Mastering Complexity and Uncertainties with Systemic Digital Twins

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Systemic Digital Twins
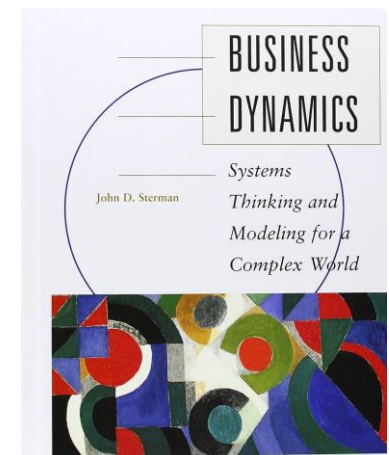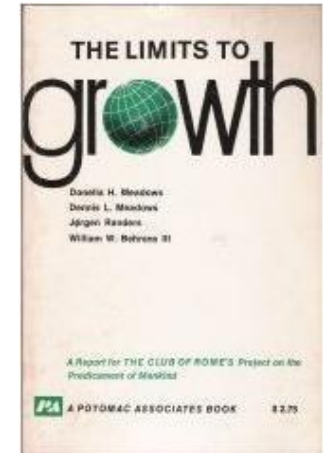
Systems of interest:

- Industrial technical and socio-technical systems
- Design and operations

Perimeter:

- Data related to the system under study,
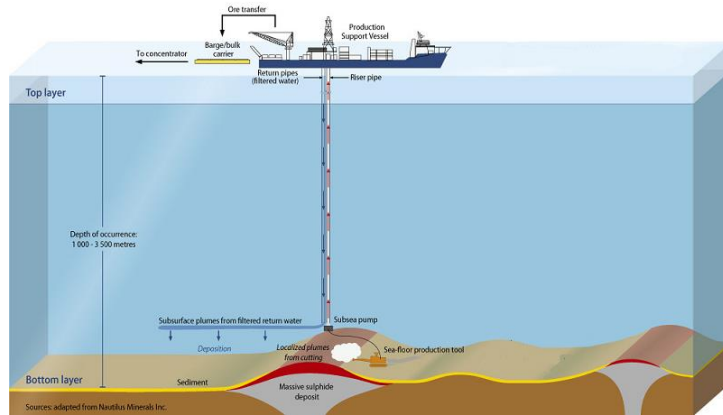- Models that represent its behavior, and
- Computerized simulations.

Objective:

- Assess complexity and uncertainties.
- Make systems robust, resilient, sustainable and profitable.

Subsea Mining

Collecting polymetallic nodes on the seabed of the Norwegian continual shelf.

A holistic problem:
- Technical choices
- Field data
- Economical data
- Regulations

Key performance indicators to be assessed in the different scenarios:
- Annual production of ore
- Energy consumption / economical viability
- Waste disposal
- Safety

Three Key Rules

Rule 1:

Models are design for specific purposes, at a specific level of abstraction, in dedicated modeling environments, by dedicated teams, at specific paces.
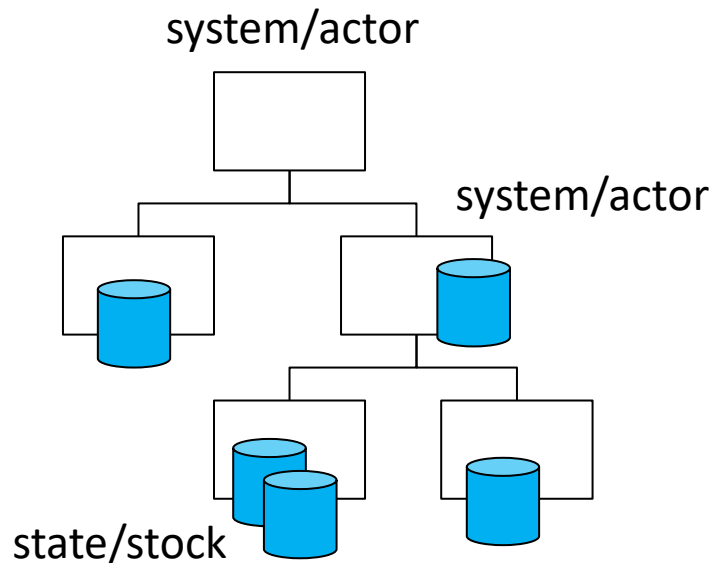
Rule 2:

Behavioral models rely heavily on operational data.

Rule 3:

Computerized simulations require well-defined mathematical frameworks.

Behavioral models must be written in formal modeling languages.
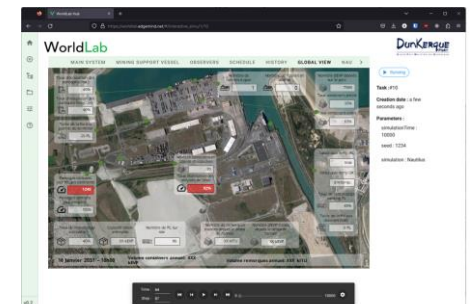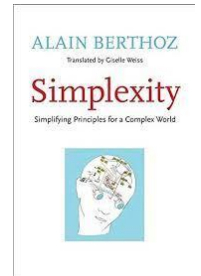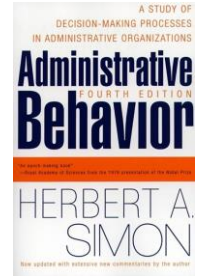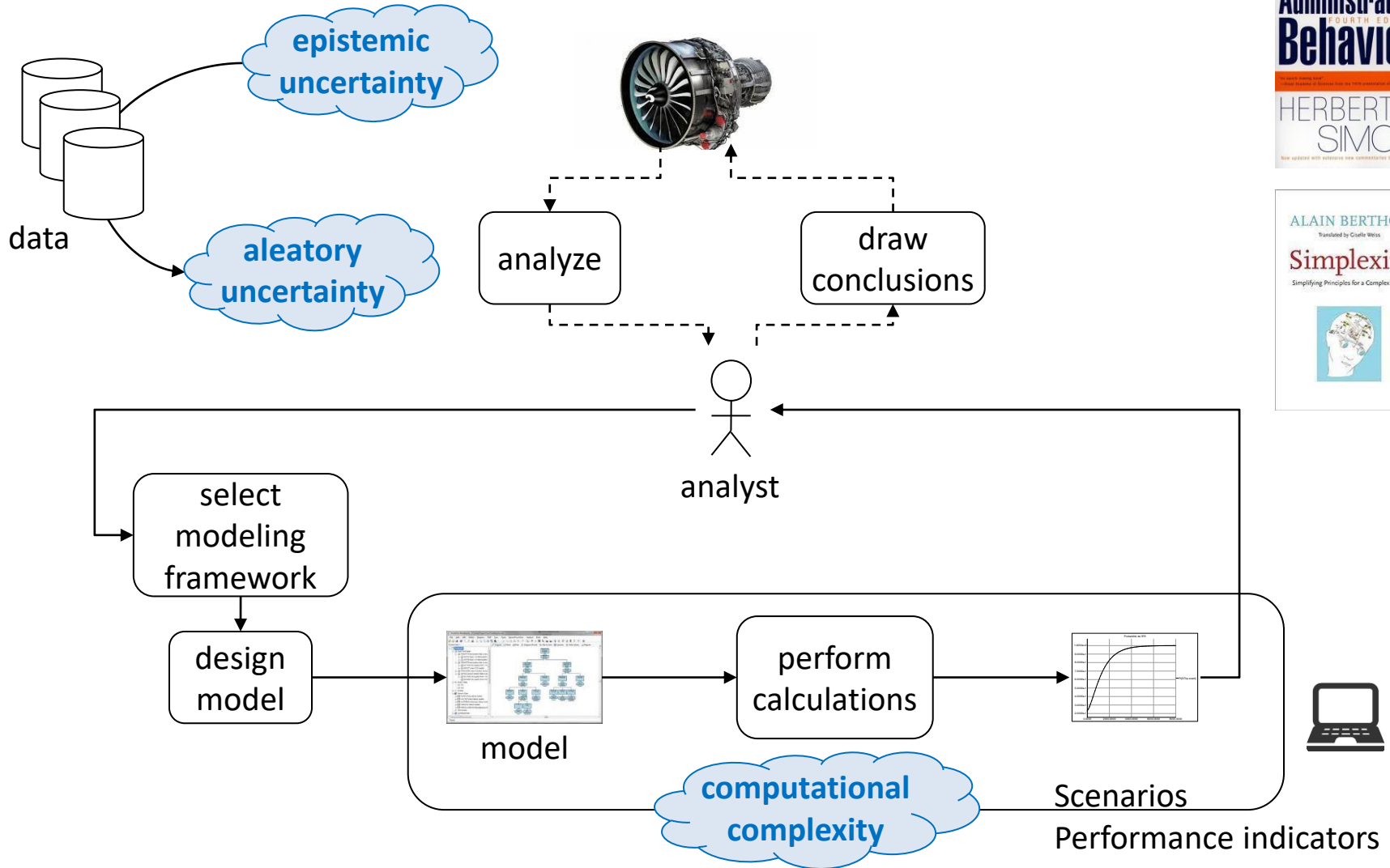
The Sigma Modeling Framework

system/actor

system/actor

state/stock

Activities

trigger
action at start
action at completion
duration

- **Sigma**: Formal language (S2ML+X)
- **Sigma Workshop**: Integrated Modeling Environment
- **WorldLab**: Collaborative pragmatic proof manager

Handling Uncertainties

data

epistemic uncertainty

aleatory uncertainty

analyze

draw conclusions

analyst

select modeling framework

design model

model

perform calculations

computational complexity

Scenarios

Performance indicators

Conclusion

Behavioral modeling of systems is an emerging domain/discipline at the confluence of several well-established disciplines:

- Mathematical Logic
- Theoretical computer science
- Software engineering
- Data science

- System and business dynamics
- Systems engineering
- Management sciences
- Cognitive sciences

Systemic digital twins are a new technology that:

- Relies on strong scientific foundations
- Support management decisions