Welcome to the Webinar – if you have not dialed into the audio portion, please do so now. In the U.S., dial 1-855-747-8824, passcode **4348124177**. If you are outside the U.S., the webinar invitation includes a list of toll-free numbers for different countries. Please note that your phone is automatically on mute when you join to avoid disturbing other participants.

INCOSE Webinar Series

Wednesday 16 December 2015

Object-Process Methodology – the new ISO 19450 Standard: Principles and MBSE Applications

Professor Dov Dori
Faculty of Industrial Engineering and Management, Technion, Israel Institute of Technology

INCOSE
International Council on Systems Engineering

Exponentially Increasing man-portable air-defense systems (MANPADs) threat

MANPADs have become <u>the</u> major threat to airborne platforms

ELBIT's MUSIC Systems

Helicopters & Small-Medium Aircraft

MUSIC®

Mini-MUSIC™

The MUSIC system Jams the missile seeker with a powerful laser system, providing protection solutions for all types aircrafts.

MITsdm system design and management

Uzi Orion, Chief Systems Engineer, Elbit Systems:

"במהלך פיתוח מערכת להגנת נוסעים מפני טילי כתף (MUSIC) נמצא צורך במידול המערכת בשלמותה. שפת המידול והמתודולוגיה שנבחרה היתה OPM, שאפשרה מידול וסימולציה מערכתית של כלל פעילויות המערכת, שהיא מורכבת ודורשת תאום מלא של מספר רב של גורמים. השימוש בתוכנת OPCAT התומכת במידול מבוסס OPM איפשר פיתוח מהיר ואמין מאד של המערכת."

איתי בלומנטל | פורסם: 19:16 , 31.10.15

Dec. 7 2015: OPM is the new ISO Standard

https://www.iso.org/obp/ui/#iso:std:iso:pas:19450:ed-1:v1:en

Online Browsing Platform (OBP) | Sign in | Language | Help | Search

Search | ISO/PAS 19450:2015(en)

ISO/PAS 19450:2015(en) Automation systems and integration — Object-Process Methodology

Buy | Follow | i

Table of contents

Foreword
Introduction
1 Scope
2 Normative references
3 Terms and definitions
4 Symbols
5 Conformance
6 OPM principles and concepts
6.1 OPM modelling principles
6.2 OPM Fundamental concepts
7 OPM thing syntax and semantics

Figures

Tables

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted

OPM is the new ISO Standard

- On December 7, 2015 Object-Process Methodology – OPM, became ISO 19450 standard
  - This is the first conceptual modeling language and model-based systems engineering (MBSE) methodology recognized by ISO
  - The motivation: Making OPM the basis for the next generation of standards
  - The new standards will be OPM model-based, not text-based
  - This will enable their checking for integrity and completeness
  - Work is underway to develop the model-based standard-authoring standard

OPM guiding principle: OCCUM's RAZOR

14th Century logician and Franciscan priest William of Ockham:

"Entities should not be multiplied unnecessarily."
"Entia non sunt multiplicanda praeter necessitatem"

In an extended version:

"If you have two equally likely solutions to a problem, choose the simplest."

OCCUM's RAZOR is an important guiding principle of OPM

Universal Ontology

Ontology: a set of concepts for describing a domain (industry, banking, military, botany, healthcare…) and systems within it.

Universal Ontology: a *domain-independent* set of concepts for describing systems in the universe, both natural and man-made.

Fundamental question 1:

What is needed to describe the universe?

Answer:

Describing the universe requires things and relations among them.

Question 2:

What **is** a thing

or

what can it **do**?

Answer:

A things can either

exist

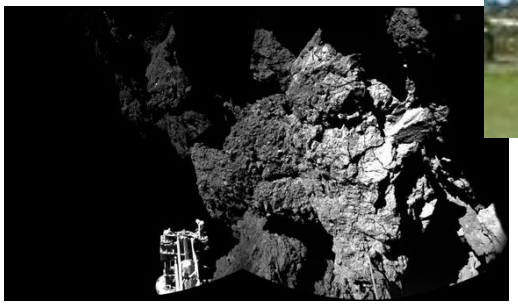
or

happen.

Any thing either **exists** or **happens** – nothing else!

Question 3:

What are the things that *exist* in the world?



Answer:

Objects *exist.*

They are ***static*** *–*

time independent.

Question 4:

What are the things that ***happen*** in the world?

Answer:

Processes *happen.*

*They are **dynamic** –*

time dependent.

Question 5:

How do **objects** and **processes** *relate* to each other?

Answer:

Processes *happen* to **objects.**

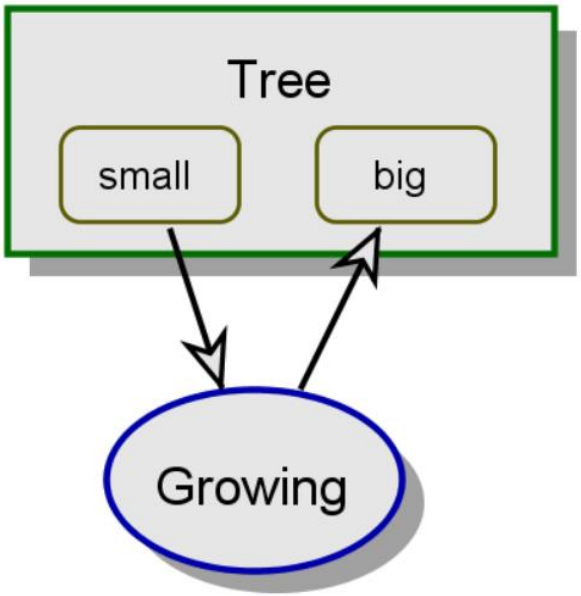
Question 6:

What does a **process** do when it happens to an **object**?

Answer:

The **process** *transforms* the **Object**.

OPM Things: **Objects** and **Processes**

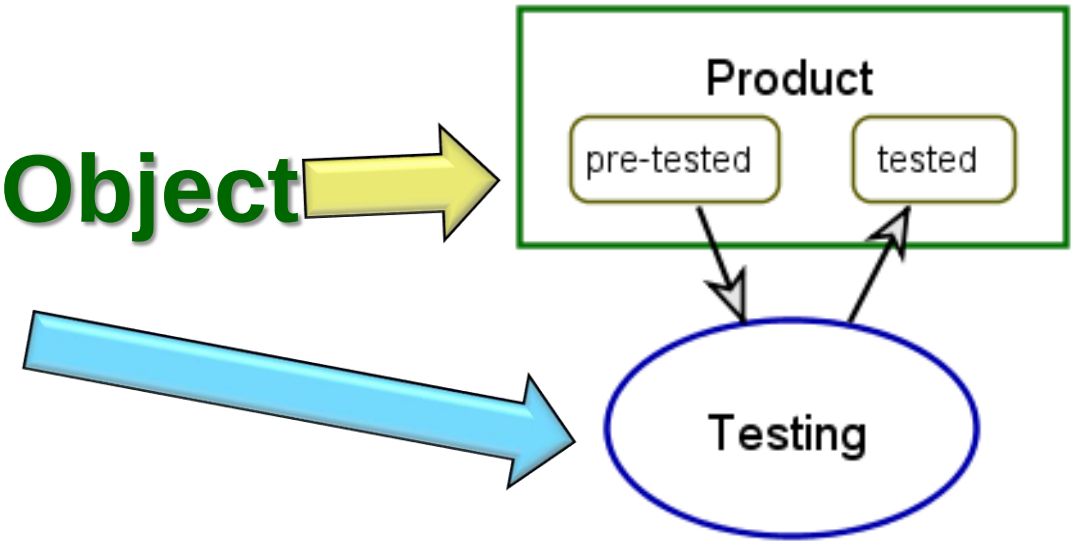


Object: A thing that exists or might exist physically or informatically.

Process: A thing that transforms one or more objects.

OPM's only two building blocks:

1. **Stateful Object**
2. **Process**



All the other elements are **relations** between things, expressed graphically as **links**.

processes *transform* objects.

Question 7:

How does a process ***transform*** an object?

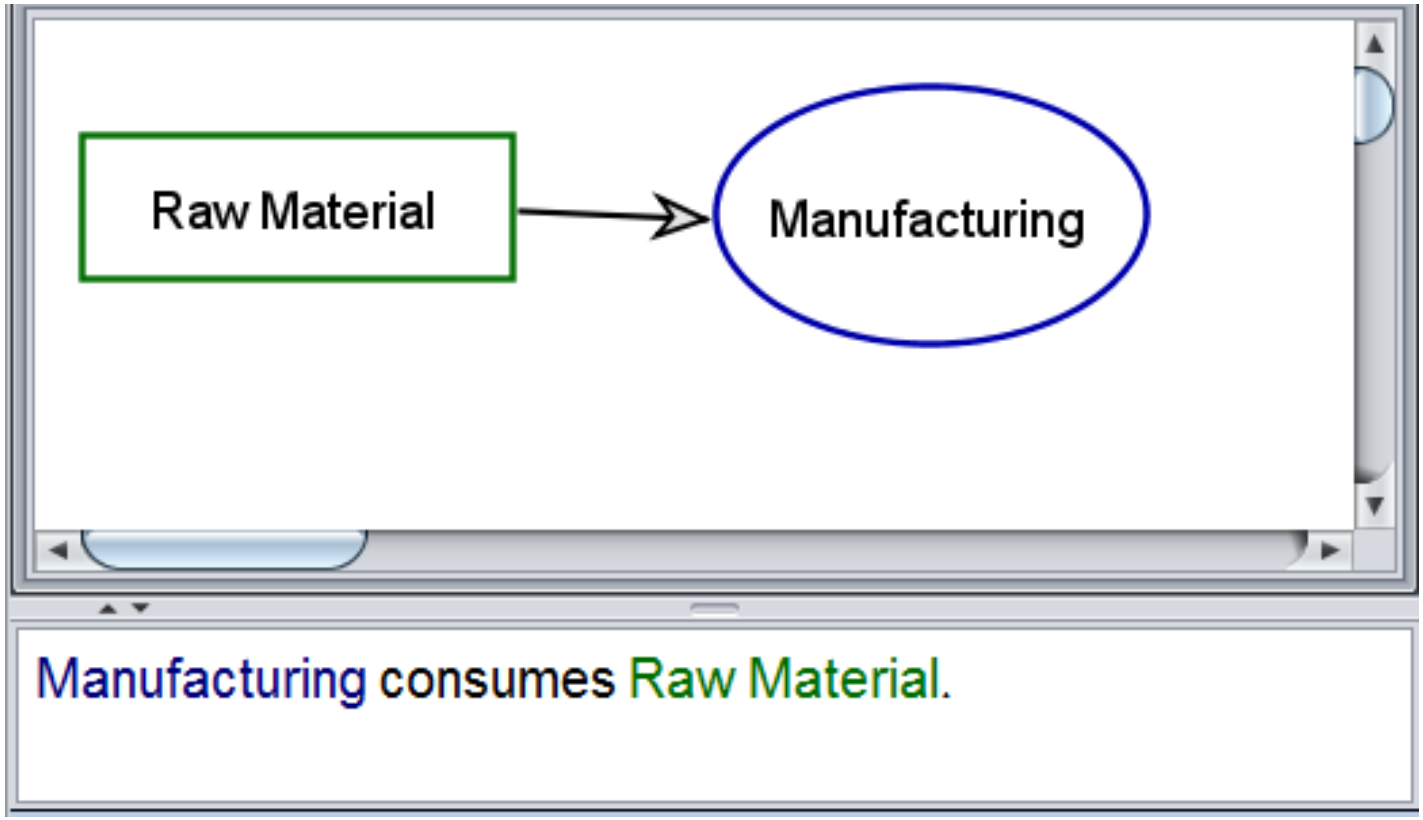
Answer:

Transforming means

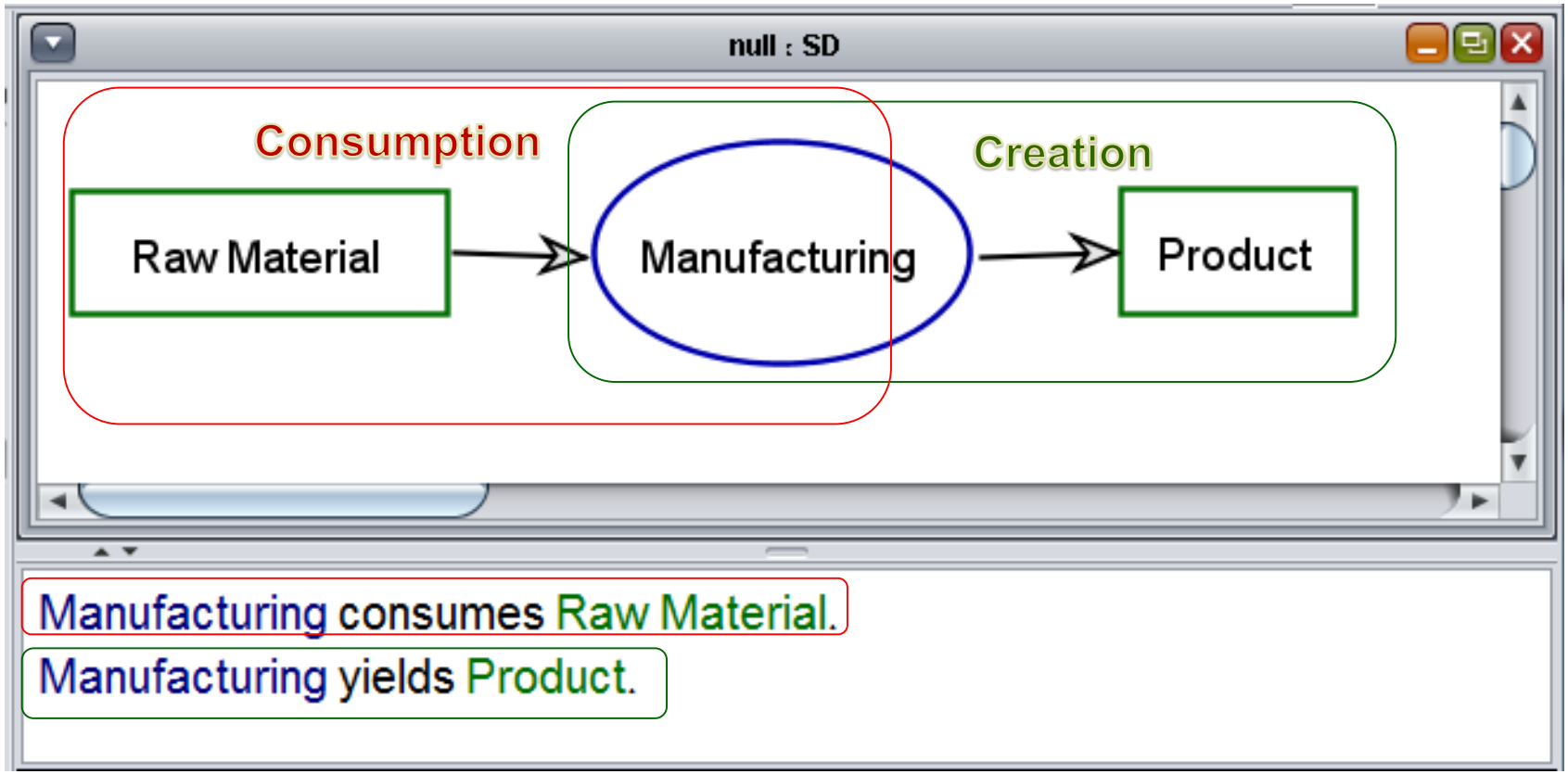
1. *creating* an object *or*
2. *destroying* an object *or*
3. *affecting* an object.

Transforming an object by a process can be done in three ways

(1) Process consumes the object



(2) Process creates the object



Processes affect **objects.**

Question 8:

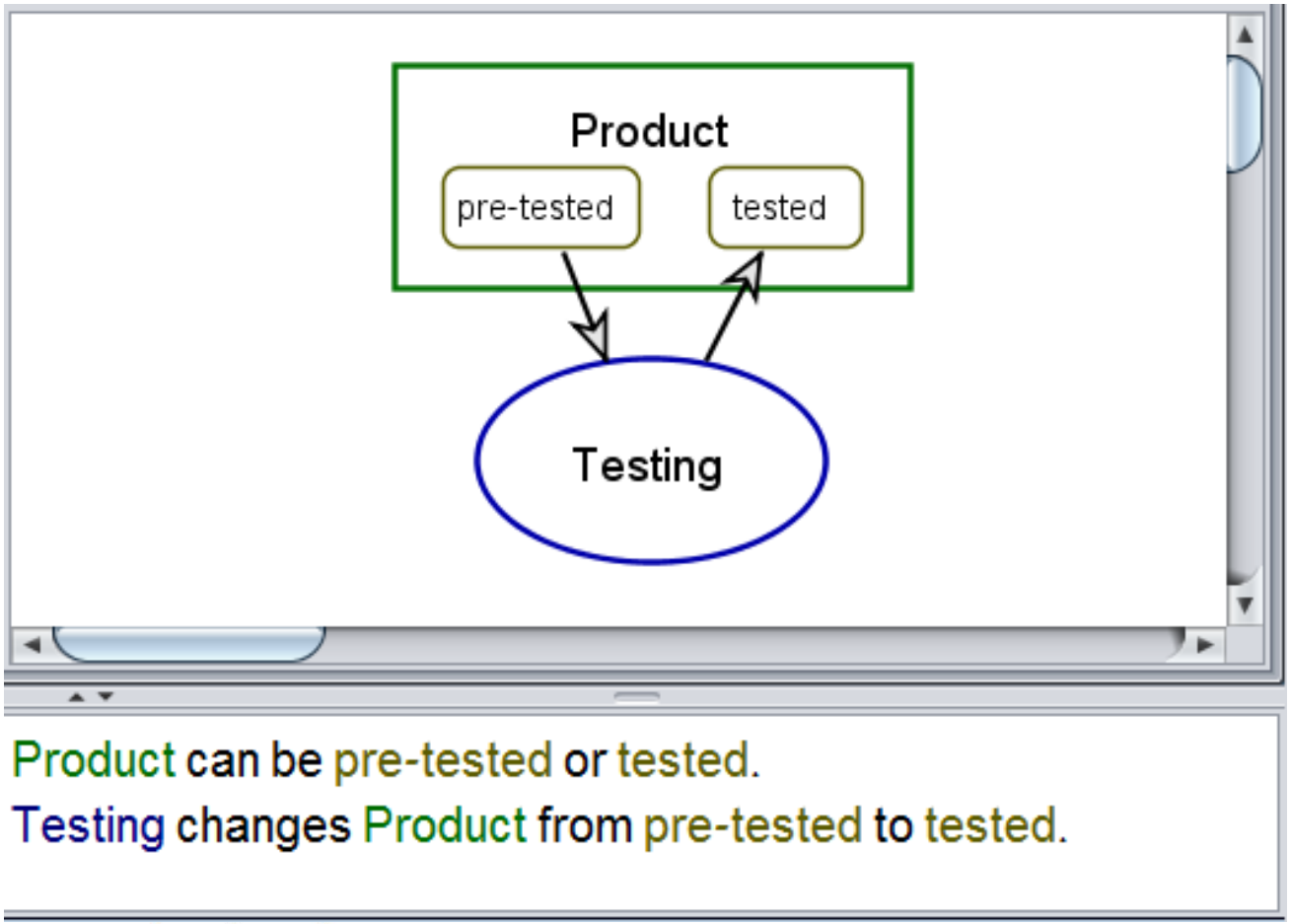
How does a process ***affect*** an object?

Answer:

- *A* **process** *affects* an **object** *by changing its* **state.**
  - *Hence,* **objects** *must be* **stateful** *– they must have* **states.**

The third and last kind of object transformation:

(3) Process affects object by changing the object's state:



The three transformation kinds

Consumption:

Germinating consumes Seed.

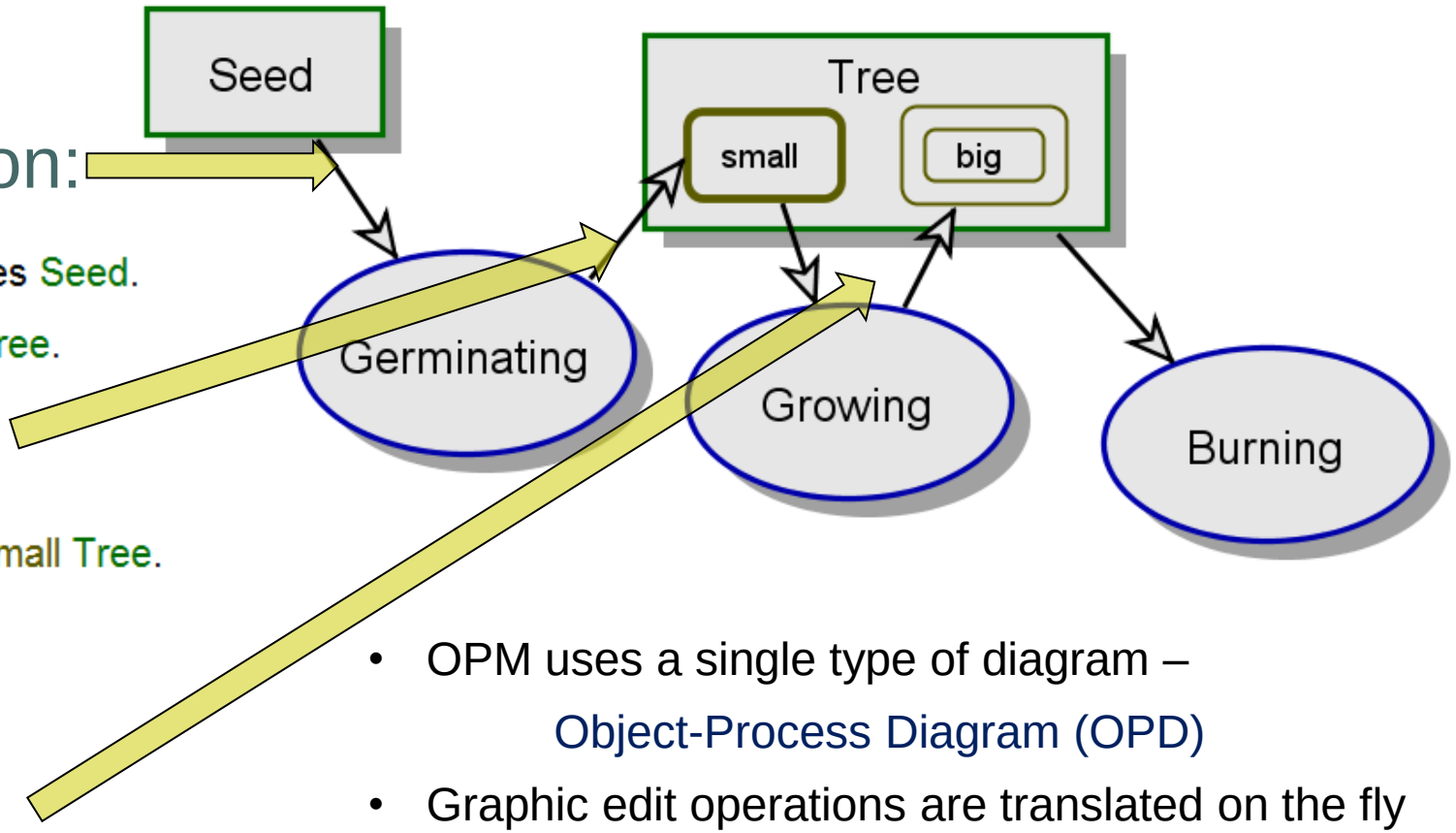
Burning consumes Tree.

Creation:

Germinating yields small Tree.

State Change:

Growing changes Tree from small to big.

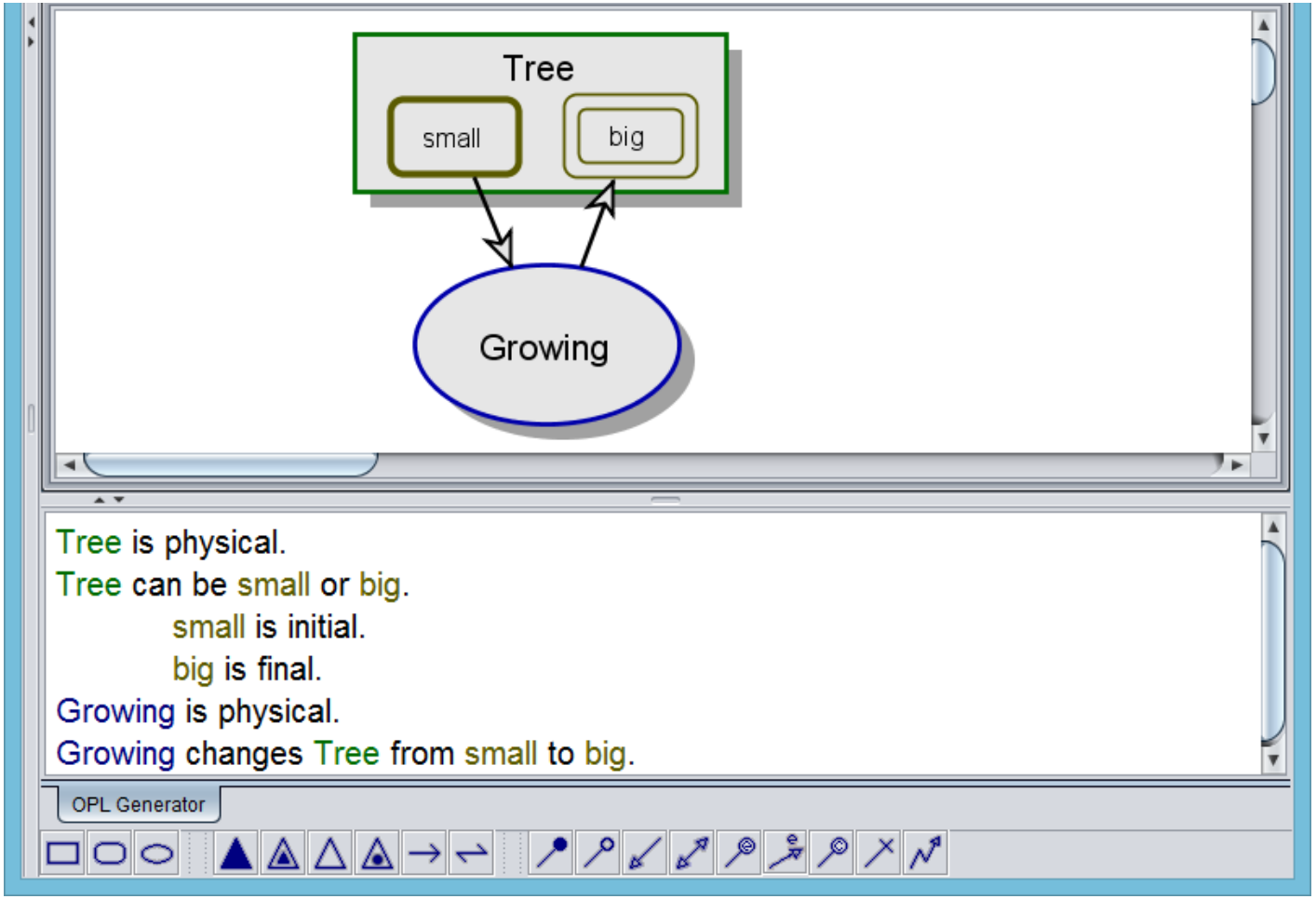


- OPM uses a single type of diagram –
  Object-Process Diagram (OPD)
- Graphic edit operations are translated on the fly to natural language –
  Object-Process Language (OPL)
- Catering to dual channel processing

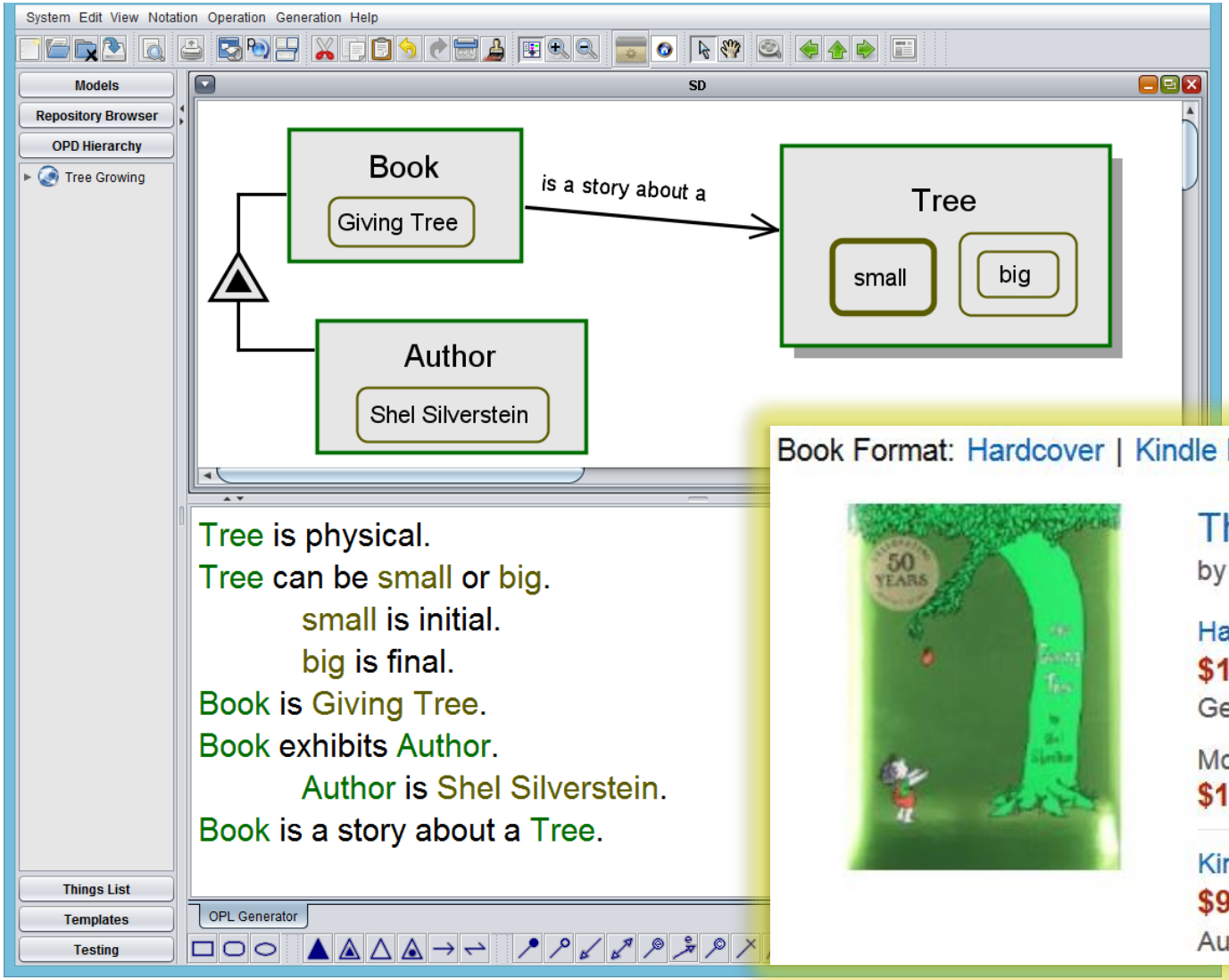
The graphics-text equivalence OPM principle

Any model fact expressed graphically in an OPD is also expressed textually in the corresponding OPL paragraph.

Caters to the dual channel cognitive assumption (Mayer, 2010)



Physical vs. Informatical Things



OPCAT – downloadable free from http://esml.iem.technion.ac.il/

Question 9: What are the two major aspects of any system?

- ***Structure*** – the static aspect:
  what the system is made of.
  - *Time-independent*
- ***Behavior*** – the dynamic aspect:
  how the system changes over time.
  - *Time-dependent*

Question 10:
What third aspect is specific to man-made systems?

- ***Function*** – the utilitarian, subjective aspect:
- ***Why*** is the system built?
- For ***whom*** is the system built?
- ***Who*** benefits from operating the system?

OPM Aspect Unification

The three system aspects:

- ***Function*** (***why*** the system is built),
- ***Structure*** (static aspect: ***what*** is the system made of), and
- ***Behavior*** (dynamic aspect: ***how*** the system changes over time)

- Are expressed bi-modally, in graphics and equivalent text
- In a **single** model, using a single diagram kind

The Object-Process Theorem

Stateful objects, **processes**, and relations among them constitute a **necessary** and **sufficient universal ontology.**

1. Theoretical, based on logic

2. Empirical, based on examples

Axiom: Representing a system Σ requires a set of things T and relations among them, R:

$$\mathbf{Rep\ (\Sigma) \rightarrow T \wedge R}$$

(skipping rest of proof)

Empirical Proof of the Object-Process Theorem

If the ontology is universal, it can model systems in any domain.

The empirical proof: Providing evidence of successful models from various, unrelated domains.

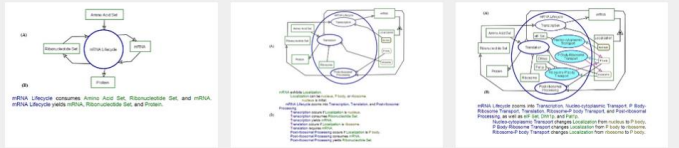
Empirical Proof from Science: Molecular biology

Conceptual Modeling in Systems Biology Fosters Empirical Findings: The mRNA Lifecycle

Dov Dori, Mordechai Choder

Published: September 12, 2007 • DOI: 10.1371/journal.pone.0000872

Figures

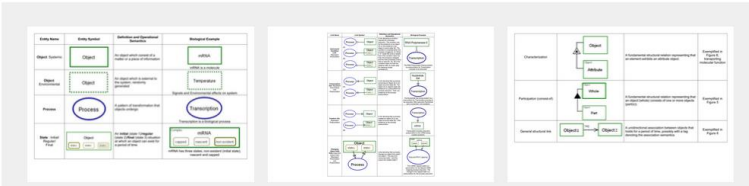


Conceptual Model-Based Systems Biology: Mapping Knowledge and Discovering Gaps in the mRNA Transcription Cycle

Judith Somekh, Mordechai Choder, Dov Dori

Published: December 20, 2012 • DOI: 10.1371/journal.pone.0051430

Figures

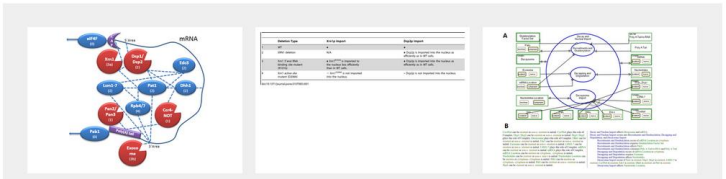


Conceptual Modeling of mRNA Decay Provokes New Hypotheses

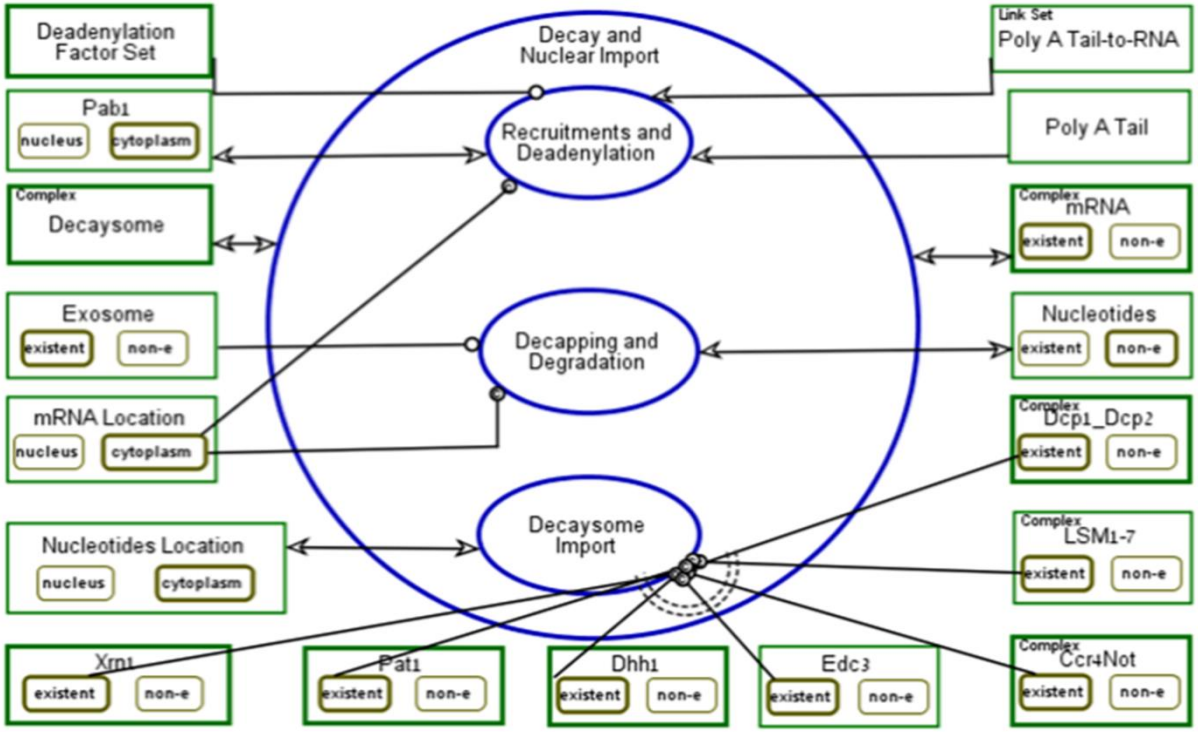
Judith Somekh, Gal Haimovich, Adi Guterman, Dov Dori, Mordechai Choder

Published: September 25, 2014 • DOI: 10.1371/journal.pone.0107085

Figures



A



B

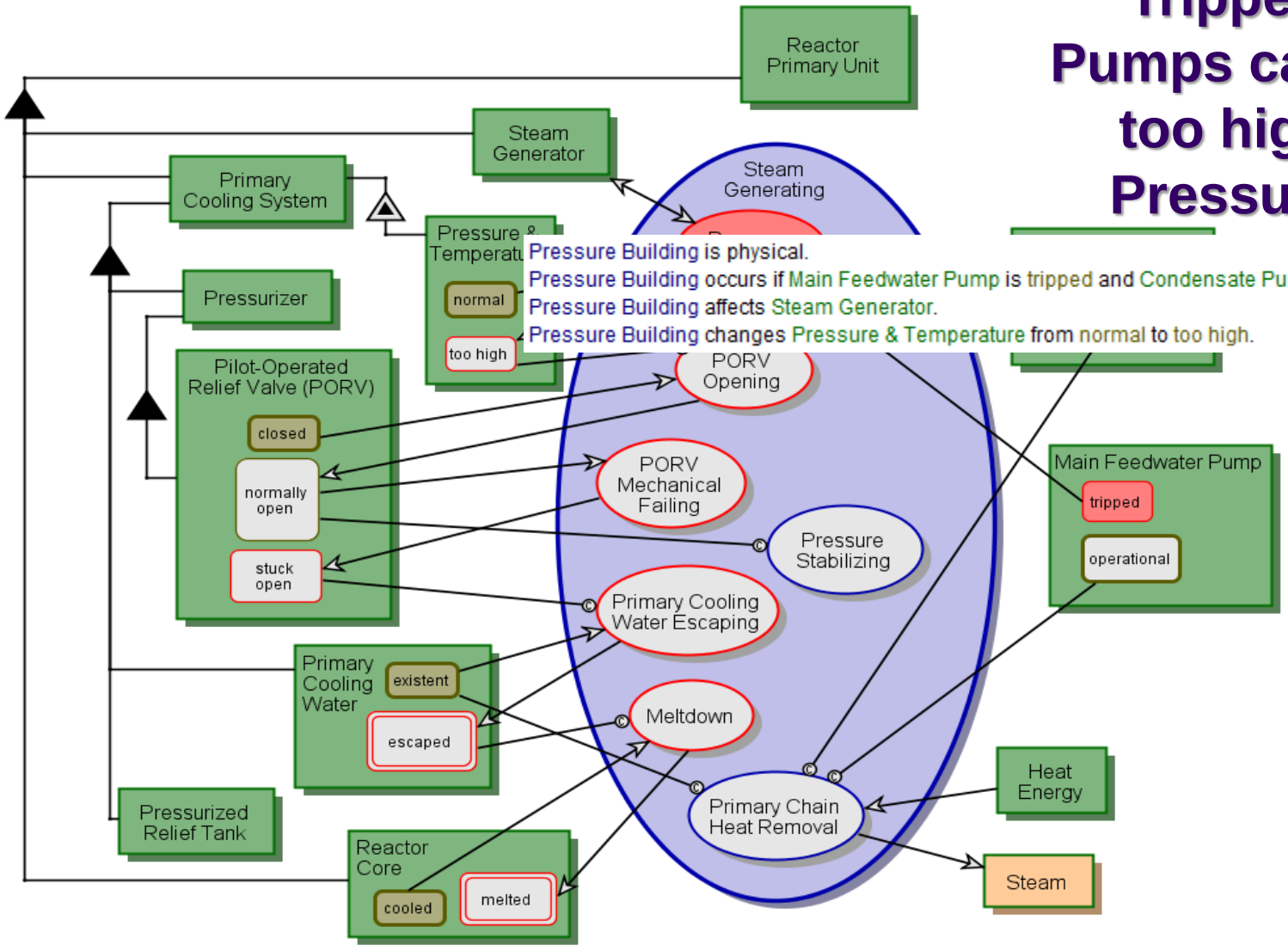
Ccr4Not can be existent or non-e. existent is initial. Ccr4Not plays the role of Complex. Dcp1_Dcp2 can be existent or non-e. existent is initial. Dcp1_Dcp2 plays the role of Complex. Decaysome plays the role of Complex. Dhh1 can be existent or non-e. existent is initial. Edc3 can be existent or non-e. existent is initial. Xrn1 can be existent or non-e. existent is initial. Pat1 can be existent or non-e. existent is initial. Lsm1-7 can be existent or non-e. existent is initial. mRNA can be existent or non-e. existent is initial. Nucleotides can be existent or non-e. existent is initial. mRNA Location can be nucleus or cytoplasm. Nucleotides Location can be nucleus or cytoplasm. Xrn1 can

Decay and Nuclear Import affects Decaysome and mRNA.
Decay and Nuclear Import zooms into Recruitments and Deadenylation, Decapping and Degradation, and Decaysome Import.
Recruitments and Deadenylation occurs if mRNA Location is cytoplasm.

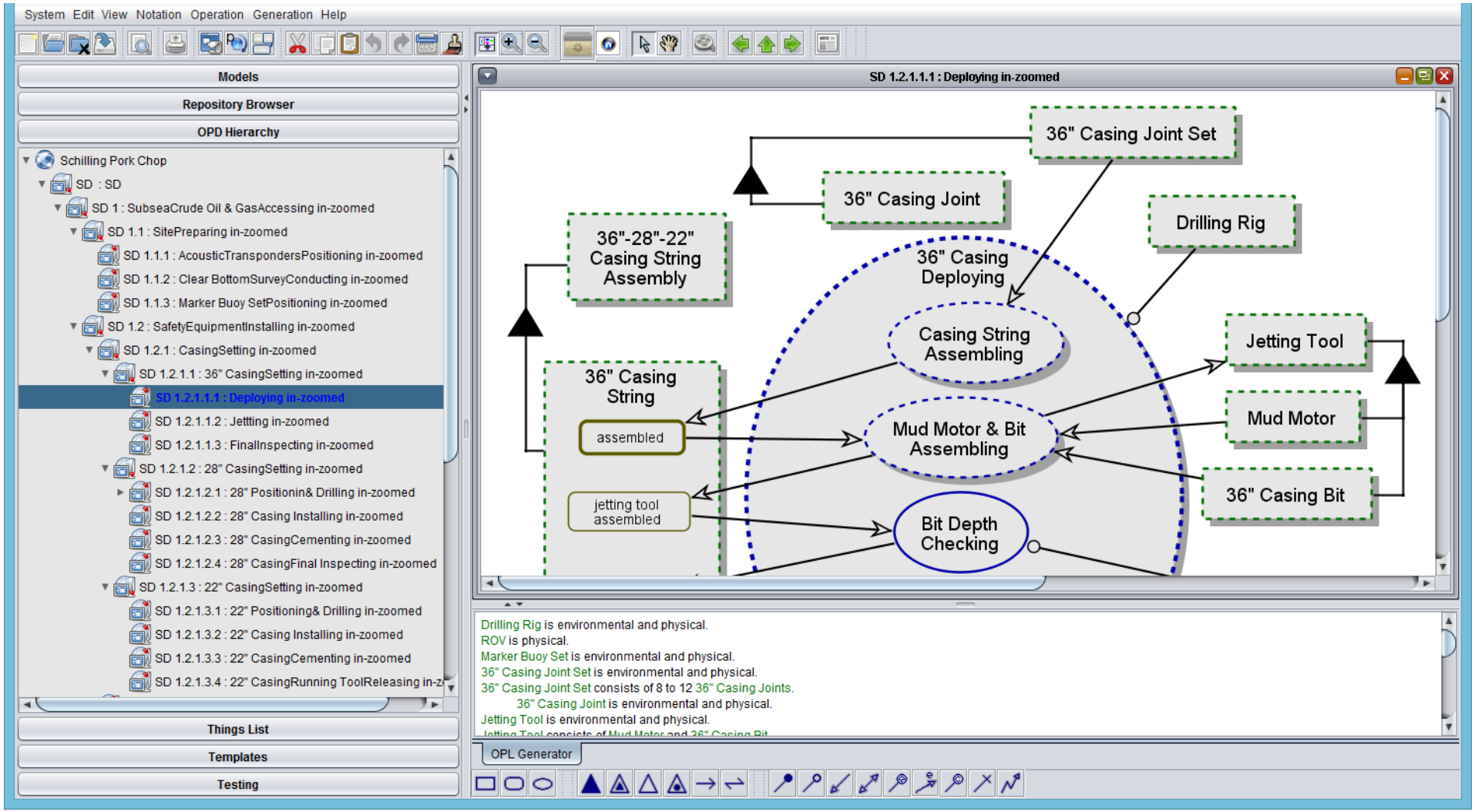
"Beyond the scientific value of these specific findings, this work demonstrates the value of the conceptual model as an in silico vehicle for hypotheses generation and testing, which can reinforce, and often even replace, risky, costlier wet lab experiments."

Nuclear reactor failure: The Three Mile Island Accident

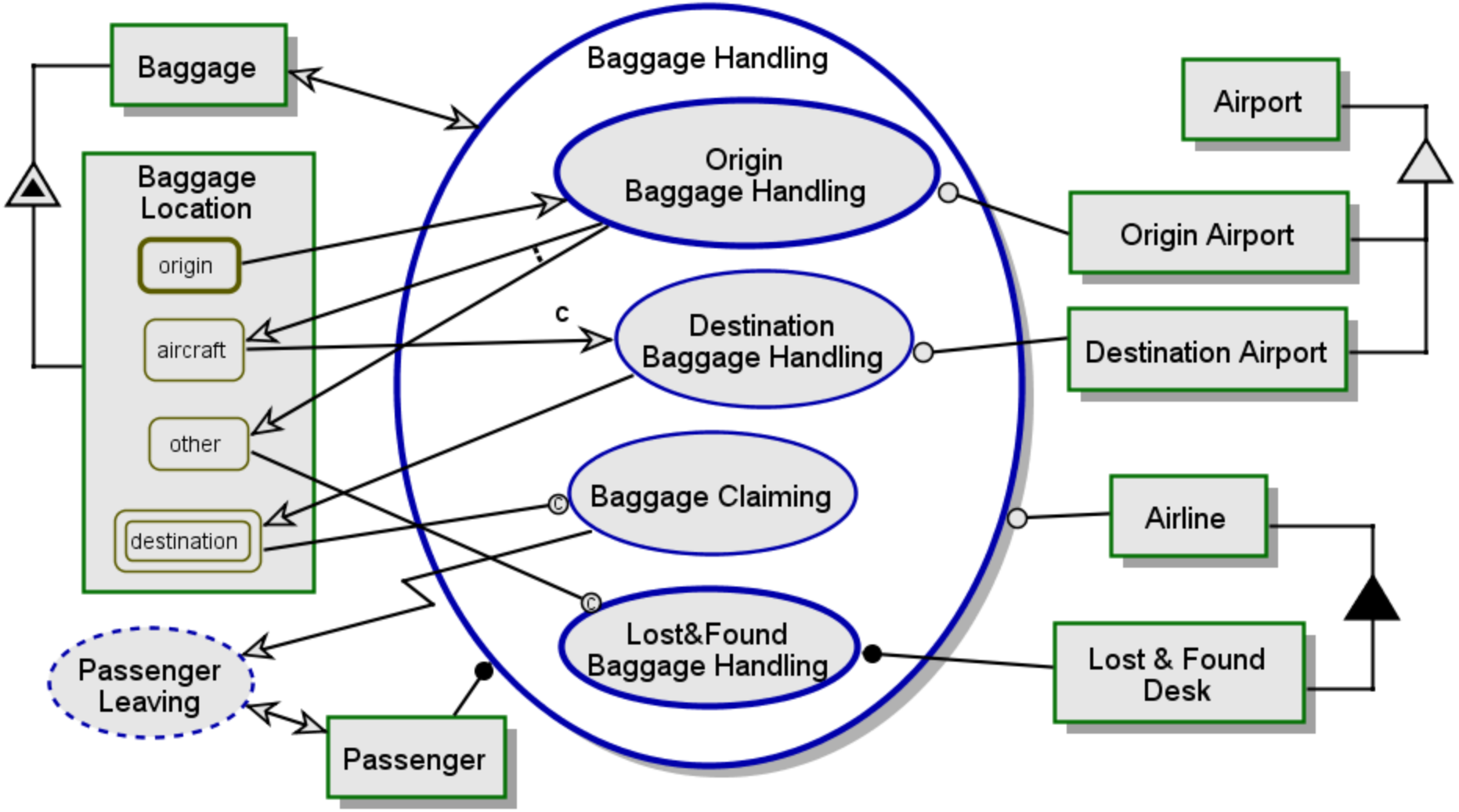
Tripped Pumps cause too high Pressure



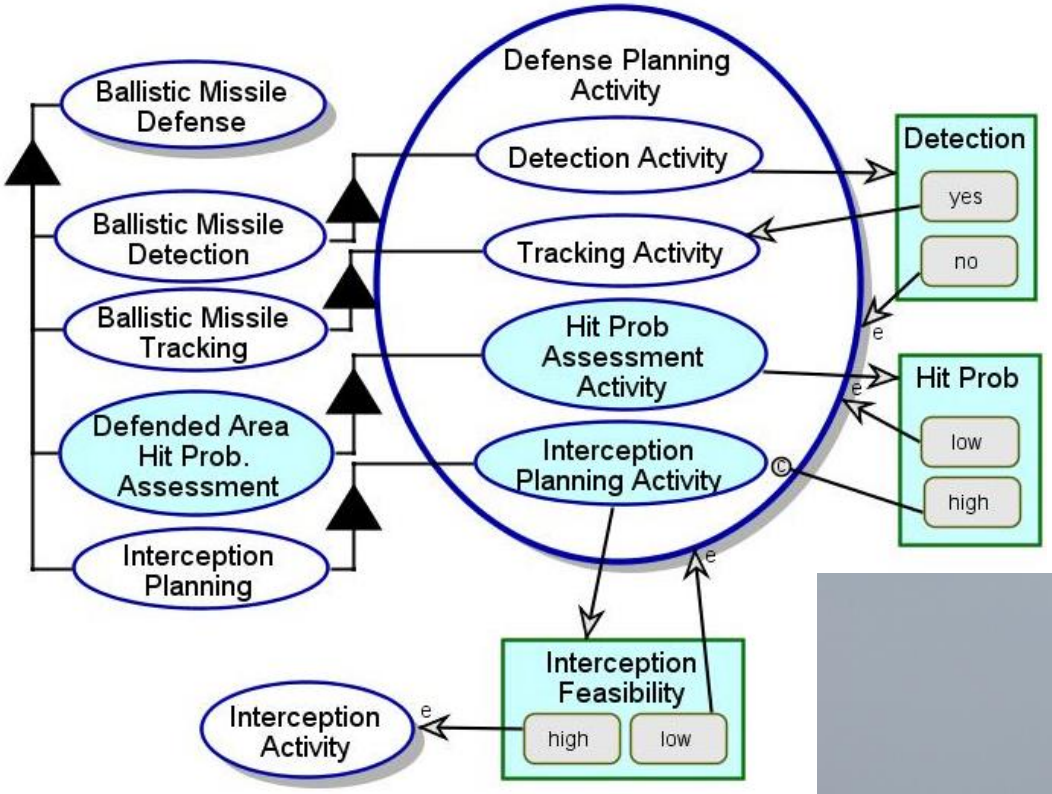
Offshore Oil Well Drilling



Airport Operations: Outgoing Passenger



Iron Dome – an Israeli ballistic missile defense system



Yaniv Mordecai and Dov Dori, Evolving System Modeling: Facilitating Agile System Development with Object-Process Methodology. *SysCon 2015 ,9th Annual IEEE International Systems Conference*, Vancouver, Canada, April 13-16 2015.
To be presented

Sample of engineering domains in which OPM has been used

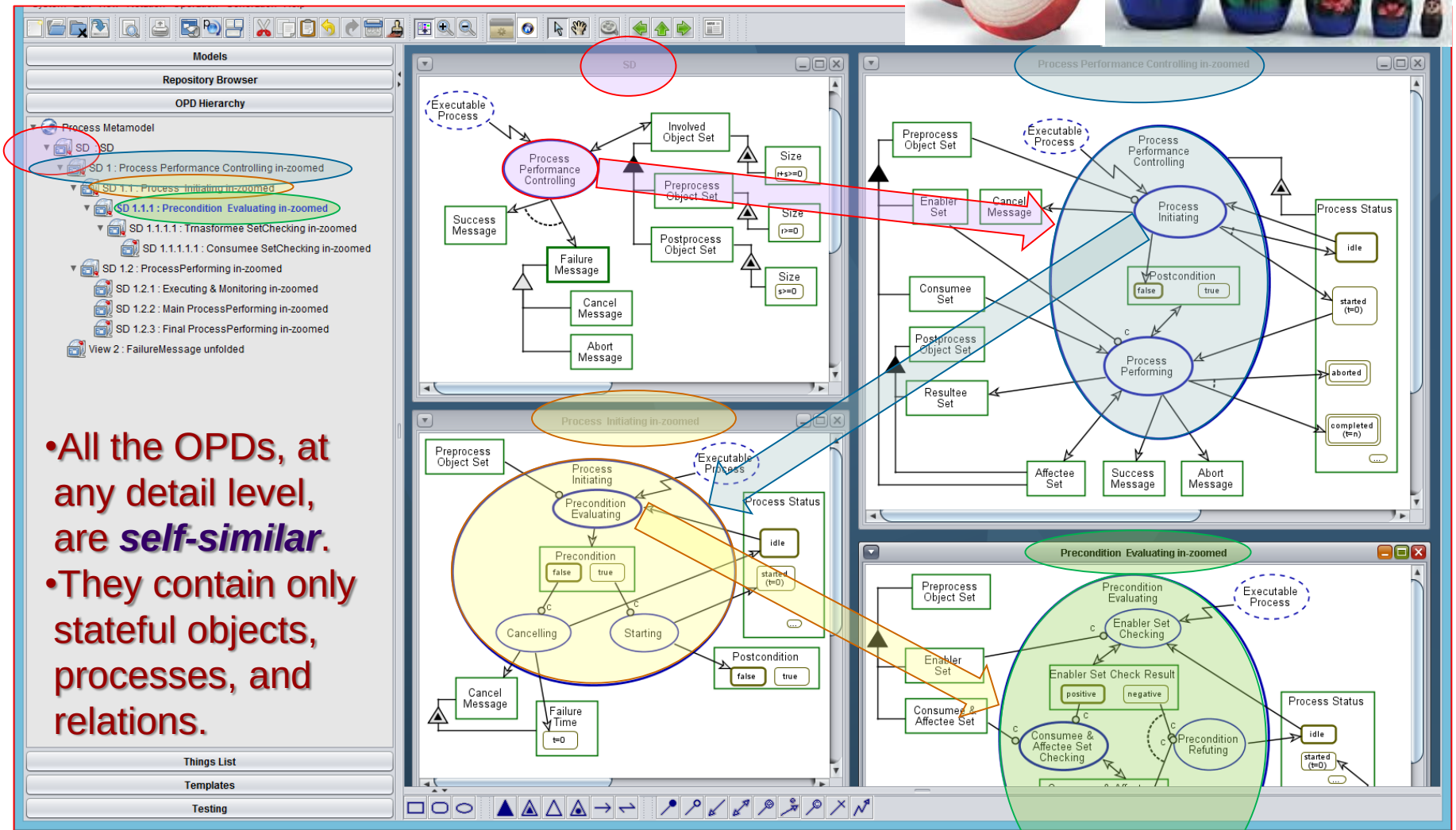
- **Complex, Interconnected, Large-Scale Socio-Technical Systems.** *Systems Engineering* 14(3), 2011.
- **Networking Mobile Devices and Computers in an Intelligent Home.** *International Journal of Smart Home* 3(4), pp. 15-22, October, 2009.
- **Multi-Agent Systems.** *IEEE Transactions on Systems, Man, and Cybernetics – Part C: Applications and Reviews*, 40 (2) pp. 227-241, 2010.
- **Semantic Web Services Matching and Composition.** *Web Semantics: Science, Services and Agents on the World Wide Web*. 9, pp. 16-28, 2011.
- **Project-Product Lifecycle Management.** *Systems Engineering*, 16 (4), pp. 413-426, 2013.
- **Model-Based Risk-Oriented Robust Systems Design.** *International Journal of Strategic Engineering Asset Management*, 1(4), pp. 331-354, 2013.
- **Medical Robotics and Miscommunication Scenarios.** An Object-Process Methodology Conceptual Model. *Artificial Intelligence in Medicine*, 62(3) pp. 153-163, 2014.
- **Modeling Exceptions in Biomedical Informatics**. *Journal of Biomedical Informatics 42*(4), pp. 736-747, 2009.

Complexity Management with OPM

- Systems are inherently complex.
- To alleviate complexity, OPM has three ***refinement-abstraction*** mechanisms:
  - In zooming – Out-zooming
  - Unfolding – Folding
  - State expression – suppression
- OPM manages complexity by ***detail decomposition***
  - Unlike aspect decomposition in other languages:
    - structure diagrams, behavior diagrams…

In-zooming – Out-zooming Example

Process Performance Controlling
- a metamodel from ISO 19450



- All the OPDs, at any detail level, are ***self-similar***.
- They contain only stateful objects, processes, and relations.

SysML and OPM – a brief comparison

Feature	SysML	OPM
Theoretical foundation	UML; Object-Oriented paradigm	Minimal universal ontology; Object-Process Theorem
Standard documentation number of pages	~1670=700 (UML Infrastructure) + 700 (UML Superstructure) + 270 (OMG SysML)	~160=100 (ISO 19450 main standard) + 60 (appendices)
Standardization body	OMG	ISO
Number of diagram kinds	9	1
Top-level concept	Block (UML object class)	Thing (object or process)
Complexity management guiding principle	Aspect-based decomposition	Detail-level-based decomposition
Hierarchical decomposition	In some diagram kinds	Yes
Number of symbols	~120	~20
Graphic modality	Yes	Yes
Textual modality	No	Yes
Built-in physical-informatical distinction	No	Yes
Systemic-environmental distinction	Partial (using boundaries)	Yes
Logical relations (OR, XOR, AND)	No	Yes
Probability modeling	No	Yes
Execution, animated simulation, validation and verification capability	Partial (in some tools for some diagram kinds)	Yes
Tool availability	Many, some free	Currently one free (OPCAT) from http://esml.iem.technion.ac.il/ Cloud-based tool under development

OPM Complexity Management Benefits

- There is no limit on the level of complexity of the system being modeled:
  - One can specify system structure and behavior at any level of detail by recursively in-zooming.
- Catering to the cognitive limited capacity:
  - Each diagram is not overly complicated.
- All the diagrams are “aware” of each other:
  - All OPDs are partial views of the same system.
  - Any change in one diagram is propagated to all the other relevant ones.

New Gen Dishwasher: Model-Based Design Outline

1. **Model requirement with customer (or Marketing as proxy)**
   - This is the problem domain model
2. **Specify alternative selection criteria based on value as benefit as cost**
   - This will enable decision making once we have alternative concepts

New Gen Dishwasher: Model-Based Design Outline

3. **Formulate 2-3 alternative concepts**

- This is the solution model which evolves from and extends the problem model
- Each concept shall be based on a different underlying idea/physical principle

4. **Model each concept with OPM to level 1 or 2 (SD is level 0)**

New Gen Dishwasher: Model-Based Design Outline

5. Evaluate the concept models based on the predefined criteria
6. Select the concept model with the best value
7. Continue modeling the selected concept to more refined subsystem & component levels
8. Where applicable, repeat developing alternatives for subsystems (steps 4-7).

New Gen Dishwasher: Model-Based Design Outline

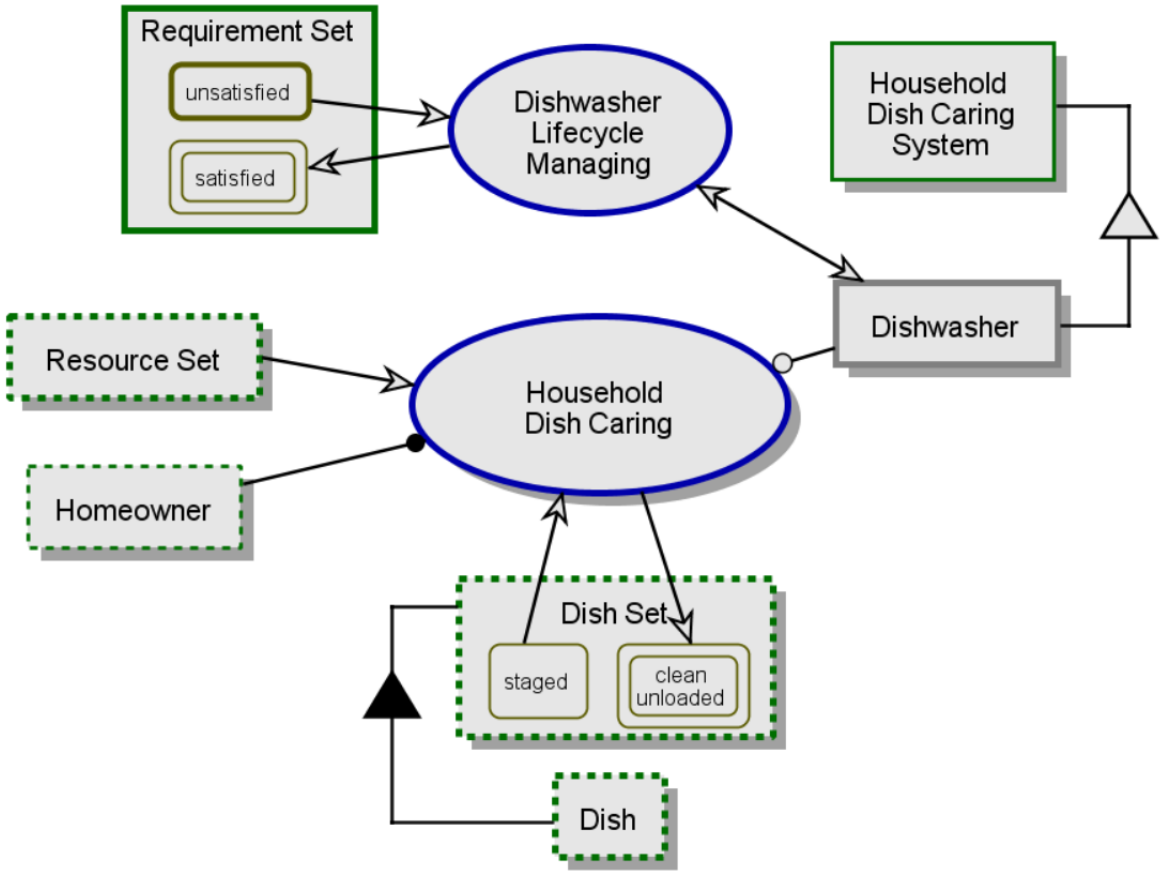
9. Involve customer or marketing throughout the modeling process
10. Stop when the conceptual model is sufficiently detailed and prescriptive for transition to hardware/software/ GUI/exterior/packaging design
11. Design the PPLM model with built-in tests for meeting all the requirements (not in this workshop)

Requirements Modeling – The Problem Domain OPM model

1. **What is the function of this system?**

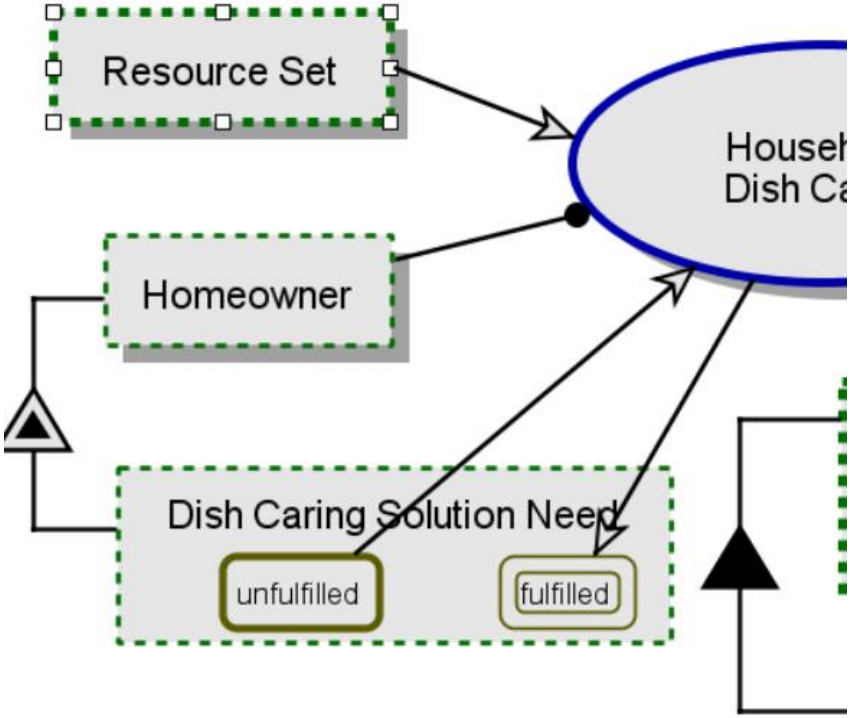
- Describe in three words, the last being a verb ending with ing (gerund)
- This will be our starting point of the requirements OPM model

The Function:
Household Dish Caring



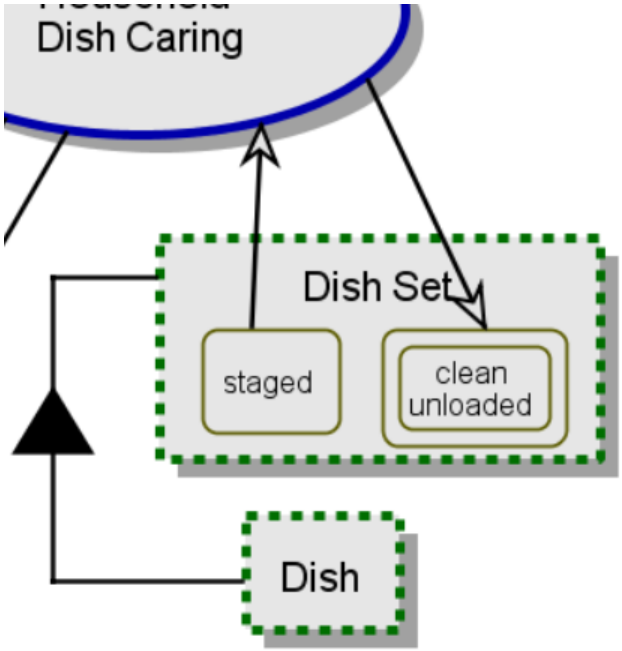
Who is the Beneficiary?

Who benefits from owning and operating the system?

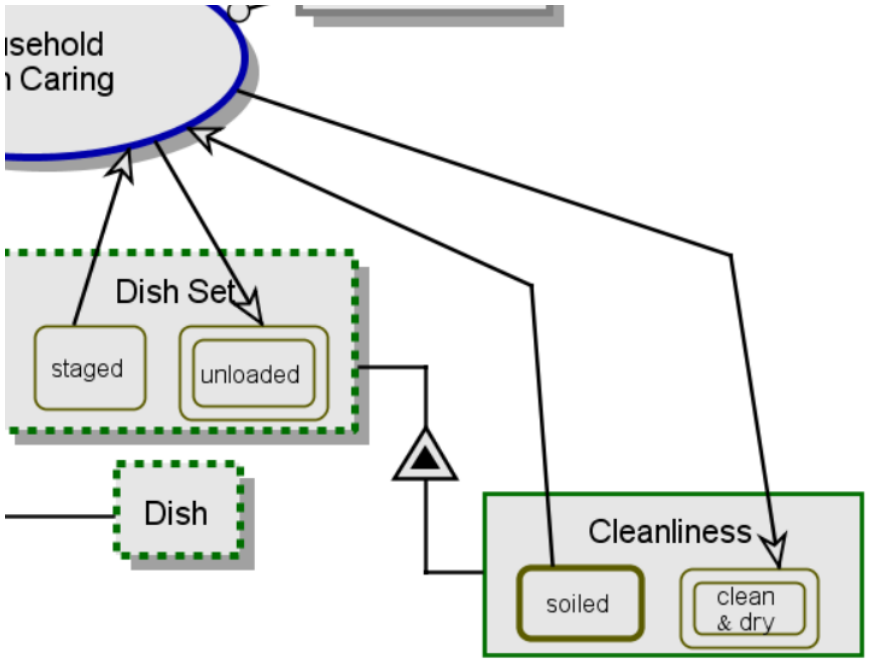


What is the Operand (the object that the function transforms)?

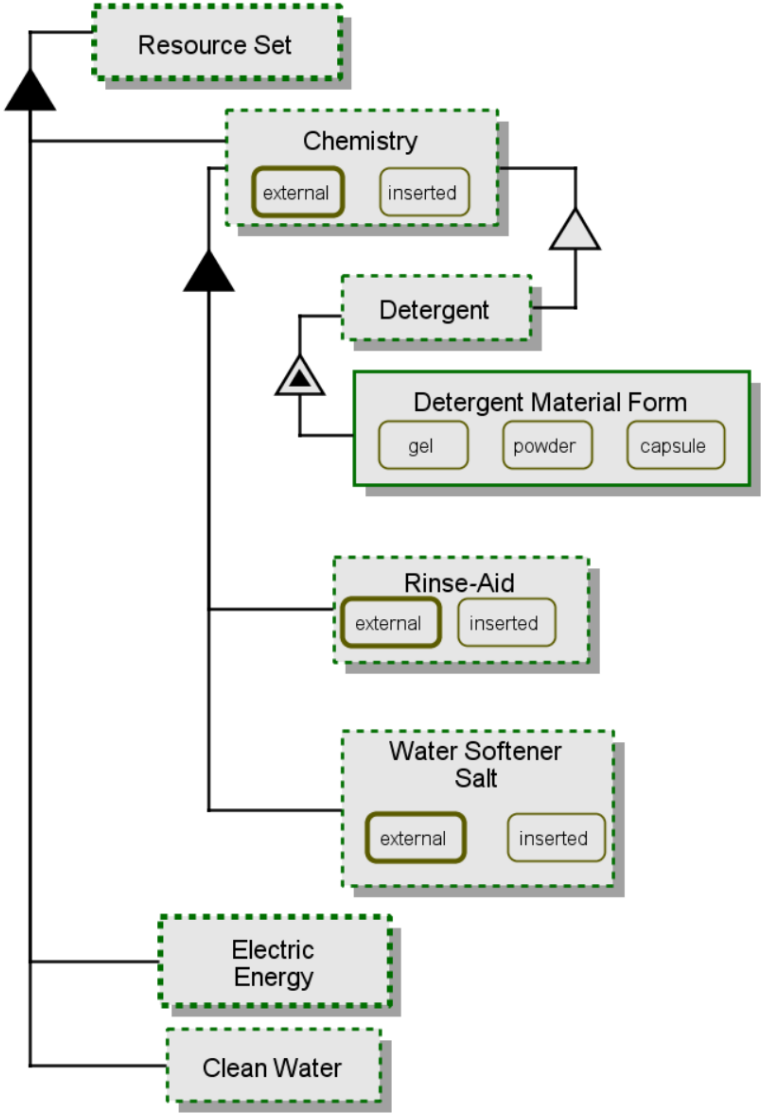
Who benefits from owning and operating the system?



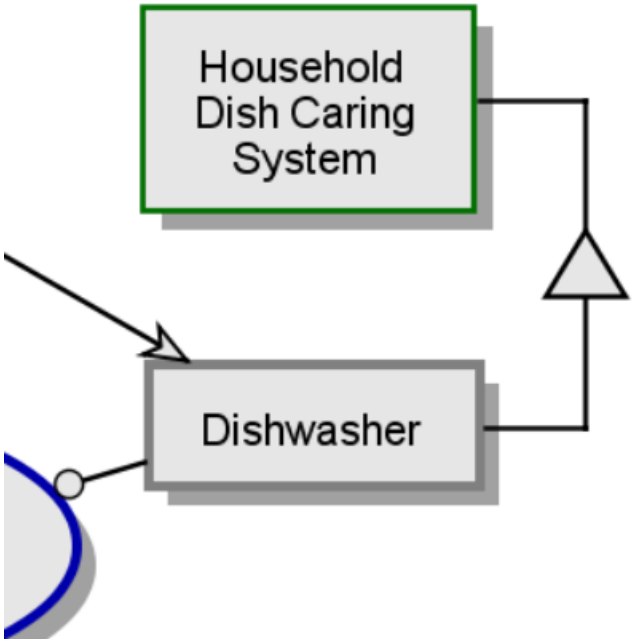
What is the attribute of the operand whose change generates value to the beneficiary?



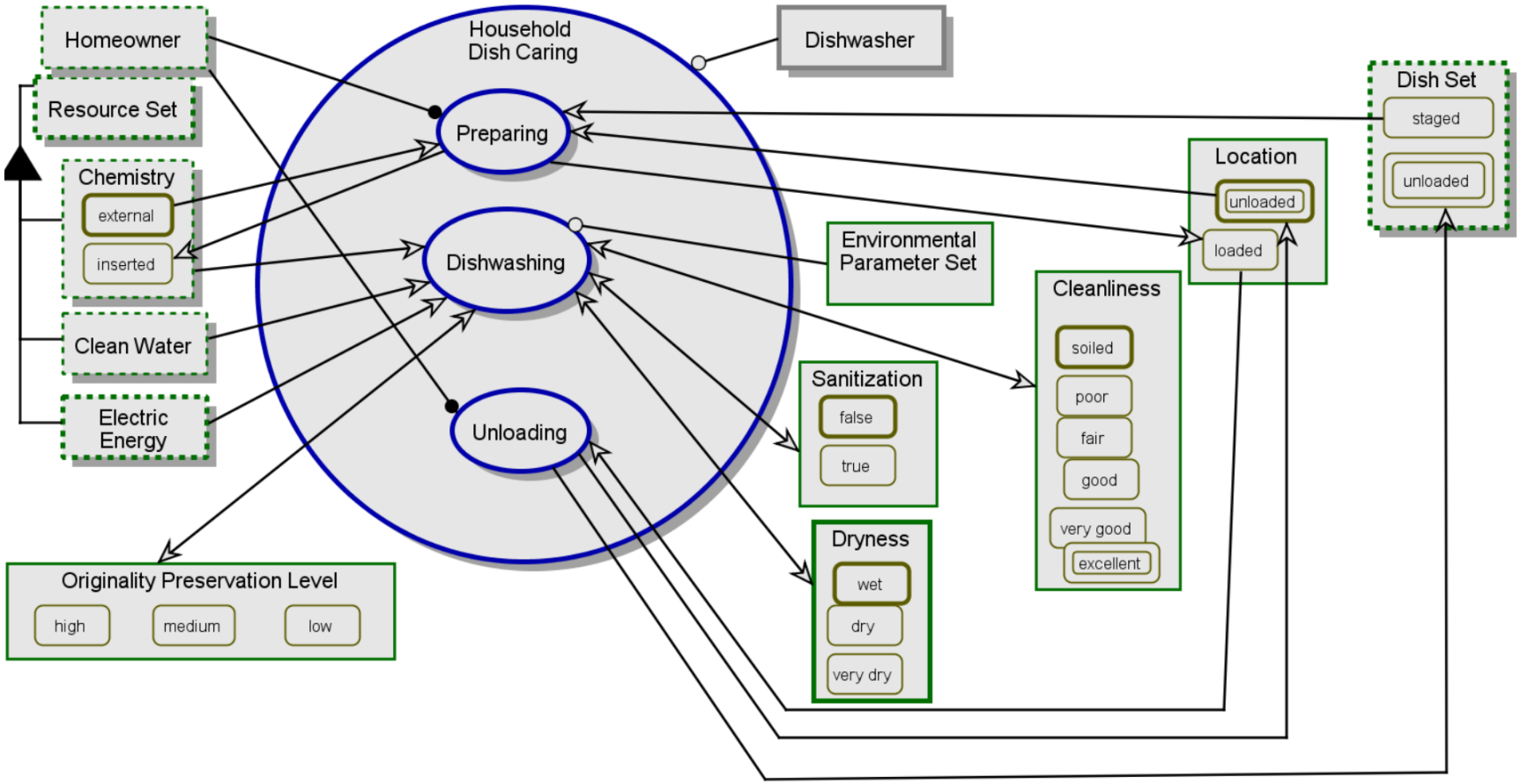
What are the system's input and output?



What is the name of the new system we are developing?



The next detail level: Zooming into the System's Function



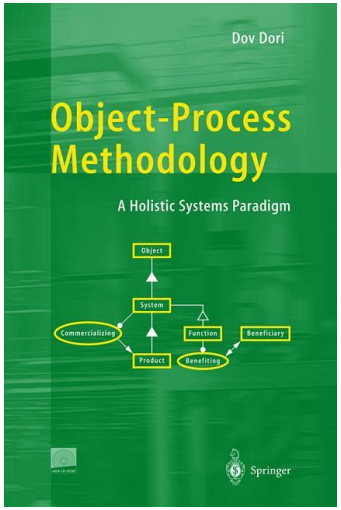
The Auto-Generated OPL Text: A self-documenting feature

Homeowner is environmental and physical.
Homeowner handles Unloading and Preparing.
Dish Set is environmental and physical.
Dish Set can be staged or unloaded.
    unloaded is final.
Dishwasher is physical.
Cleanliness can be poor, excellent, fair, good, very good, or soiled.
    excellent is final.
    soiled is initial.
Resource Set is environmental and physical.
Resource Set consists of Chemistry, Clean Water, and Electric Energy.
    Chemistry is environmental and physical.
    Chemistry can be external or inserted.
        external is initial.
    Clean Water is environmental and physical.
    Electric Energy is environmental and physical.
Dryness can be wet, dry, or very dry.
    wet is initial.
Sanitization can be true or false.
    false is initial.
Location can be unloaded or loaded.
    unloaded is initial.
    unloaded is final.
Originality Preservation Level can be high, medium, or low.
Household Dish Caring is physical.
Household Dish Caring consists of Unloading, Dishwashing, and Preparing.
Household Dish Caring requires Dishwasher.
Household Dish Caring zooms into Preparing, Dishwashing, and Unloading.
    Preparing is physical.
    Preparing changes Location from unloaded to loaded and Chemistry from external to inserted.
    Preparing consumes staged Dish Set.
    Dishwashing is physical.
    Dishwashing requires Environmental Parameter Set.
    Dishwashing affects Originality Preservation Level, Cleanliness, Sanitization, and Dryness.
    Dishwashing consumes Chemistry, Electric Energy, and Clean Water.
    Unloading is physical.
    Unloading changes Location from loaded to unloaded.
    Unloading yields unloaded Dish Set.

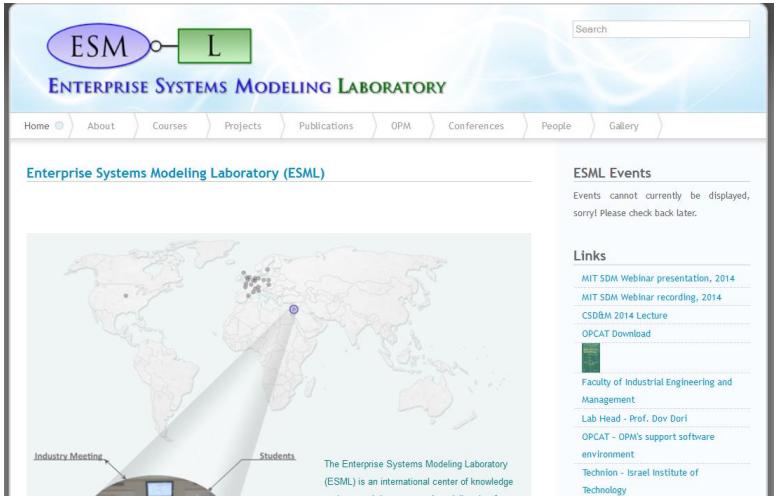
OPL Generator

MITsdm system design and management

OPM Resources:



- Book: Object-Process Methodology - A Holistic Systems Paradigm, Springer Verlag, Berlin, Heidelberg, New York, 2002.
- Upcoming book (2015) Model-Based Systems Engineering with OPM and SysML, Springer, New York.
- Standard ISO 19450 OPM
- Website: Enterprise Systems Modeling Laboratory contains
  - journal & conference papers,
  - free OPCAT software,
  - presentations,
  - projects, and more.



Join the growing OPM community Here!

https://www.jiscmail.ac.uk/cgi-bin/webadmin?SUBED1=OPM&A=1

Questions and (hopefully) Answers

Contact: Dov Dori – dori@mit.edu