COMPLEX WEAPON SYSTEMS SIMULATION

The experience of DIPRIDA

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SIMULATION

- Why simulation?
- What have we done?
- What have we learned?

Why simulation?

TASK

One of the main tasks derived from DIPRIDA's mission is:

To apply Operations Research in support of Tactics Development and Naval Forces Structuring.

DIPRIDA TASK

- Systematic application of the scientific method to the solution of decision making related problems of the Navy, particularly in the areas of tactical procedures and weapons or ships acquisition

Scientific method

- Develop an analytical model to describe the problem under study
- Make predictions based on the model
- Test the validity of the model by means of controlled experiments

MODEL

- An “representation of reality” that provides an insight into the real world.

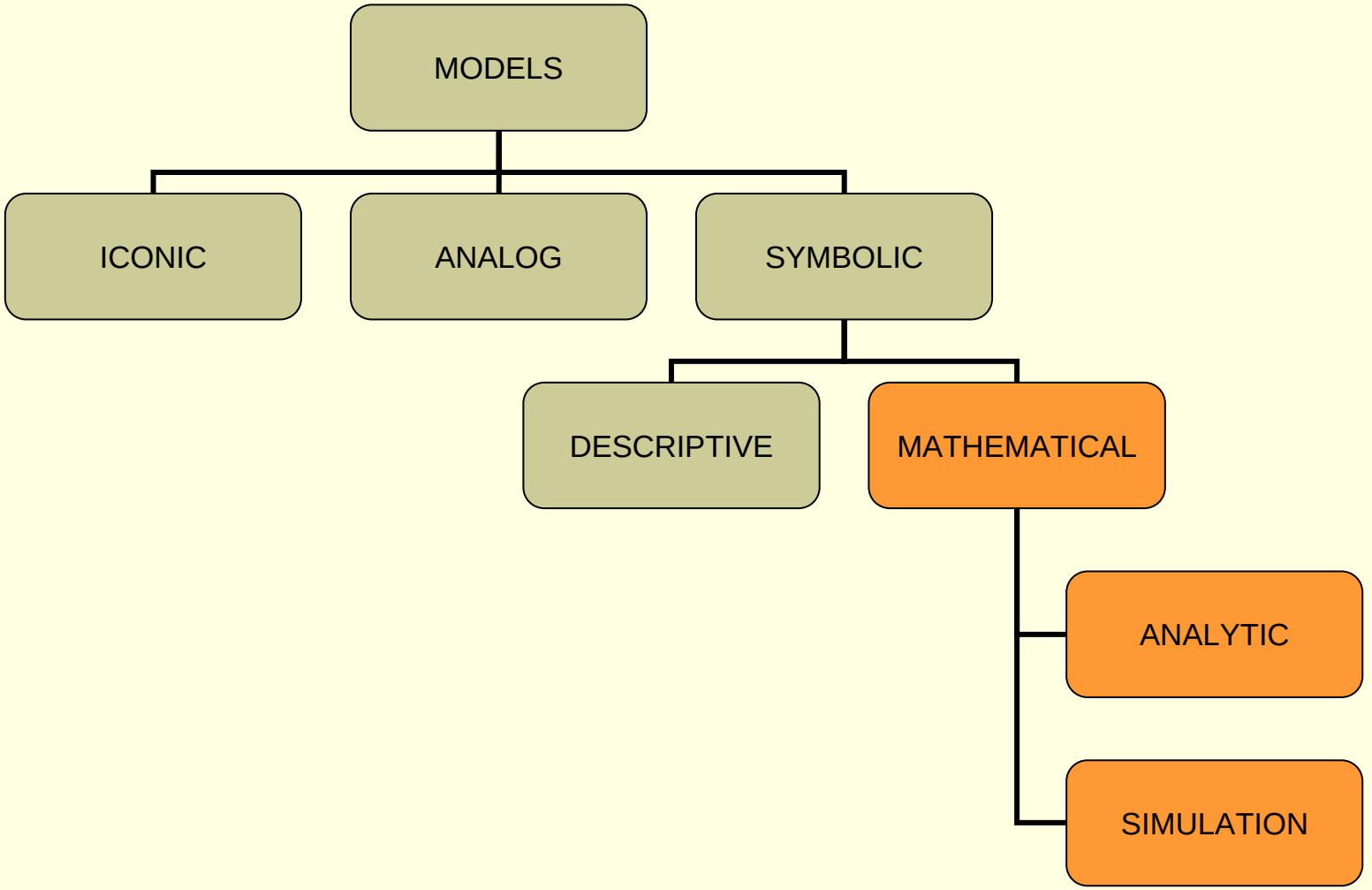
MODEL

- Is a tool for the prediction of future events
- A model is developed to answer specific questions
- As any tool, it gains in usefulness at the expense of generality
- It achieves its ability through the simplicity of representing the most relevant properties while ignoring others judged irrelevant for the task at hand

MODELS

A good model is the simplest one which can still be justified

MODELS


MODELS
ICONIC
ANALOG
SYMBOLIC
DESCRIPTIVE
MATHEMATICAL
ANALYTIC
SIMULATION

MATHEMATICAL MODEL (DECISION)

$$E = f(\tilde{x}, \tilde{y}) \qquad \text{where} \qquad \tilde{x} \in \tilde{X}$$

$\tilde{x}$	decision variables
$\tilde{X}$	possible decisions
E	objetive function
$\tilde{y}$	uncontrolable parameters

SOLUTION

$$E = f\left(\tilde{x}, \tilde{y}\right)$$

Solution: Find $\tilde{x}^*$ such that

$$\mathrm{E}^* = \max_{\tilde{x} \in \tilde{X}} \left\{ f\left(\tilde{x}, \tilde{y}\right) \right\}$$

PROBLEM VIEWS

- Decision maker
  - Content of the problem.
- O.R. analyst
  - Structure of the problem.

PROBLEM STRUCTURE EXAMPLES

- Inventory
- Queuing
- Linear programming
- Dynamic programming
- Stochastic processes
- Search theory
- Games

ANALYTICAL MODEL

- Not always possible to build due to factors like:
  - Complexity of the system
  - Physical size of operation
- No suitable techniques exist for its solution

SIMULATION

- Method of duplicating a real-world operation by other than formal analytic techniques

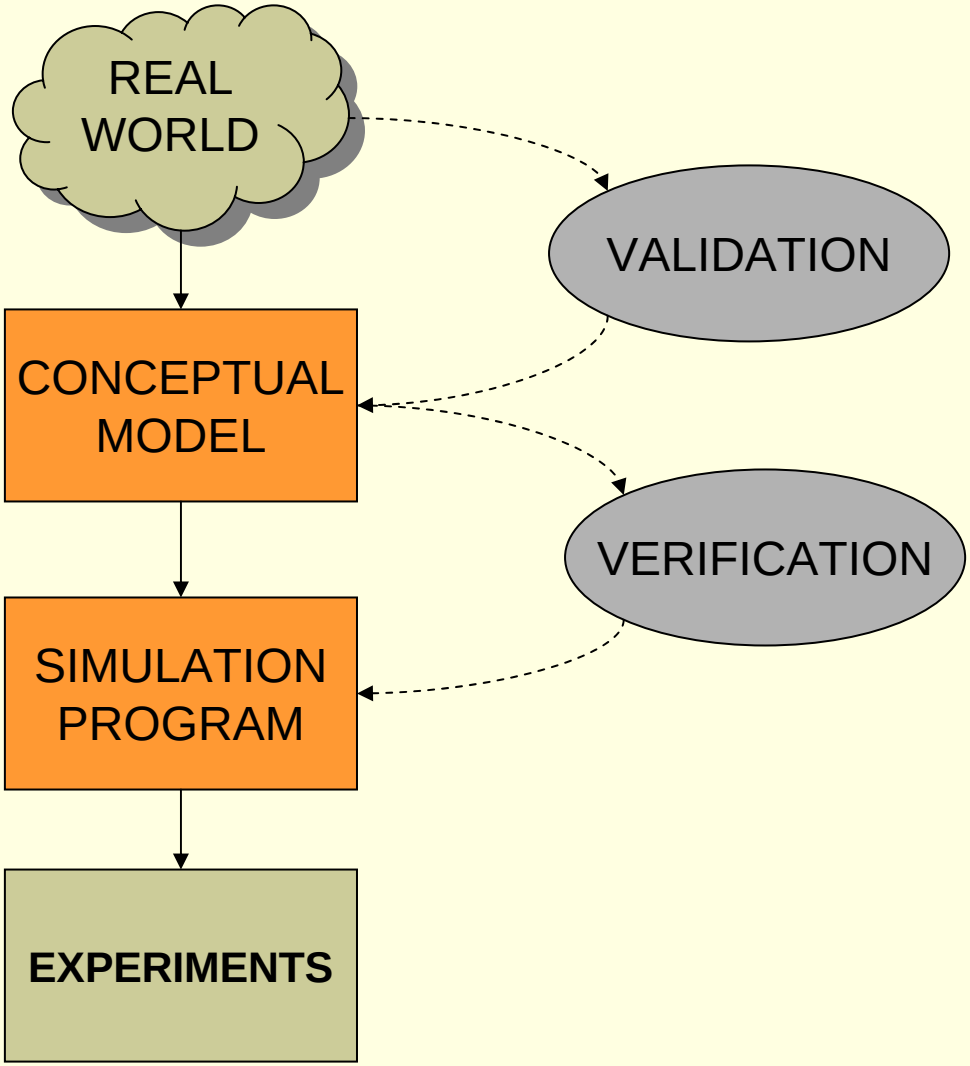
SIMULATION MODEL

- Divides the system into smaller component elements, describable by
  - Analytical methods
  - Probability distributions
- Component predictable behavior for each of the system’s possible states and inputs
- Relationships between components also built into the model

SIMULATION MODELS PURPOSES

- Decision making
  - Usefulness lies in the accuracy of its predictions
- Improved understanding of complex systems
  - The purpose is insight not numbers

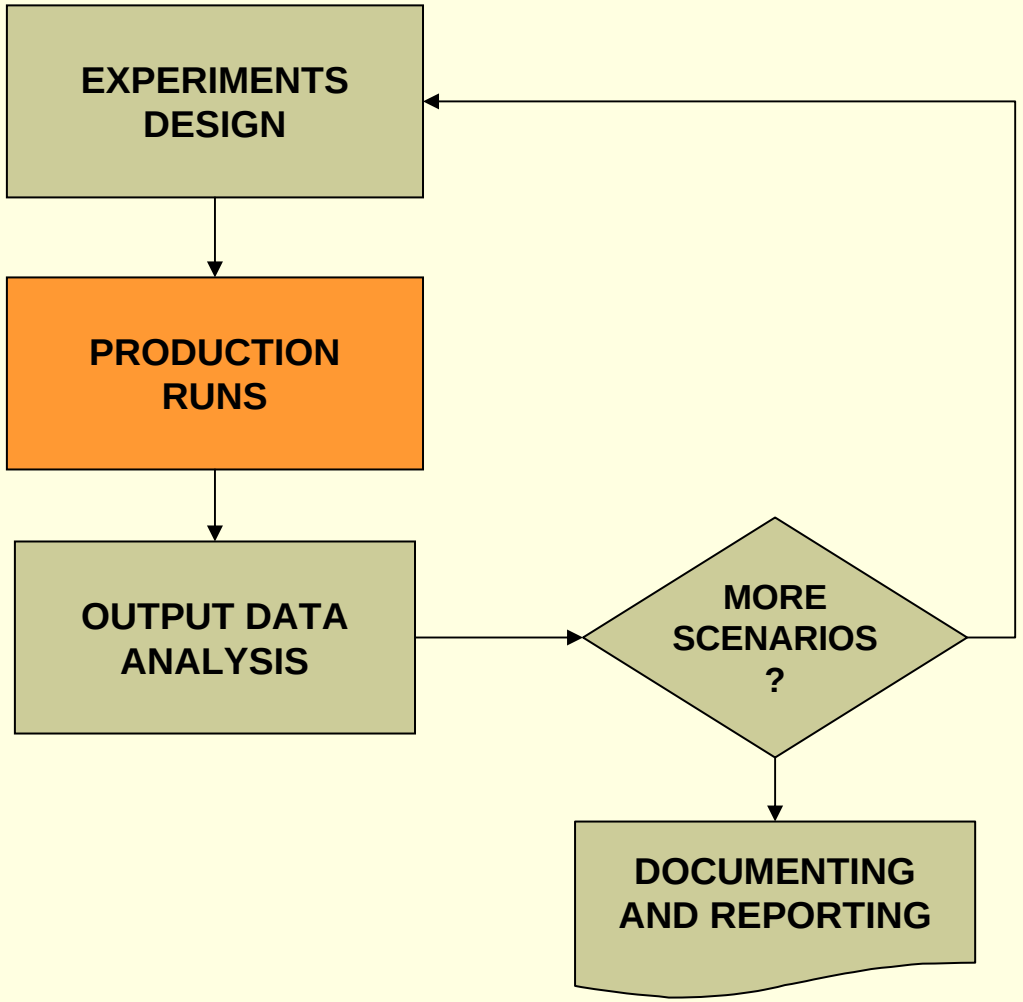
SIMULATION PROJECT



Building the right model

Building the model right

SIMULATION EXPERIMENTS



SIMULATION EXPERIMENTS

- Input data generation
- Activate the model to simulate the real operation
- Record its aggregate behavior
- Repetitions for different alternatives
  - Configurations (system selection)
  - Operating policies (tactics development)
- Select best alternative

SIMULATION MODELS APPLICATIONS

- Explanatory devices
  - To define a system or problem
- Analysis tools
  - To determine critical elements or aspects
- Design support
  - To synthesize and evaluate proposed solutions
- Predictors
  - As aids in the planning of future events

SIMULATION

- Why simulation?
- What have we done?
- What have we learned?

What have we done?

Some examples

HISTORY

- DIRINDESA 1986 – 1992
  - First organization in our Navy specifically commissioned to conduct OR activities
- DIPRIDA 1993
  - Fusion of DIRINDESA and project “Olimpo”

AREAS WHERE DIPRIDA HAS EMPLOYED SIMULATION

- A/S helicopter screens
- Submarine patrol areas
- Air maritime reconnaissance
- Torpedo countermeasures
- Antimissile electronic countermeasures
- Hard kill antimissile defense
- Surface encounters

SIMULATOR SOURCES

- In-house development
- Development under contract
- Off-the-shelf products

SIMULATION PROJECTS

- In-house developments
  - Started with isolated projects by individuals: modelers/programmers/analysts
  - Evolving over the years to a team approach

PROGRAMMING LANGUAGES USED

- BASIC
- FORTAN
- PASCAL
- C
- C++
- VISUAL BASIC
- SLAM
- MODSIM
- JAVA
- POWERBUILDER

EXAMPLES

1. Development of A/S helicopter screens
2. Development of torpedo countermeasures
3. Surface encounter simulation

EXAMPLE 1

Development of A/S helicopter screens

EXAMPLE 1. DESCRIPTION

- Probability of detecting submarines attacking with wire guided torpedoes a naval force in transit.
- Force screened by helicopters, using VDS and sonobuoys.

EXAMPLE 1. CAPABILITIES

- Determination of the TDZ for wire guided torpedoes
- Submarine approach to the TDZ
- Helicopter search patterns
- Submarine detection by active and passive sonar

EXAMPLE 1. DEVELOPMENT

- Initial version of the simulation model developed under contract with external source
- Later modifications of the programs with in house resources
- Exercises at sea to characterize helicopter pilots behavior and validate predicted detection ranges for VDS
- Exercises using CENTARM Tactical Simulator to characterize submarine human component

EXAMPLE 1. PRODUCT

- Development of helicopter A/S screens
- General recommendations for submarines on the conduct of their attacks

EXAMPLE 1. EXPERIENCES

- Integrating the results of computer simulation with real exercises and simulation with human intervention
- Inconvenience of development using external sources with fixed contracts

EXAMPLE 2

Development of torpedo countermeasures

EXAMPLE 2. DESCRIPTION

- Homing acoustic torpedo attacking a surface vessel
- Detection of torpedo by ship
- Decoy countermeasures
- Evasive actions by attacked ship

EXAMPLE 2. CAPABILITIES

- Torpedo dynamics
- Torpedo passive sonar detection of surface ship
- Torpedo search, attack and re-attack logic
- Detection of torpedo by ship´s sonar, hull mounted or towed array
- Towed, floating and autonomous acoustic decoys

EXAMPLE 2. MODES OF OPERATION

- Animation
  - Graphic presentation of single run, showing trajectories and logic states
  - Availability of detailed variables and logical states for any instant of the run
- Montecarlo
  - Multiple runs with random variation of specific parameters
  - Statistical measures of results

EXAMPLE 2. DEVELOPMENT

- One simulator (A), developed in-house, for a specific torpedo
- A second simulator (B), obtained off the shelf, with configurable torpedo parameters and logic

EXAMPLE 2. PRODUCT

- Development of anti-torpedo tactics
- Evaluation of new acoustic countermeasure devices
- Evaluation of new torpedoes

EXAMPLE 2. EXPERIENCES

SIMULATOR ‘A’	SIMULATOR ‘B’
Only for a specific torpedo	Useful for different torpedoes
The simulated logic is identical to the real logic	The logic of a particular torpedo can be represented only approximately
Possibility of changing and improving the model and software	Not modifiable by user organization
Detailed knowledge of the conceptual models used for torpedo, ship, sensors, decoys and environment	Only superficial knowledge of the models involved

EXAMPLE 3

Surface encounter simulation

EXAMPLE 3. DESCRIPTION

- Transit and encounter of two surface forces in open sea.
- Evaluates the contribution of weapon systems and defenses to the global effectiveness.
- Detailed modeling of space-time relationships.
- Threat evaluation and weapons assignment.
- Simple models for the sensors and weapons interactions, calibrated using the results of other simulators, specific to each system.

EXAMPLE 3. CAPABILITIES

- Detection by ships, airplanes and submarine radars
- Air maritime search plans
- Air attacks by land based planes
- Submarine attacks against surface units
- Sonar detection and A/S screens effectiveness
- Torpedo countermeasures effects
- Antimissile electronic countermeasures effects
- Antimissile hard kill and A/A defense systems
- Missile attacks against surface units from ships and helicopters

EXAMPLE 3.DEVELOPMENT

- In house development
- MODSIM language
- Conceptual modeling
  - 2 analysts for approximately 1 year
  - Supported by a panel of officers with operational expertise in the different fields of naval warfare
- Programming
  - 3 programmers for approximately 3 years
- Testing
  - 2 analysts

EXAMPLE 3. PRODUCT

- Extensive use in support of fleet renewal and upgrading programs
- Ammunition allocation studies

EXAMPLE 3. INPUT DATA

- Data collection for platforms and systems characterization took 3-4 months to a team of 5 naval officers.
- Stored using spreadsheets in multiple files
- Administration and maintenance of data is cumbersome

EXAMPLE 3. VERIFICATION

- Tests runs using special scenarios with predetermined outcomes
- Check for expected interactions

EXAMPLE 3. EXPERIENCES

- Most difficult parts to model were those related with the human decisional component
- Input data should be traceable
- Input data should be handled by an DBMS
- Difficult verification and validation due to the type of output available (events log)

SIMULATION

- Why simulation?
- What have we done?
- What have we learned?

What have we learned?

- Simulation project management
- Modeling process
- Simulator as a system

SIMULATOR SOURCE

- Sources
  - In-house development
    - Time
    - Resources
    - Insight
  - External, made to order
    - Learning curve
    - Price
    - Contracting
  - External, off-the-shelf
    - Availability
    - Fidelity

SIMULATION PROJECT

- Internal development
  - Single person versus team
  - Minimum team:
    - Full time: modeler, programmer (core), and programmer (support).
    - Part time: analyst (tests)
      - Different person

MODELING PROCESS

Problem : Access to information

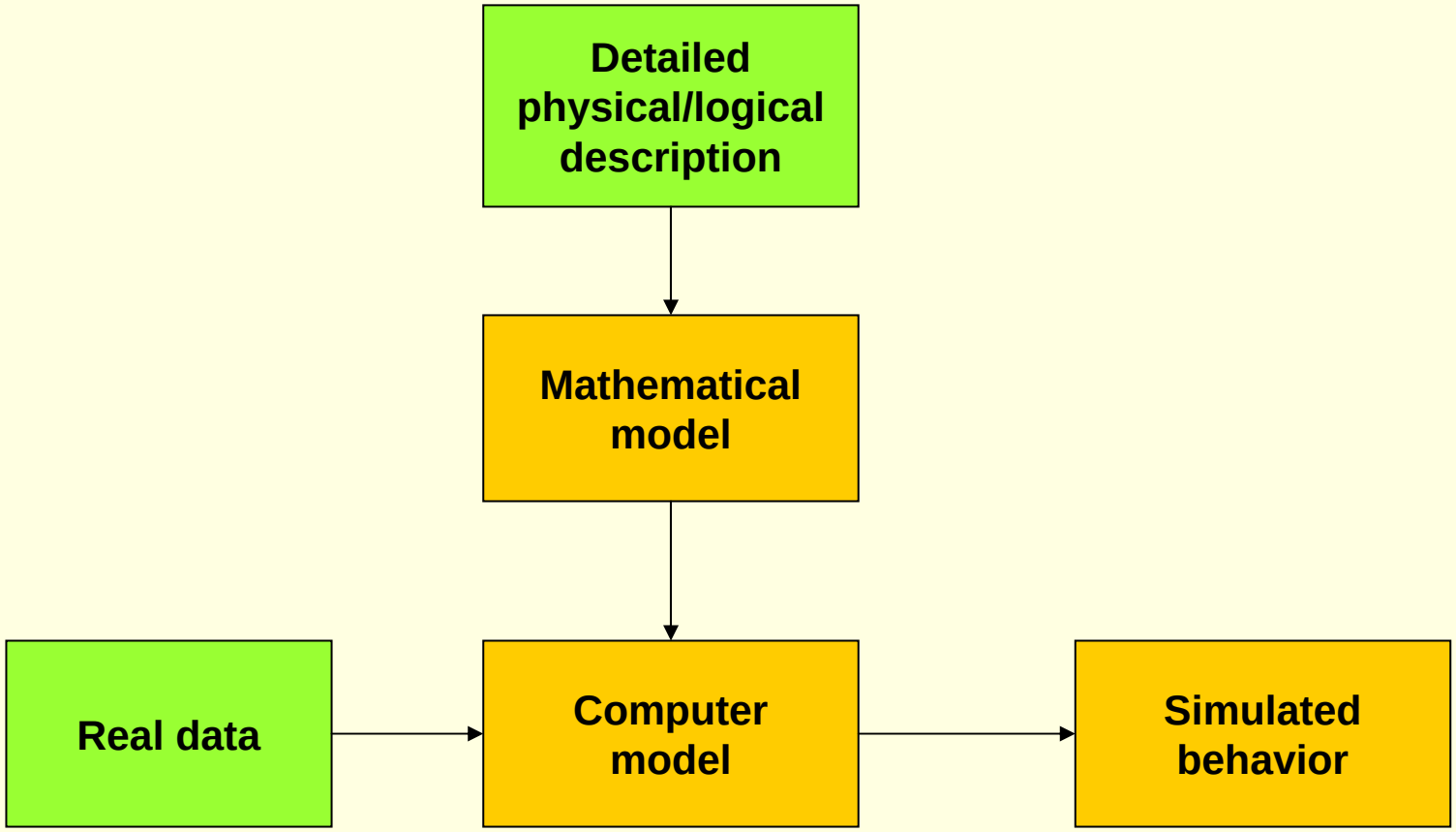
Modeling a system whose logic is only partially known.

- Threat
- Owned system, but incomplete information available
- Non-existent

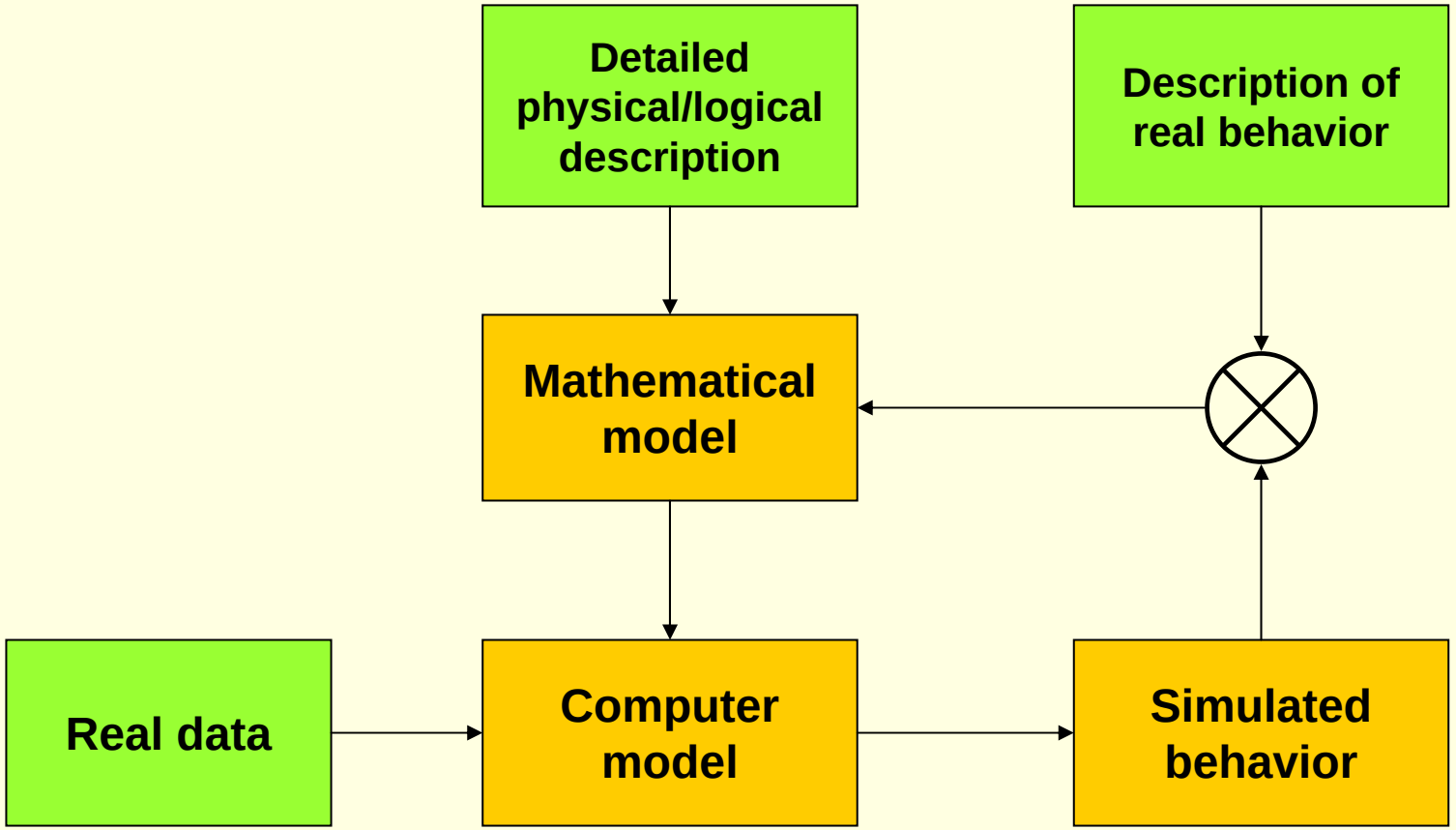
MODELING PROCESS

- DIRECT
  - All information on the system is available or obtainable
- INDIRECT
  - Information only partially available and obtainable

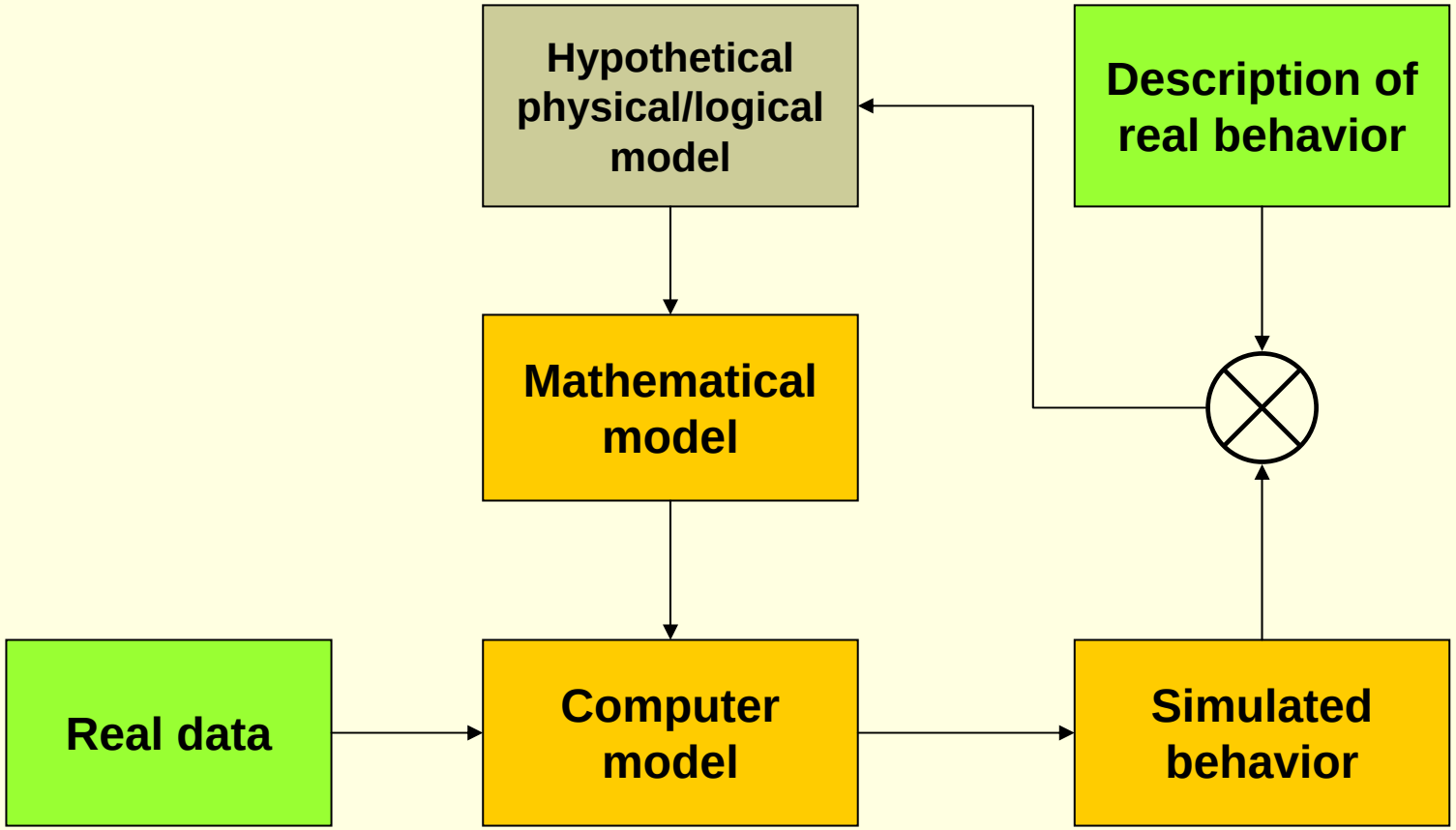
DIRECT MODELING



DIRECT MODELLING. VALIDATION



INDIRECT MODELING



INDIRECT MODELING PROCESS

- Perform experiments with the model
- Initial simple model
- Gradual building up of the model
- Tool for the development of the model
- Guide the search for more information on the behavior and physical details of the system under study

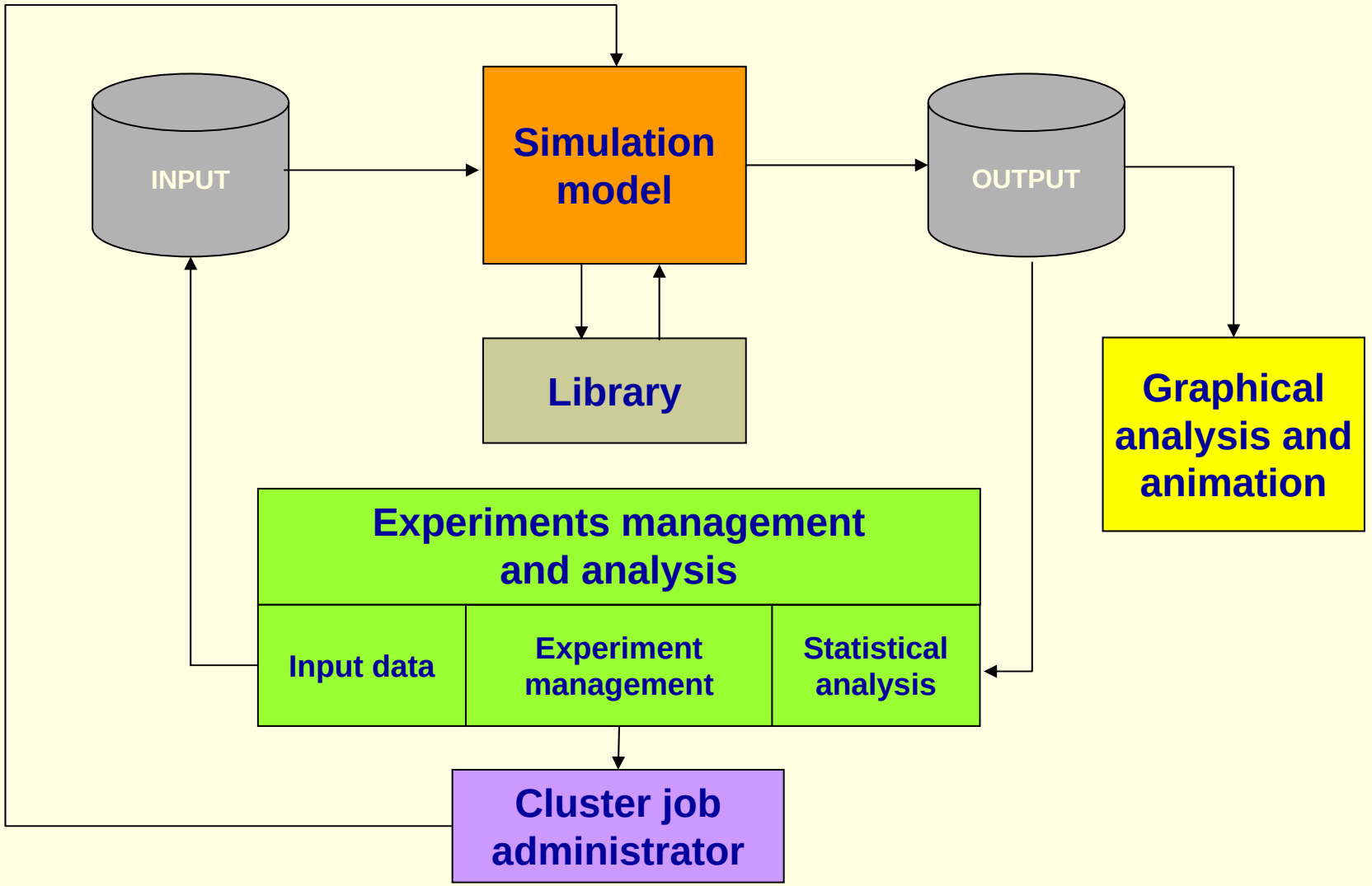
SIMULATOR SYSTEM REQUIREMENTS

- User (analyst) needs
  - Design, conduct and analyze experiments
- Programmer / Maintainer needs
  - Changing and upgrading the code
- Modeler needs
  - Developing and improving the model

SIMULATION SYSTEM REQUIREMENTS

- Component reutilization
- Ease of experiments management
- Detailed output of many variables for each instant of any run
- Handle large amounts of data
- Graphical tools for the presentation and analysis of individual runs results

GENERAL SIMULATION SYSTEM



SUMMARY

- DIPRIDA has an accumulated experience in simulation of more than 20 years
- Important decisions on fleet and weapon systems renewal and upgrading have been supported by simulation projects.
- Many tactical procedures in use today by the fleet have been based on simulation studies.
- A systems approach to simulation has been developed by the organization