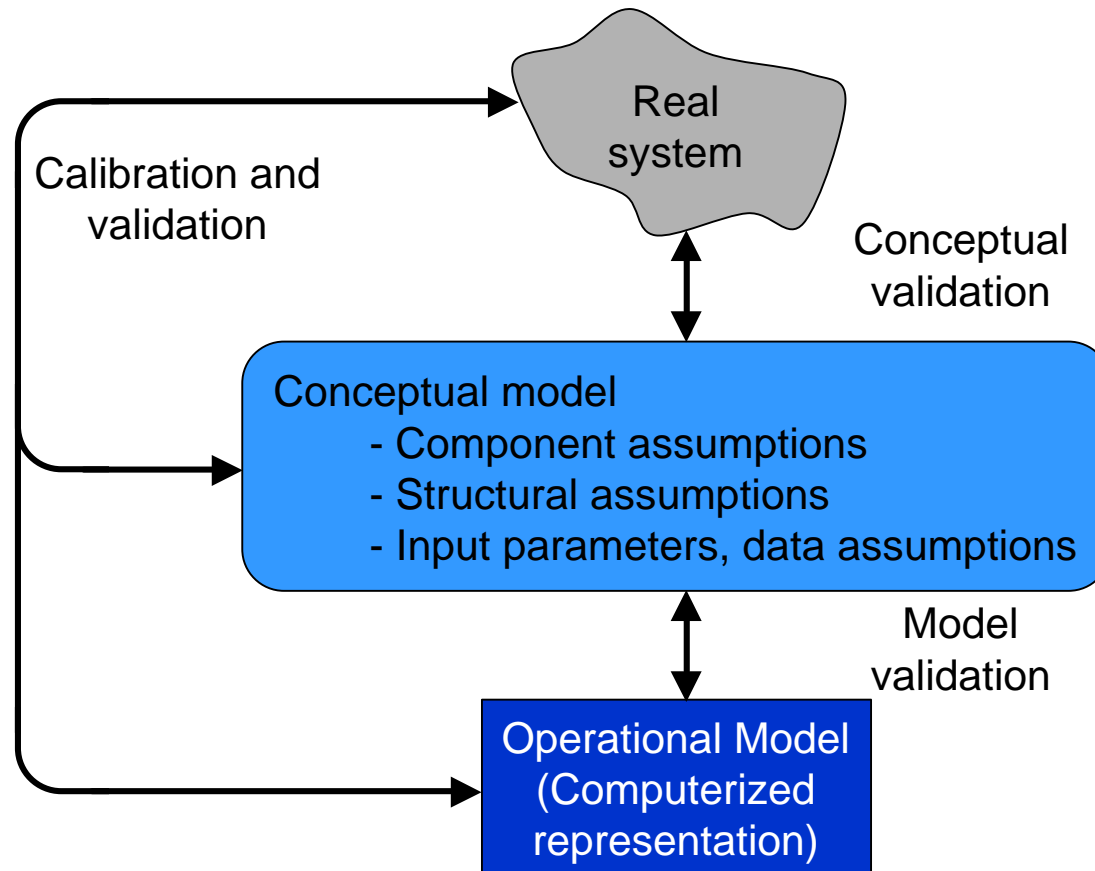
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# Model Building, Verification, and Validation



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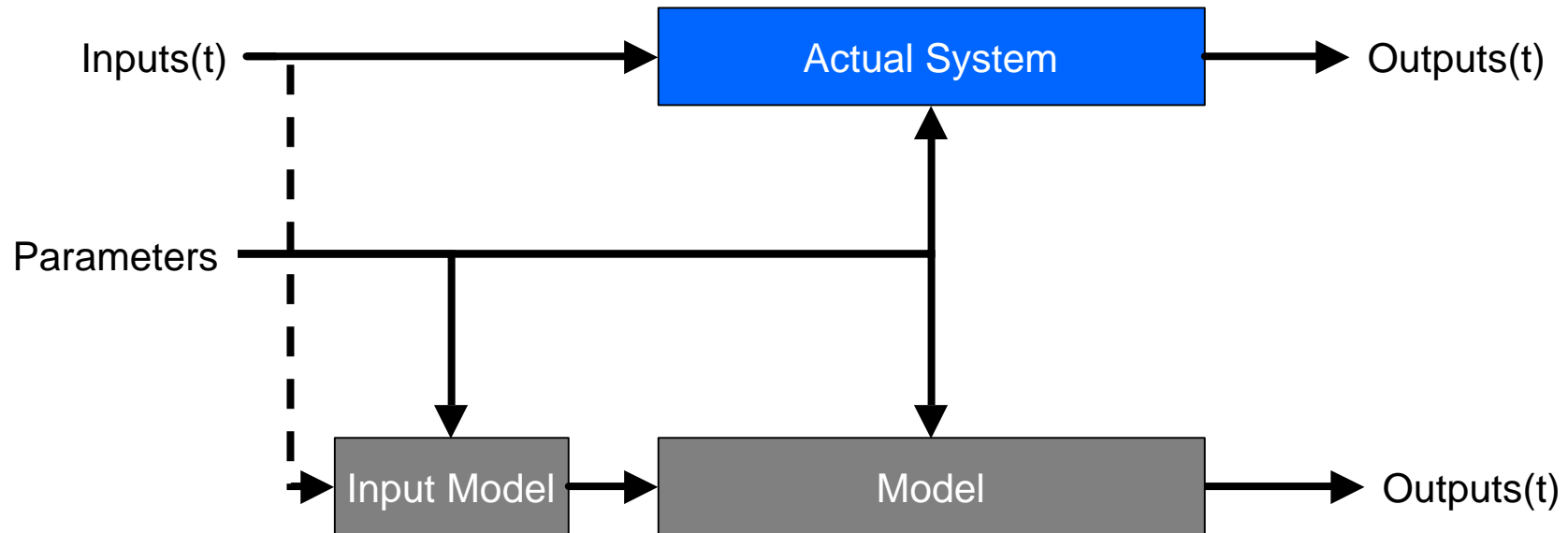


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# Verification of Simulation Models

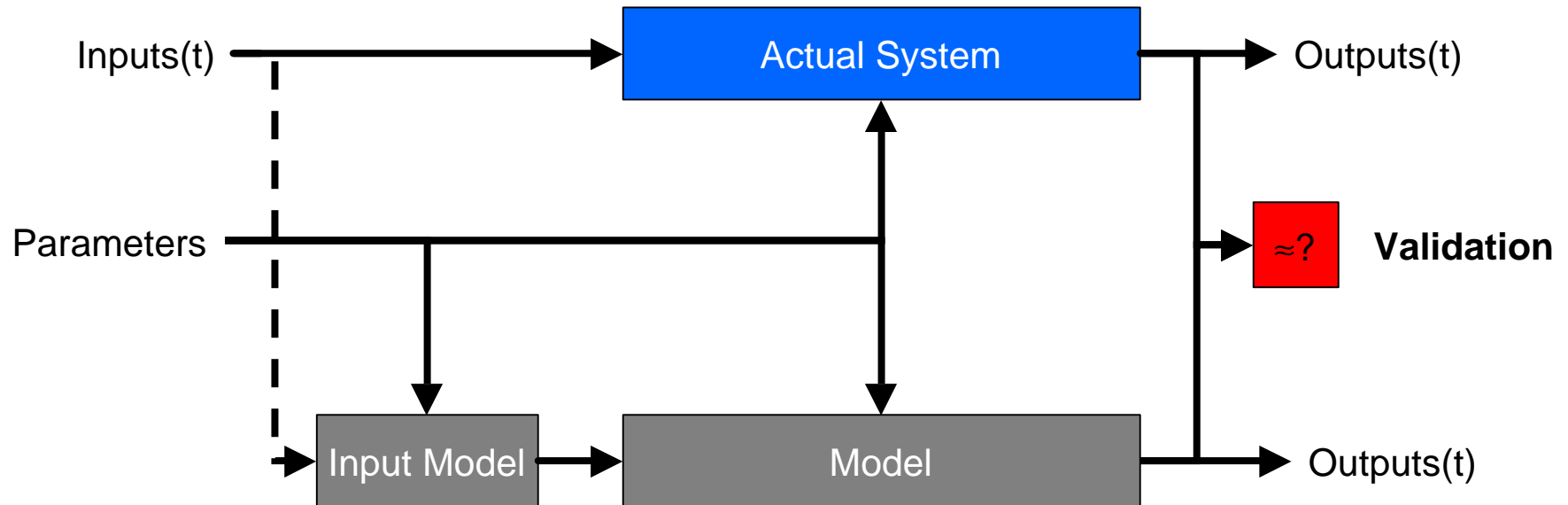
- Is the computer simulation an accurate representation of the conceptual model?
- Common sense approach to verification:
  - **VERIFY INITIAL CONDITIONS!**
  - Use graphical representation whenever possible - you can scan a 2 dimensional (graphical) view faster than a 1 dimensional (textual) view
    - Flow charts
    - Graphs of output behavior
    - Graphs of internal operation of model
    - Animations
  - Where possible, create internal model partitions that correspond to partitions in the real system - i.e., a top-down hierarchical view of model
  - **Test the simulation model for reasonableness under extreme value conditions.**
  - Test the simulation model for reasonableness under *variation* in parameters. Does the response follow the *direction* of the change?
  - Examine inputs and outputs of subsystems - too few or too many events may indicate errors elsewhere
  - Whenever possible, compare selected test conditions to analytical results

# Calibration and Validation of Model



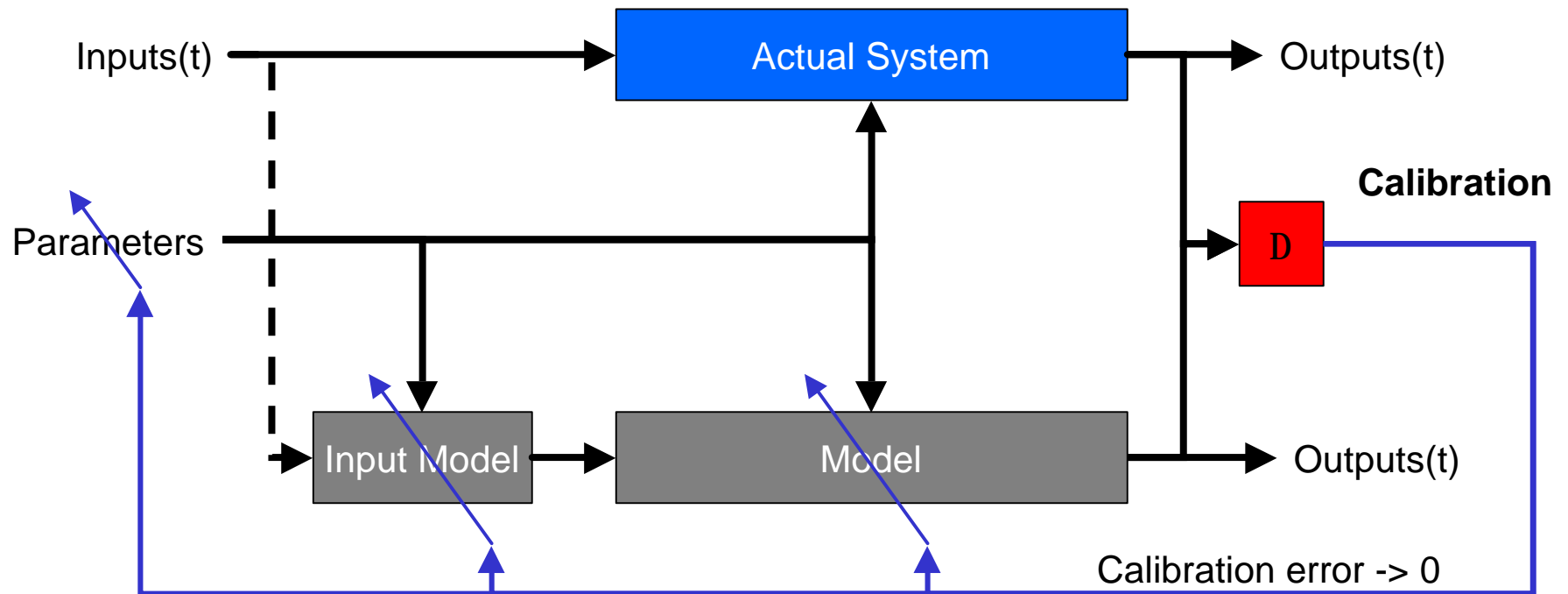
- Calibration and validation processes are distinct processes, normally performed simultaneously and interactively

# Calibration and Validation of Model



- Validation - does the behavior of the simulated system match that of the real system?

# Calibration and Validation of Model



- Calibration - adjust or alter models and parameters to best fit real system behavior
- Consider the calibration process as a feedback control system, adjusting model to minimize the error (difference between model and reality)
- Calibration/Validation stops when error is less than some threshold, often cost-based

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- Does behavior of model change in expected ways with modification of parameters?

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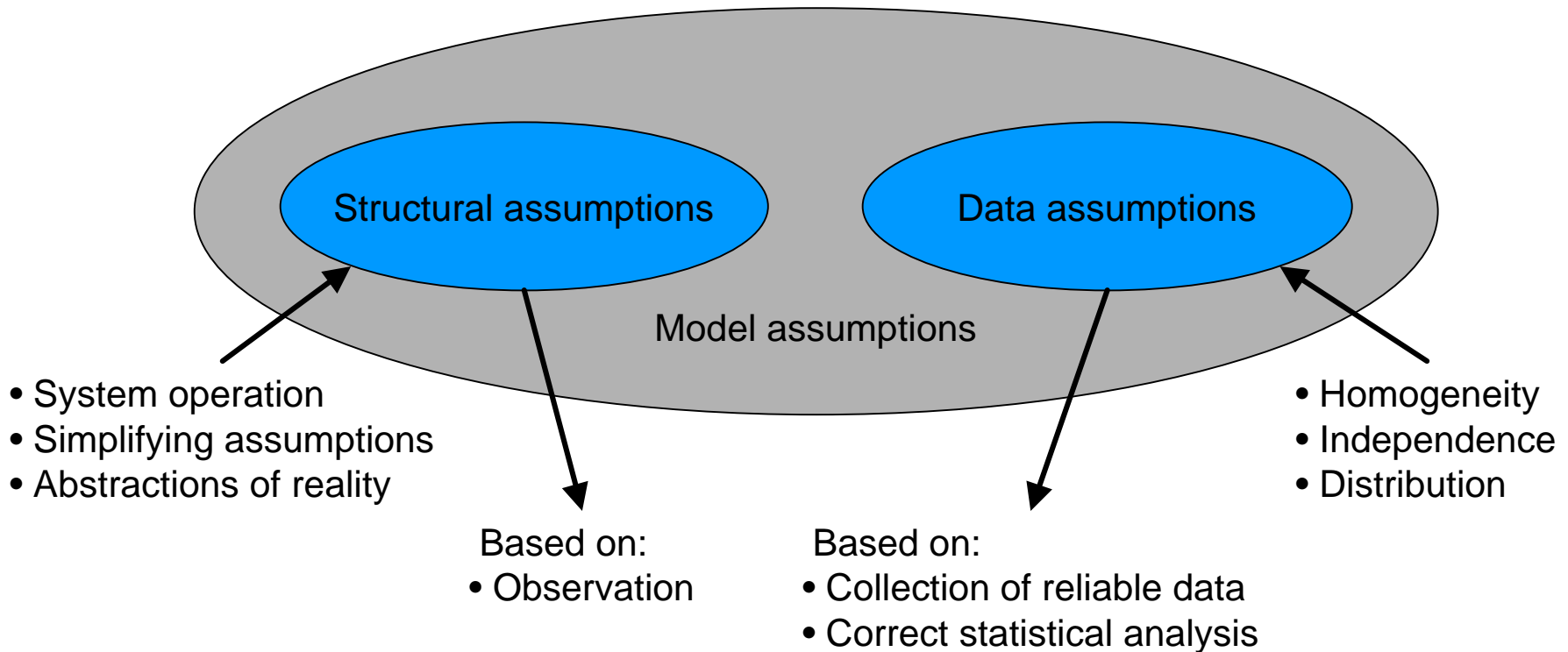
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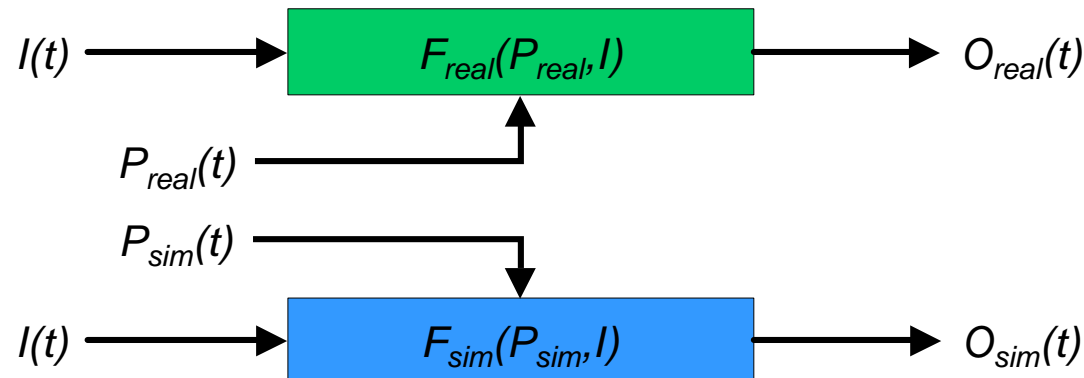
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    - What happens to server utilization as the arrival rate,  $I$ , or service rate,  $m$ , increase, or as we change the number of servers,  $c$ ?
    - $r$  increases with increasing  $m$  and decreases with increasing  $m$ , which is obviously incorrect. The change with changing  $c$  is appropriate.
    - This model is invalid on its face.

# Validation of Model Assumptions

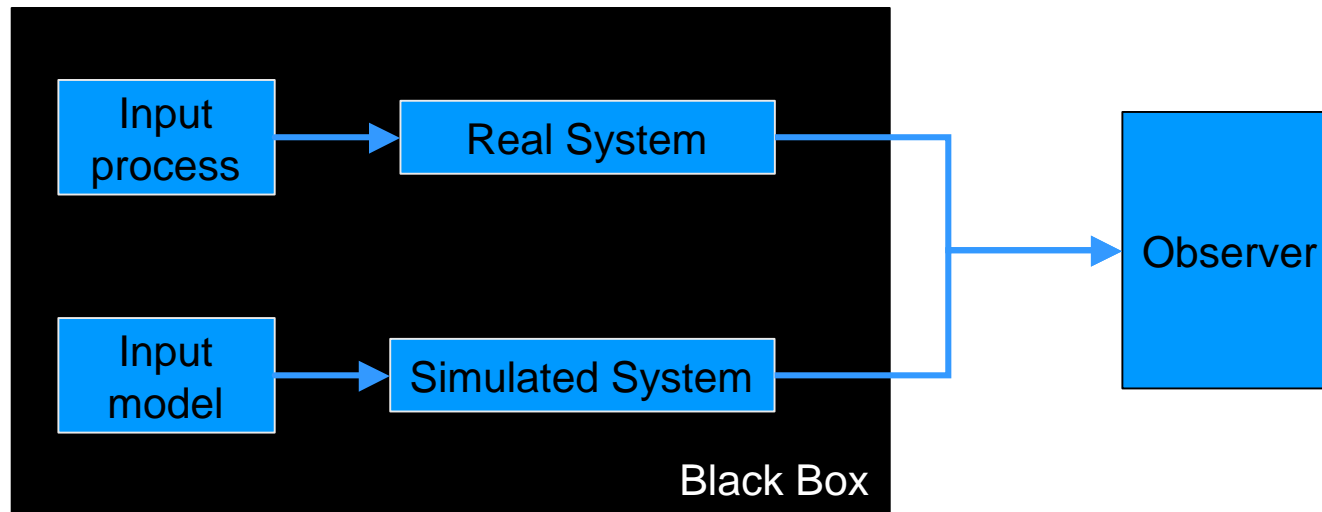


# Validating Input-Output Transformations



- Consider real system and simulation to be functional transformations of inputs, based on parameter settings
- To what extent does simulation:
  - agree with real system
  - accurately predict future behavior of real system
  - accurately predict behavior of real system under different input conditions or parameters?
- This is the only objective measure of the model as a whole
- Usable for comparison only if there is something to compare to!

# The Turing Test



- If expert observer cannot distinguish output from real and simulated system with any consistency, validity of simulation is not refuted by this test
- If observer consistently identifies simulation, their critical observations can be used to improve simulation

# Summary

- The quality of decisions made, based on a simulation and its underlying model, are only as good as the validity of the simulation and the model
- Possible validation techniques:
  - Develop models with high face validity, use existing knowledge
  - Conduct statistical tests on input
  - Conduct a Turing test
  - Compare model to real system output with statistical tests
  - Build new system based on simulation, collect data and use to validate model (*a.k.a. a cart-horse ordering problem*)
  - Do little or no validation (*Is this your lucky day?*)

cost



value



# Homework

- Describe an algorithm, applying the Turing Test, to mathematically quantify the validity of a simulation.
- Separate submission (graded as part of class project - one per group):
  - Provide a flow chart of the tasks you have completed and must still complete for your project (e.g., data collection, analysis, etc.). Indicate completion status by color coding task blocks.
  - Provide a flow chart of your simulation software
  - Each chart should be ~1 page.