Model-Based Meta-Standardization: Modeling Enterprise Standards with OPM

Dov Dori
Technion, Israel Institute of Technology
Massachusetts Institute of Technology
dori@mit.edu
Richard Martin
Tinwisle Corporation, USA
Alex Blekhman
Technion, Israel Institute of Technology

IEEE International Systems Conference
San Diego
April 5-8, 2010

Leading MBSE Methodologies

(INCOSE Task, Estefan, 2008 p 43)

- IBM Telelogic Harmony-SE
- INCOSE Object-Oriented Systems Engineering Method (OOSEM)
- IBM Rational Unified Process for Systems Engineering (RUP SE) for Model-Driven Systems Development (MDSD)
- Vitech Model-Based System Engineering (MBSE) Methodology
- JPL State Analysis (SA)
- Object-Process Methodology (OPM)

What is OPM - Object-Process Methodology?

- A simple comprehensive language for
  - Modeling and knowledge capturing,
  - Documenting,
  - Communicating
  - Engineering, and
  - Lifecycle support

of complex, multi-disciplinary systems and standards

- Based on simultaneous bimodal (graphics and text) representation of
  - structure (via stateful objects) and
  - behavior (via processes)

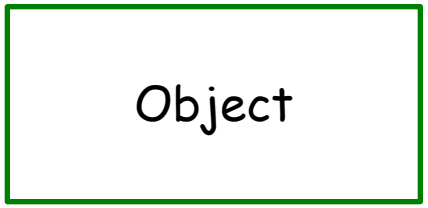
What are the 3 main system aspects?

- The functional (utilitarian) aspect:
  - *What is the system designed to do?*
  - *Why was it built? Who does it serve, what value does it provide?*
- the structural (form, static, existential) aspect:
  - *What is out there, what is the system made of?*
  - *What are the objects in the system?*
- the behavioral (procedural, dynamic, time-varying) aspect:
  - *How does the system behave along the time line?*
  - *What makes the system change its states?*
  - *how is this done?*

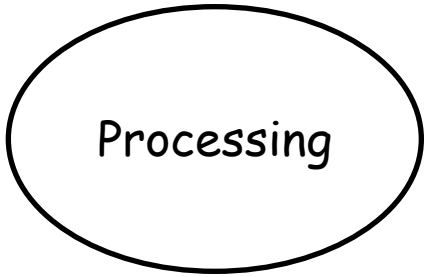
OPM combines the three in a SINGLE coherent diagram type using a compact set of concepts

OPM Entities – the bricks: Things and States

- **Object**: A **thing** that **exists** or might exist.
  - **Objects are stateful**:
    - Objects can have **states**
    - At each point in time a stateful object is
      - at one of its states - static, or
      - in transition between two states – undergoing change



- **Process**: A **thing** that **happens** to an object and transforms it.
  - Transforming an object is:
    - creating it,
    - consuming it, or
    - changing its state.

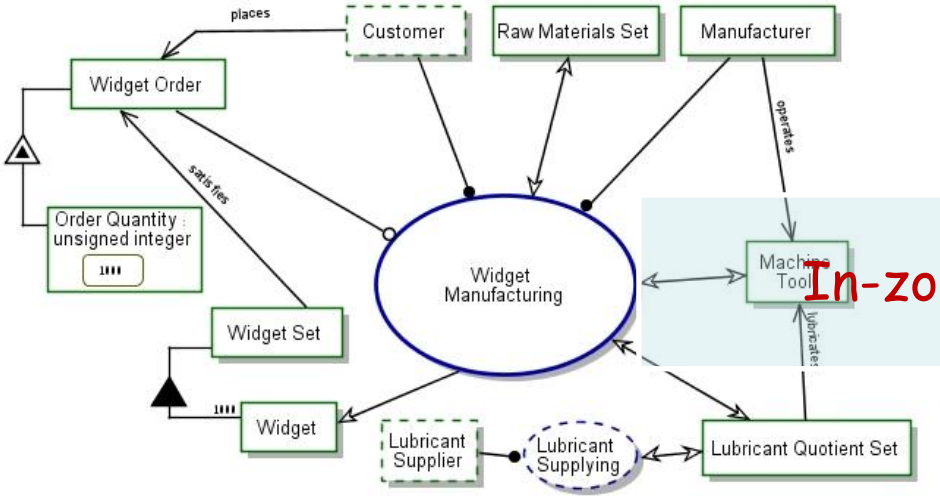


What is in an OPM Model?

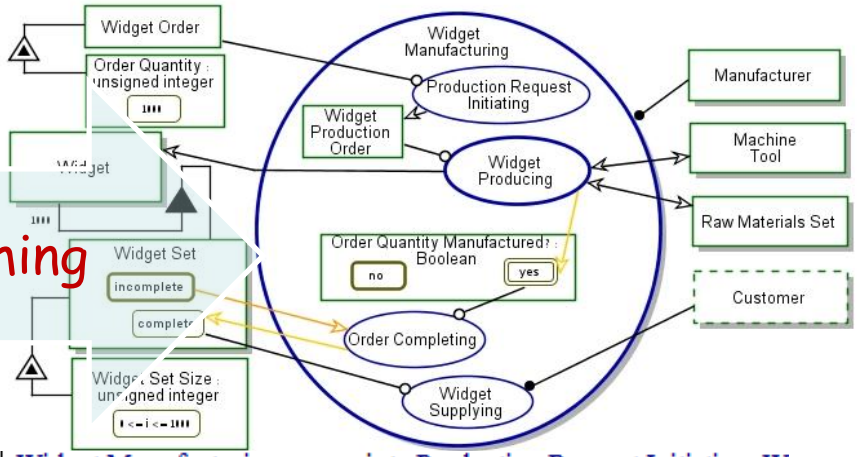
- The OPM model consists of a set of
  Object-Process Diagrams (**OPD set**) and a corresponding
  Object-Process Language (**OPL text**) – a subset of English
- The root diagram is the most abstract level called *System Diagram* (SD)
- The OPDs in the OPD set are hierarchical by construction via recursively zooming into process(es) of interest.
- Each is a refinement of its ancestor.
- The "BIG PICTURE" is clear and not lost when looking at details

What is in an OPM Model?

- The OPM model consists of a set of
  Object-Process Diagrams (**OPD set**) and a corresponding
  Object-Process Language (**OPL text**) – a subset of English
- The root diagram is the most abstract level called *System Diagram* (SD)
- The OPDs in the OPD set are hierarchical by construction via recursively zooming into process(es) of interest.
- Each is a refinement of its ancestor.
- The "BIG PICTURE" is clear and not lost when looking at details



In-zooming



Widget Manufacturing requires Widget Order
Widget Manufacturing affects Machine Tool,
Widget Manufacturing yields Widget.
Lubricant Supplying is environmental and phy
Lubricant Supplying affects Lubricant Quotie

Widget Manufacturing zooms into Production Request Initiating, W
and Widget Supplying, as well as Order Quantity Manufactured? an
Order Quantity Manufactured? is of type Boolean.
Production Request Initiating requires Widget Order.
Production Request Initiating yields Widget Production Orde
Widget Producing requires Widget Production Order.
Widget Producing affects Machine Tool and Raw Materials
Widget Producing yields yes Order Quantity Manufactured?
Order Completing requires yes Order Quantity Manufacture
Order Completing changes Widget Set from incomplete to c
Widget Supplying requires complete Widget Set.

Major OPM features

- **Unification** of structure and behavior in a **single** diagram
- **Generic** ontology of **stateful objects** and **processes** that transform them
- **Models** systems and standards comprising

hardware, software, regulations, humans, enterprises…

- **Bimodal** model expression via:
  - intuitive yet formal **graphics** - Object-Process Diagrams (OPDs)
  - equivalent subset of **natural language** - Object-Process Language (OPL)
- Built-in **abstraction-refinement mechanisms** for complexity management
- **Executable**, can be **simulated** and animated

"Each level has **structure** and **behavior**"
(Richard Martin)

OPM Aspect Unification

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

Are expressed in OPM bi-modally in a **single** model.

The *model multiplicity problem* is avoided – no mental integration load.

ISO OPM Study Group

- Tasked on April 2009 at the Paris Annual Meeting of TC184/TC5 with evaluating OPM and other tools for:
  A. Improving the **standards development process** – consistency (inter-, intra-), reusability, …
  B. Use as a **modelling tool for SC5** work.
- Participation of 27 experts
- Used (parts of) IEC 62264 as test case
- Has produced an Interim Report (SC5 N1070)
- Conclusions and recommendations made to SC5
- Presented to the Annual Meeting of TC184/TC5 Tokyo, March 26 2010.
- Unanimously decided to ask the ISO OPM Study Group to produce a normative Draft International Standard for the 2011 Meeting.

What is in an OPM Model?

- The OPM model consists of a set of

  Object-Process Diagrams (**OPD set**)
  and a corresponding

  Object-Process Language (**OPL text**) –
  a subset of English
- The root diagram is the most abstract level called *System Diagram* (SD)
- The OPDs in the OPD set are hierarchical by construction via recursively zooming into process(es) of interest.
- Each is a refinement of its ancestor.
- The "BIG PICTURE" is clear and not lost when looking at details

Major OPM features

- **Unification** of structure and behavior in a **single** diagram
- **Generic** ontology of **stateful objects** and **processes** that transform them
- **Models** systems and standards comprising

hardware, software, regulations, humans, enterprises…

- **Bimodal** model expression via:
  - intuitive yet formal **graphics** - Object-Process Diagrams (OPDs)
  - equivalent subset of **natural language** - Object-Process Language (OPL)
- Built-in **abstraction-refinement mechanisms** for complexity management
- **Executable**, can be **simulated** and animated

OPM Aspect Unification

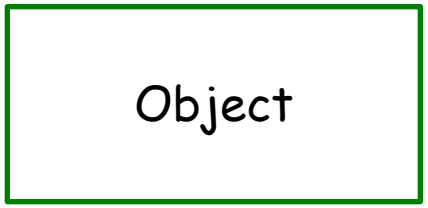
- ***Structure*** (static aspect: ***what*** is the system made of), and
- ***Behavior*** (dynamic aspect: ***how*** the system changes over time)

Are expressed in OPM bi-modally in a **single** model.

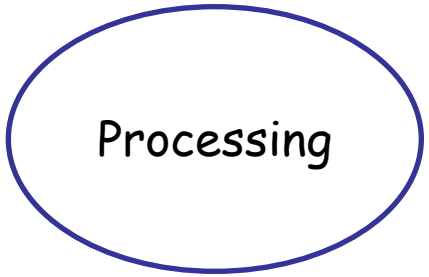
The *model multiplicity problem* is avoided – no mental integration load.

OPM Entities – the bricks: Things and States

- **Object**: A **thing** that **exists** or might exist.
  - **Objects are stateful**:
    - Objects can have **states**
    - At each point in time a stateful object is
      - at one of its states - static, or
      - in transition between two states – undergoing change



- **Process**: A **thing** that **happens** to an object and transforms it.
  - Transforming an object is:
    - creating it,
    - consuming it, or
    - changing its state.



Source standard specification: text and figure fragment of paragraph 7.5.1.1 – Personnel Model of ISO/IEC 62264

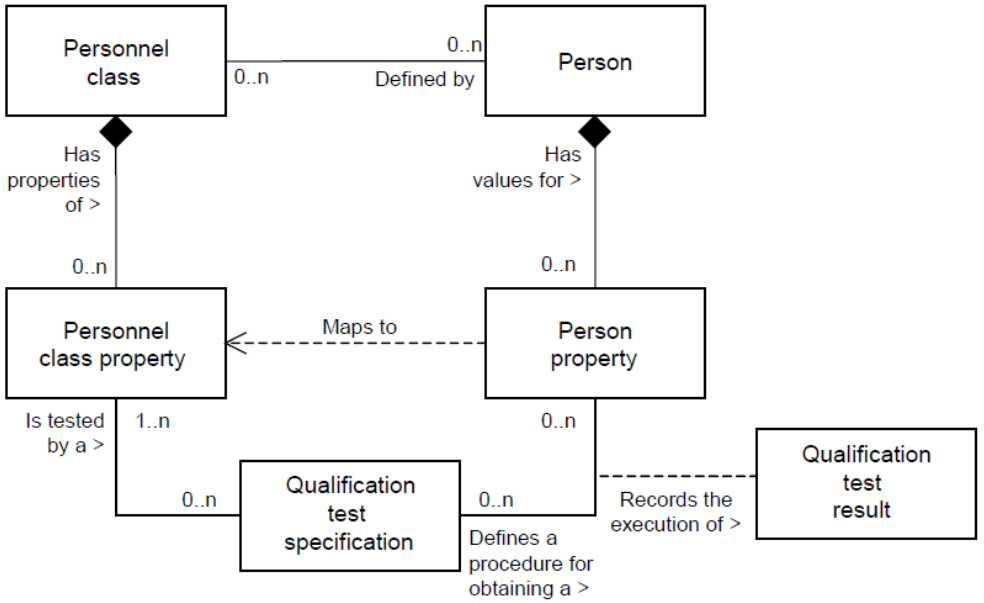
Text	Figure
The personnel model contains the information about specific personnel, classes of personnel, and qualifications of personnel. Figure 14 illustrates the personnel model. This corresponds to a resource model for personnel, as given in ISO 15704 and ISO 15531-1	

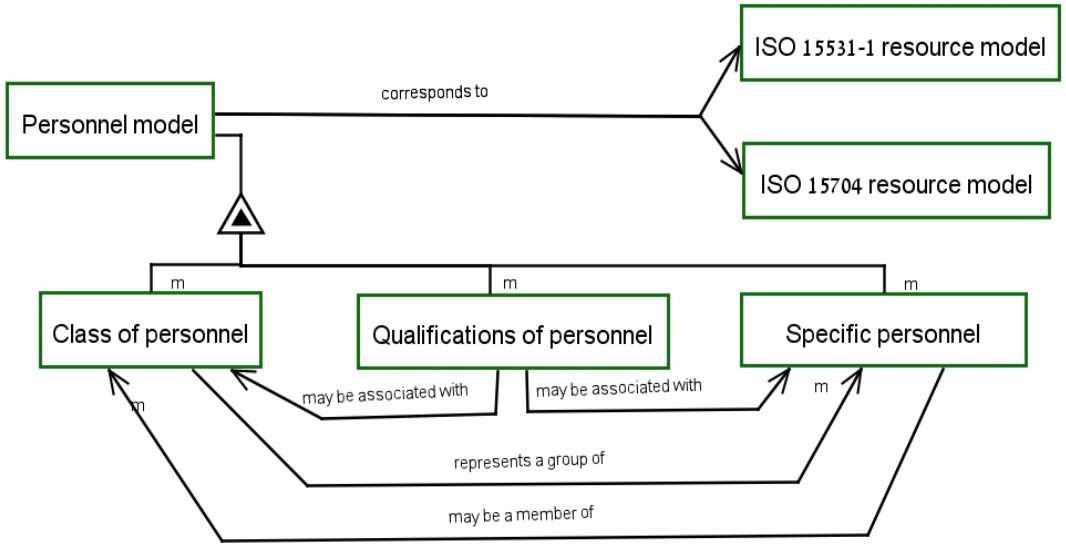
Figure 14 – Personnel model

typical problems of combining free text with graphic specifications

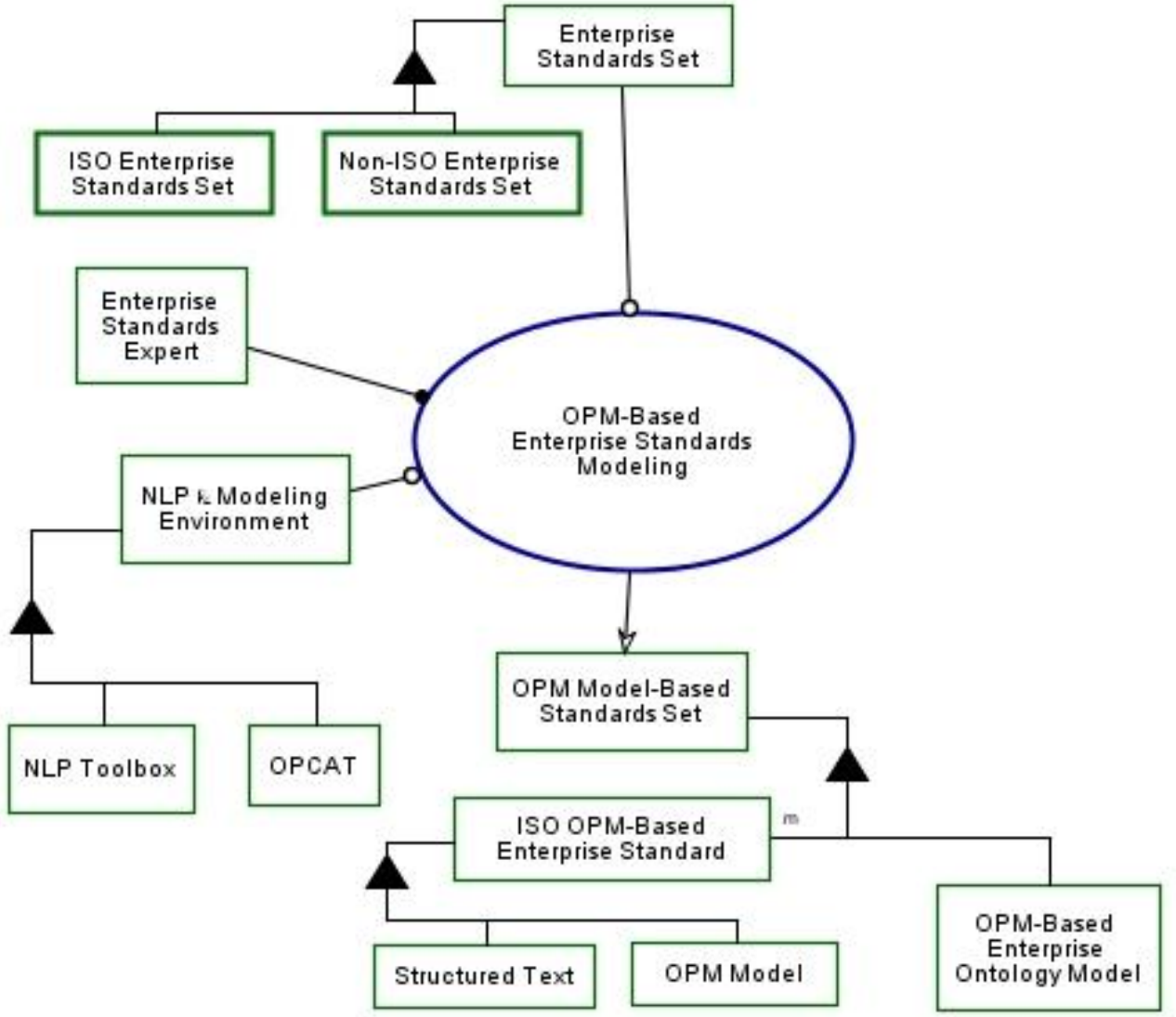
- Inconsistency between figure notation and notation in text: e. g., specific personnel (text of this paragraph) vs. Person (in the model and later in the text) or qualifications of personnel (in the text of this paragraph) vs. Person property (in the model and later in the text).
- Incomplete text (information in the model is not present in the text): e. g., the relation "records the execution of" between Qualification test result and Person property.
- Incomplete figure (information in the text is not present in the figure): e.g., correspondence to ISO 15704 and ISO 15531-1.

- Only a few of these issues are resolved later in the standard's text;
- The majority must be inferred from context.
- This situation can be avoided if we move from text-only to a model-based representation for standards.

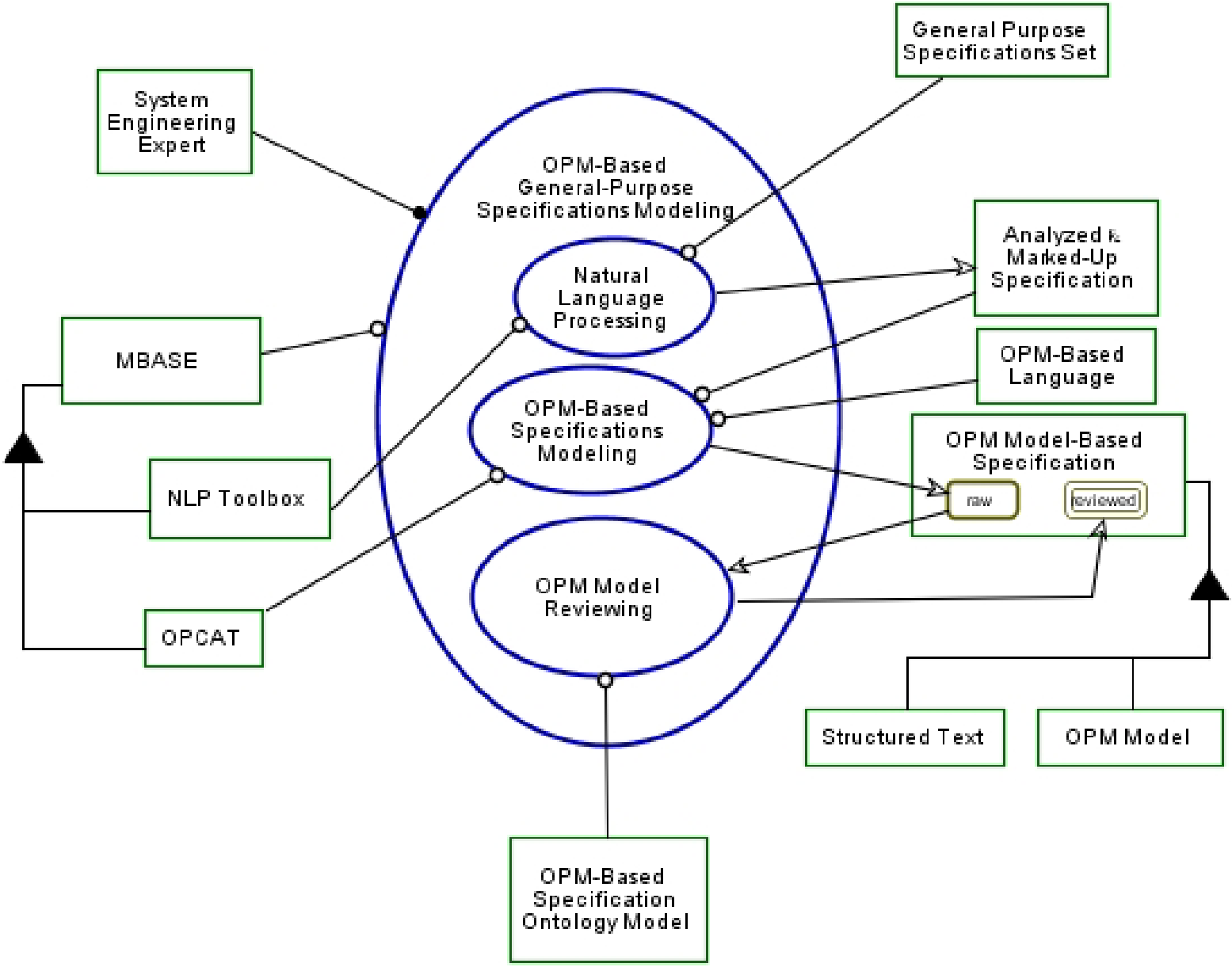
Model-Based specification of the text

Structured Text	Graphical OPM Model – Object-Process Diagram (OPD)
Automatically-generated Object-Process Language (OPL) paragraph Personnel model exhibits many Specific personnels, many Class of personnels, and many Qualifications of personnels. Specific personnel may be a member of many Class of personnels. Class of personnel represents a group of many Specific personnels. Qualifications of personnel may be associated with Class of personnel. Qualifications of personnel may be associated with Specific personnel. Personnel model corresponds to ISO 15531-1 resource model. Personnel model corresponds to ISO 15704 resource model. Manually tweaked OPL – "Tesperanto" Personnel model corresponds to ISO 15704 and ISO 15531-1 resource models and contains the information about Specific personnel, Qualifications of personnel and Classes of personnel: • Class of personnel represents a group of many Specific personnel. • Specific personnel may be a member of many Classes of personnel. • Qualifications of personnel may be associated with Class of personnel and/or with Specific personnel.	

Standards Modeling System Overview



Next Level OPD



MBSAE –Model-Based Standards Authoring Environment

The current MBSAE implementation has the following capabilities:

- ❑ Pre-processing: Extracting structure and keywords from documents: tables of contents, indices, glossaries, etc.
- ❑ Natural Language Processing: integrated open-source tools for sentence simplification, parts-of-speech tagging, semantic similarity analysis, and text modeling.
- ❑ Ontology tools: Object-process-link heuristics and phrase repository, text-to-model consistency.
- ❑ General editing tools: Syntax highlighting, phrase completion, smart tips, and snippets.

Widget Manufacturing Case Study

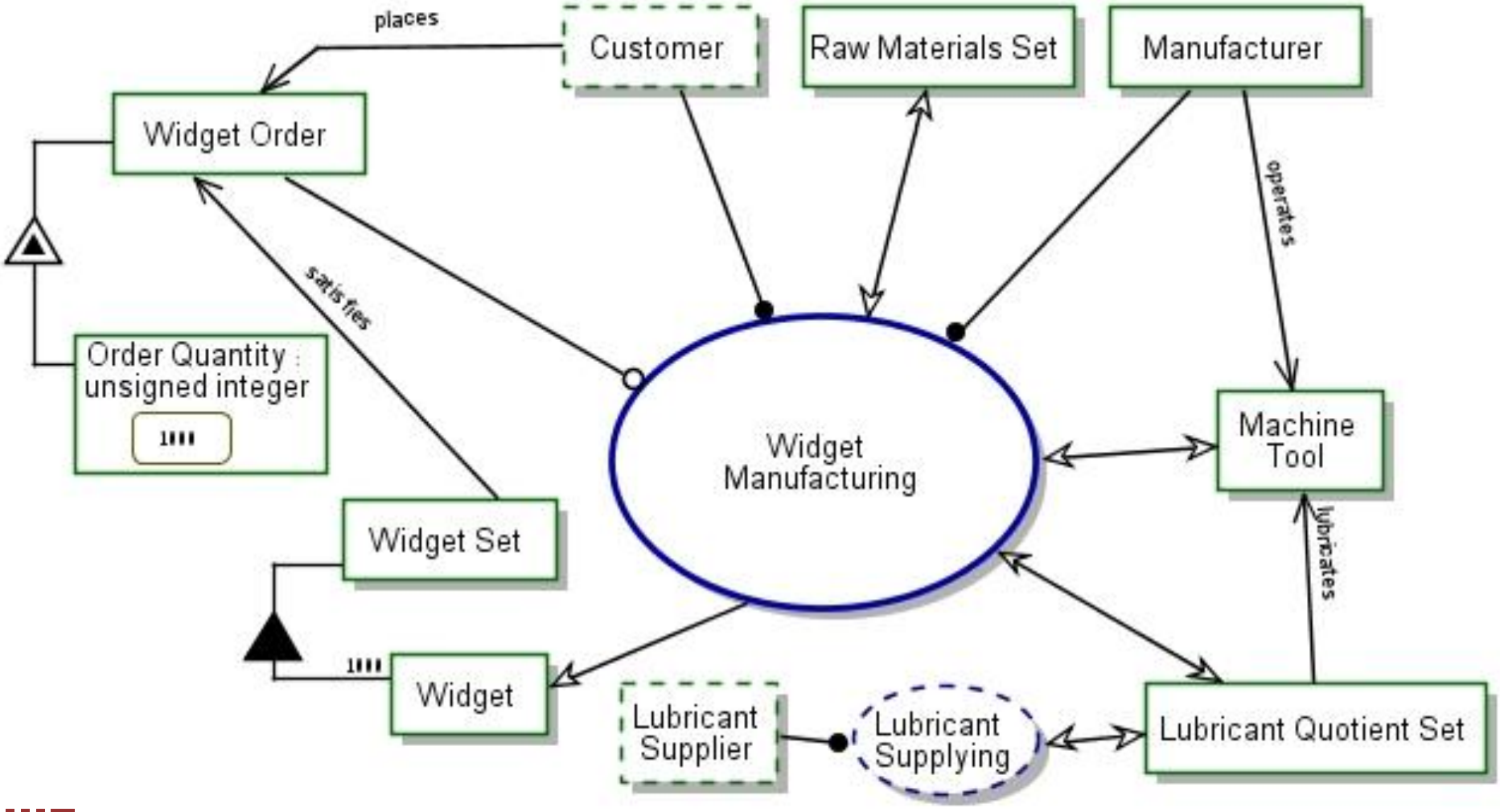
(*specified by Richard Martin)*

A customer order initiates a production request for 1000 units of widget A for which all raw material is already on hand.

The machine tool that makes widget A, by a four step machining process, has a preventive maintenance cycle of 350 units, at which time it requires inspection to assure proper tolerance limits and lubrication before resuming production.

After the first cycle the reserve of lubricant is exhausted and must be replenished from a supplier.

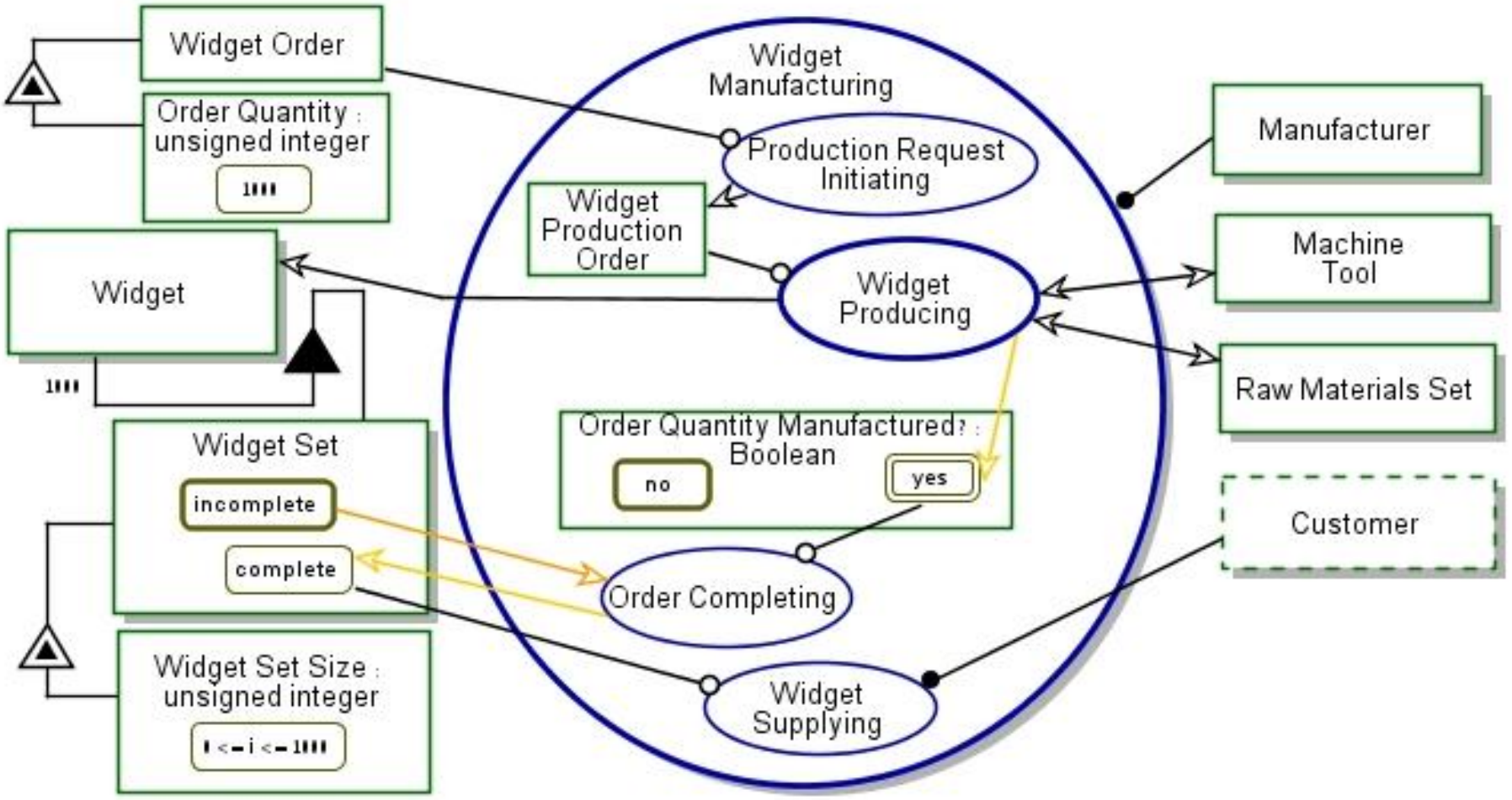
Widget Manufacturing – System Diagram



The equivalent, automatically-generated text:

Customer is environmental and physical.
Customer places Widget Order.
Customer handles Widget Manufacturing.
Manufacturer is physical.
Manufacturer operates Machine Tool.
Manufacturer handles Widget Manufacturing.
Machine Tool is physical.
Lubricant Quotient Set is physical.
Lubricant Quotient Set lubricates Machine Tool.
Lubricant Supplier is environmental and physical.
Lubricant Supplier handles Lubricant Supplying.
Widget Order exhibits Order Quantity.
    Order Quantity is of type unsigned integer.
Widget Set is physical.
Widget Set consists of 1000 Widgets.
    Widget is physical.
Widget Set satisfies Widget Order.
Raw Materials Set is physical.
Widget Manufacturing is physical.
Widget Manufacturing requires Widget Order.
Widget Manufacturing affects Machine Tool, Raw Materials Set, and Lubricant Quotient Set.
Widget Manufacturing yields Widget.
Lubricant Supplying is environmental and physical.
Lubricant Supplying affects Lubricant Quotient Set.

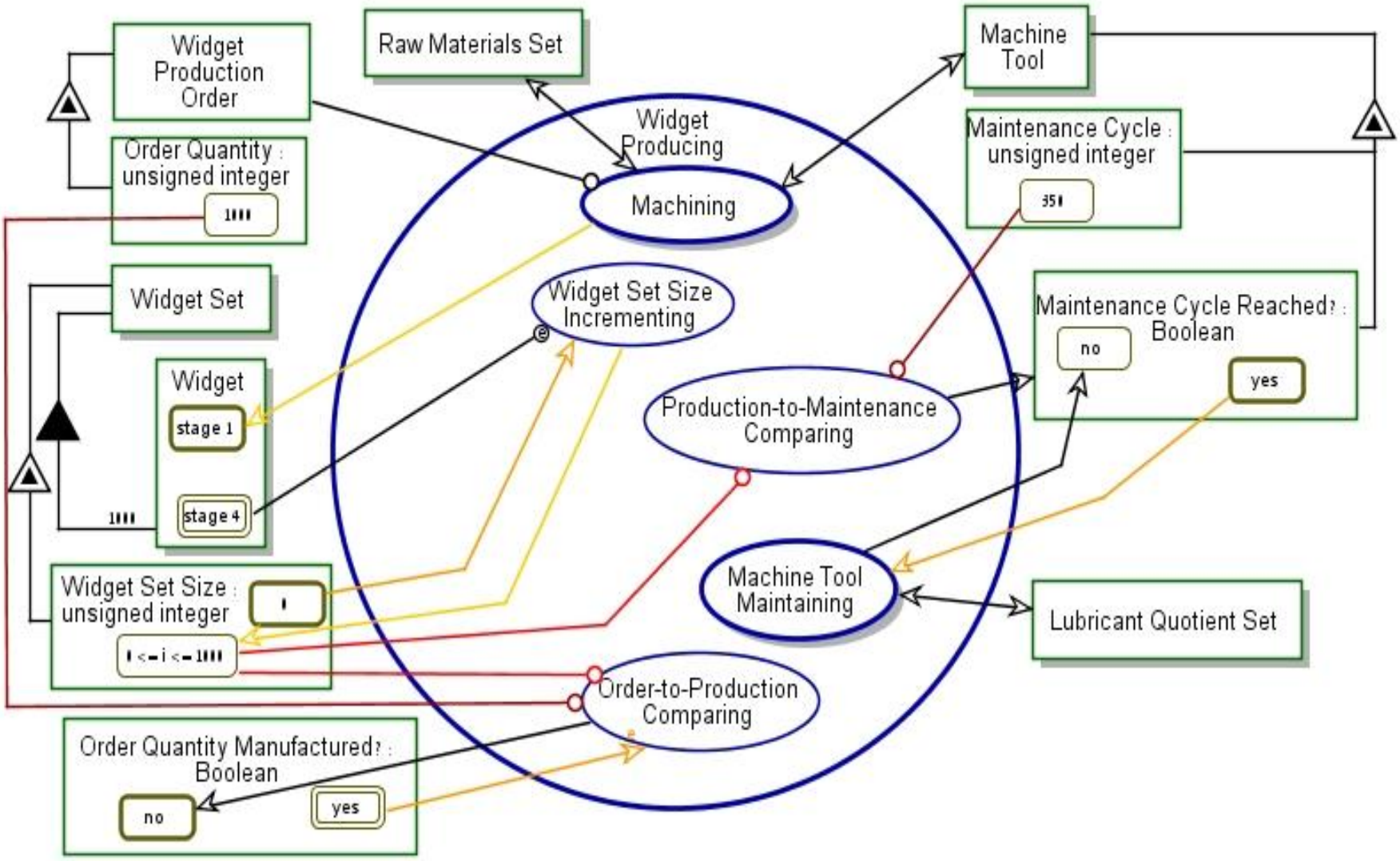
SD1: Widget Manufacturing process in-zoomed



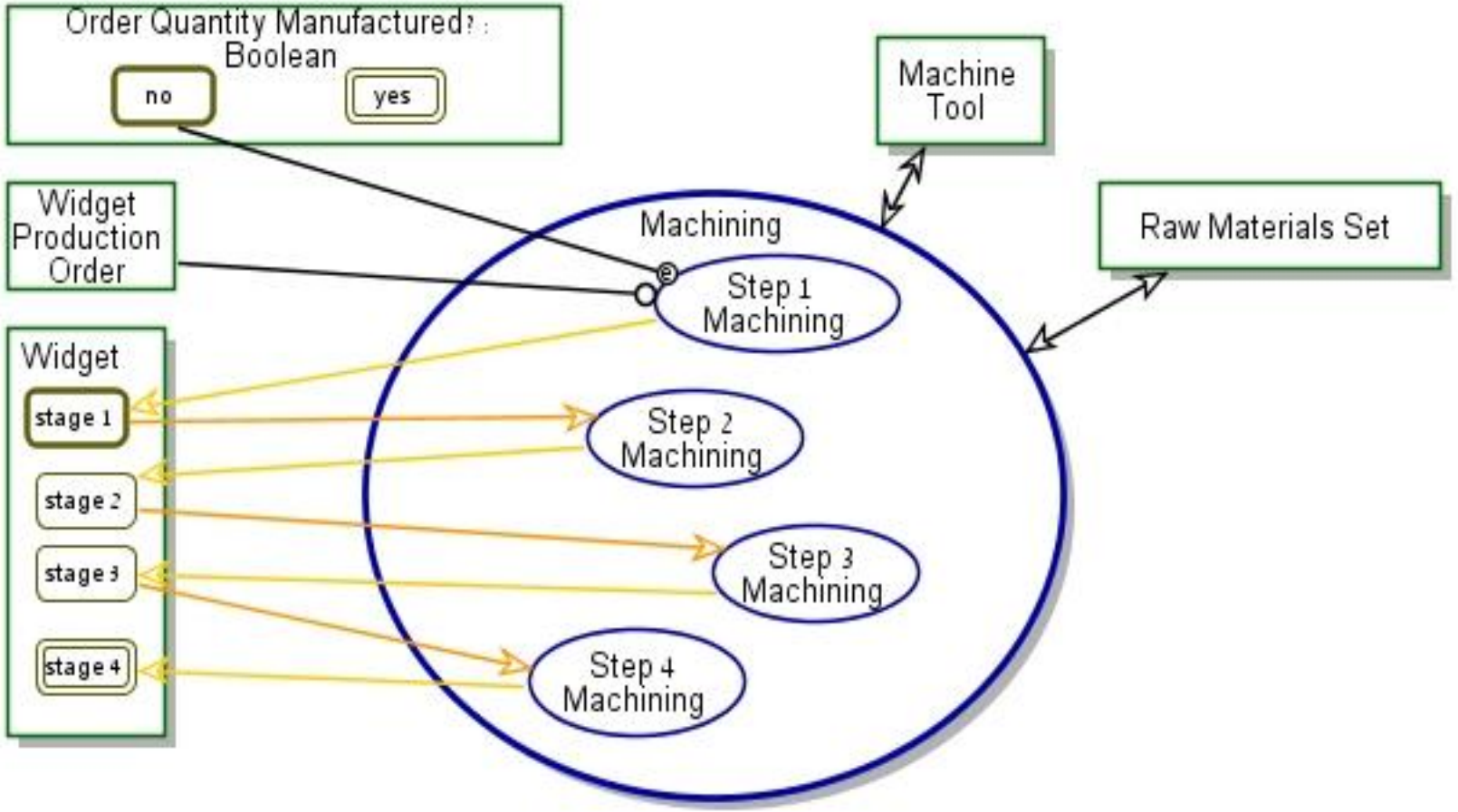
The equivalent, automatically-generated text:

Customer is environmental and physical.
Customer handles Widget Supplying.
Manufacturer is physical.
Manufacturer handles Widget Manufacturing.
Machine Tool is physical.
Widget Order exhibits Order Quantity.
    Order Quantity is of type unsigned integer.
Widget Set is physical.
Widget Set can be incomplete or complete.
    incomplete is initial.
Widget Set exhibits Widget Set Size.
    Widget Set Size is of type unsigned integer.
Widget Set consists of 1000 Widgets.
    Widget is physical.
Raw Materials Set is physical.
Widget Manufacturing is physical.
Widget Manufacturing exhibits Widget Production Order and Order Quantity Manufactured?.
Widget Manufacturing consists of Production Request Initiating, Widget Producing, Widget Supplying, and Order Completing.
Widget Manufacturing zooms into Production Request Initiating, Widget Producing, Order Completing, and Widget Supplying, as well as Order Quantity Manufactured? and Widget Production Order.
    Order Quantity Manufactured? is of type Boolean.
    Production Request Initiating requires Widget Order.
    Production Request Initiating yields Widget Production Order.
    Widget Producing requires Widget Production Order.
    Widget Producing affects Machine Tool and Raw Materials Set.
    Widget Producing yields yes Order Quantity Manufactured? and Widget.
    Order Completing requires yes Order Quantity Manufactured?.
    Order Completing changes Widget Set from incomplete to complete.
    Widget Supplying requires complete Widget Set.

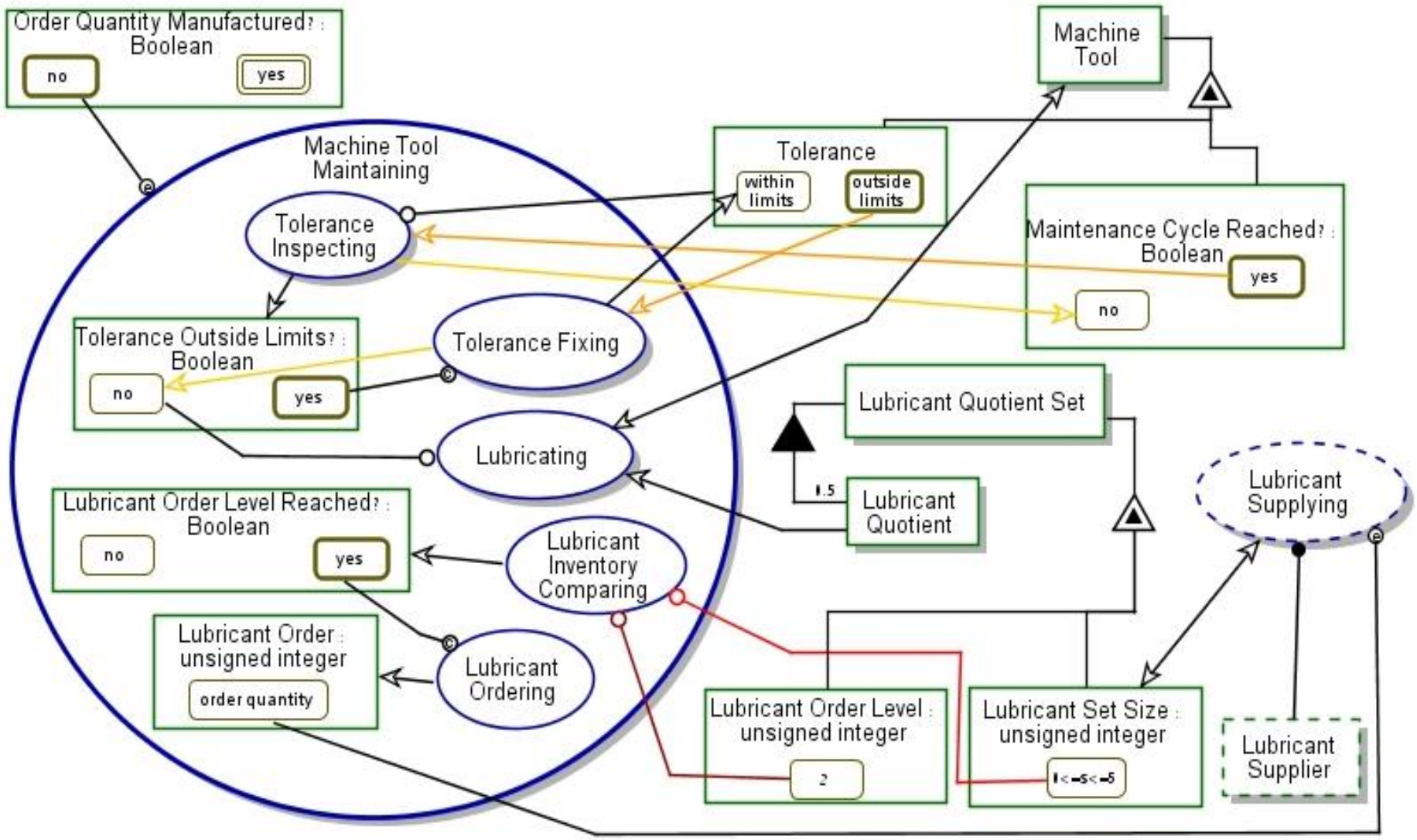
SD1.1: Widget Producing in-zoomed



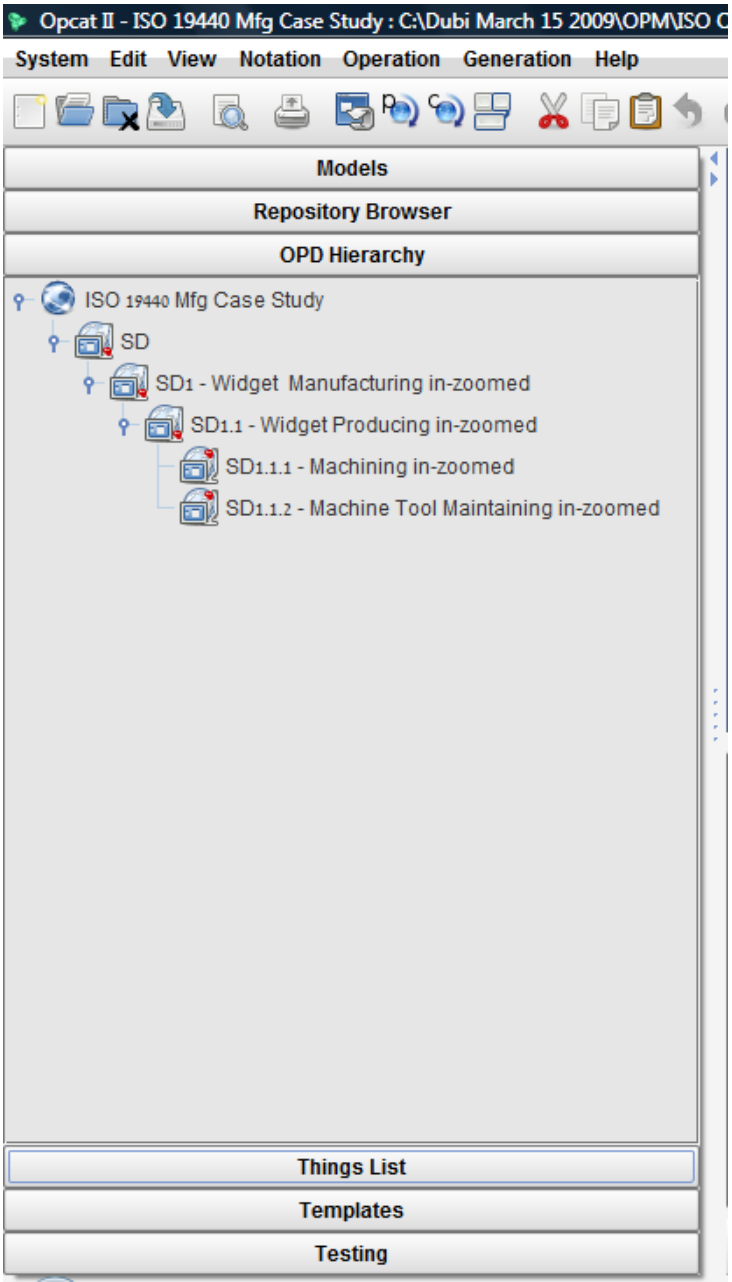
SD1.1.1: Machining in-zoomed

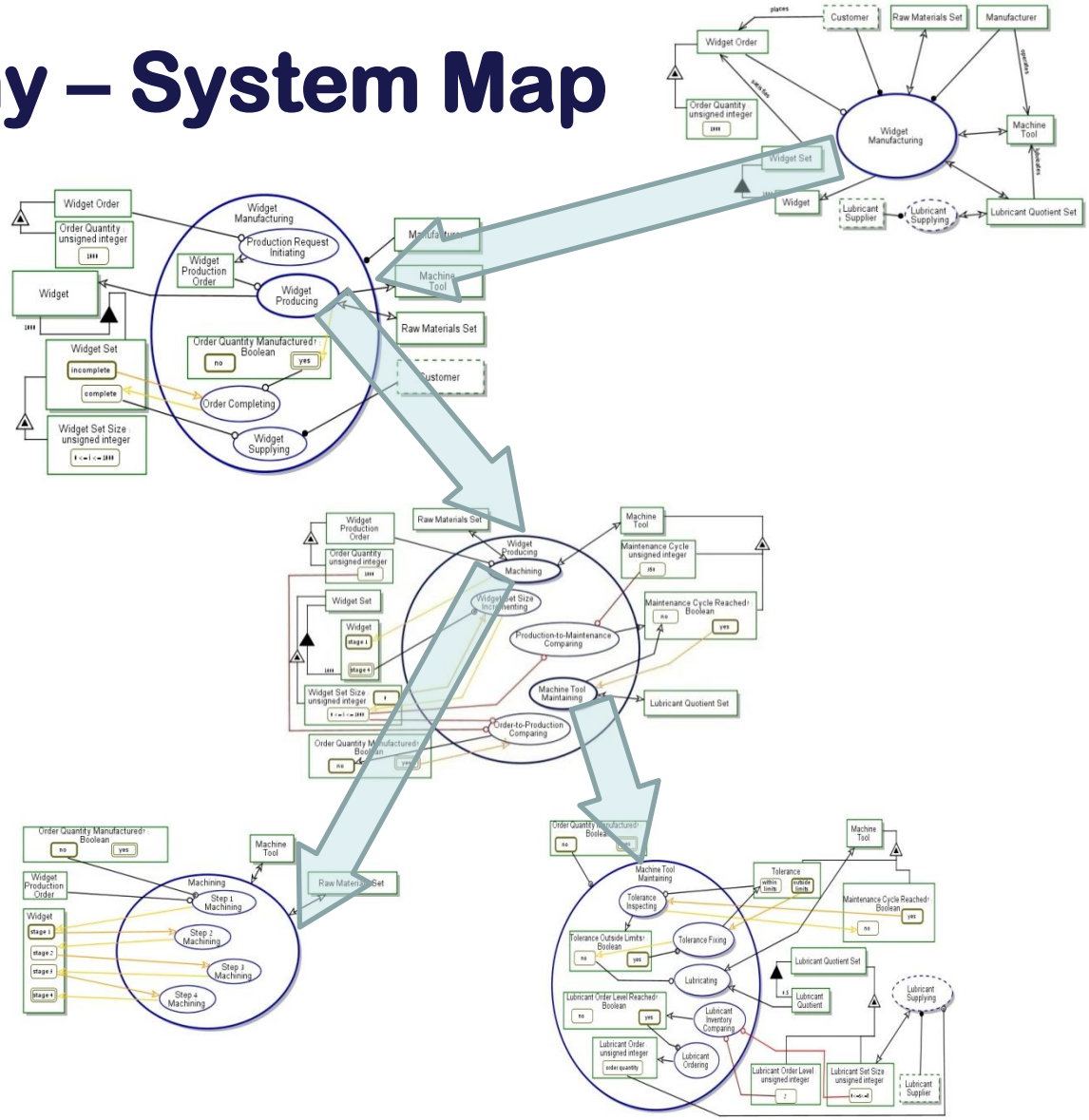


SD1.1.2: Machine Tool Maintaining in-zoomed



The OPD Hierarchy – System Map

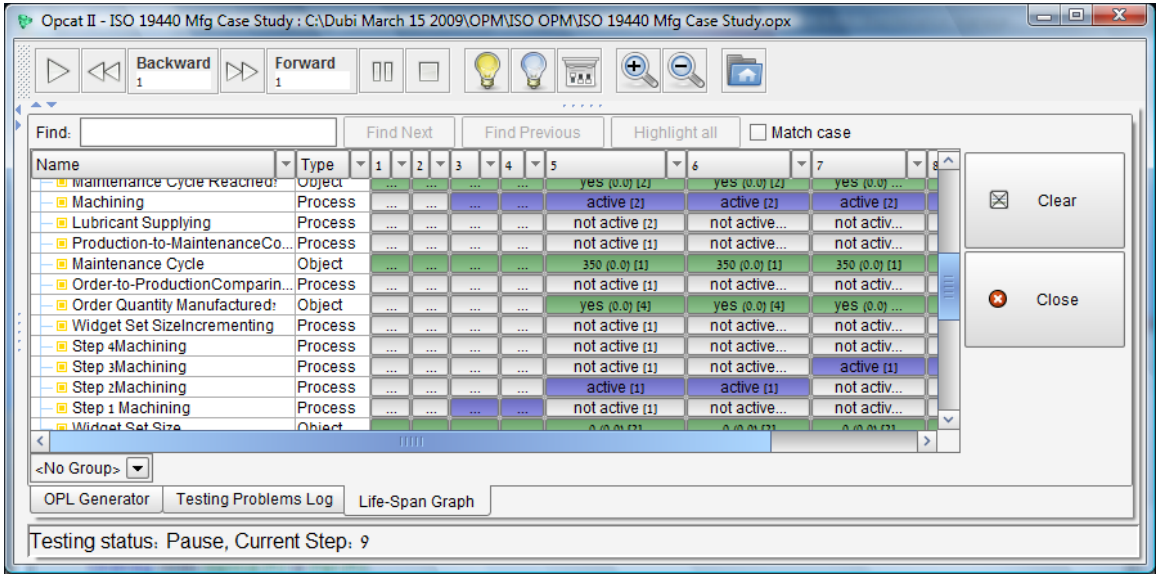




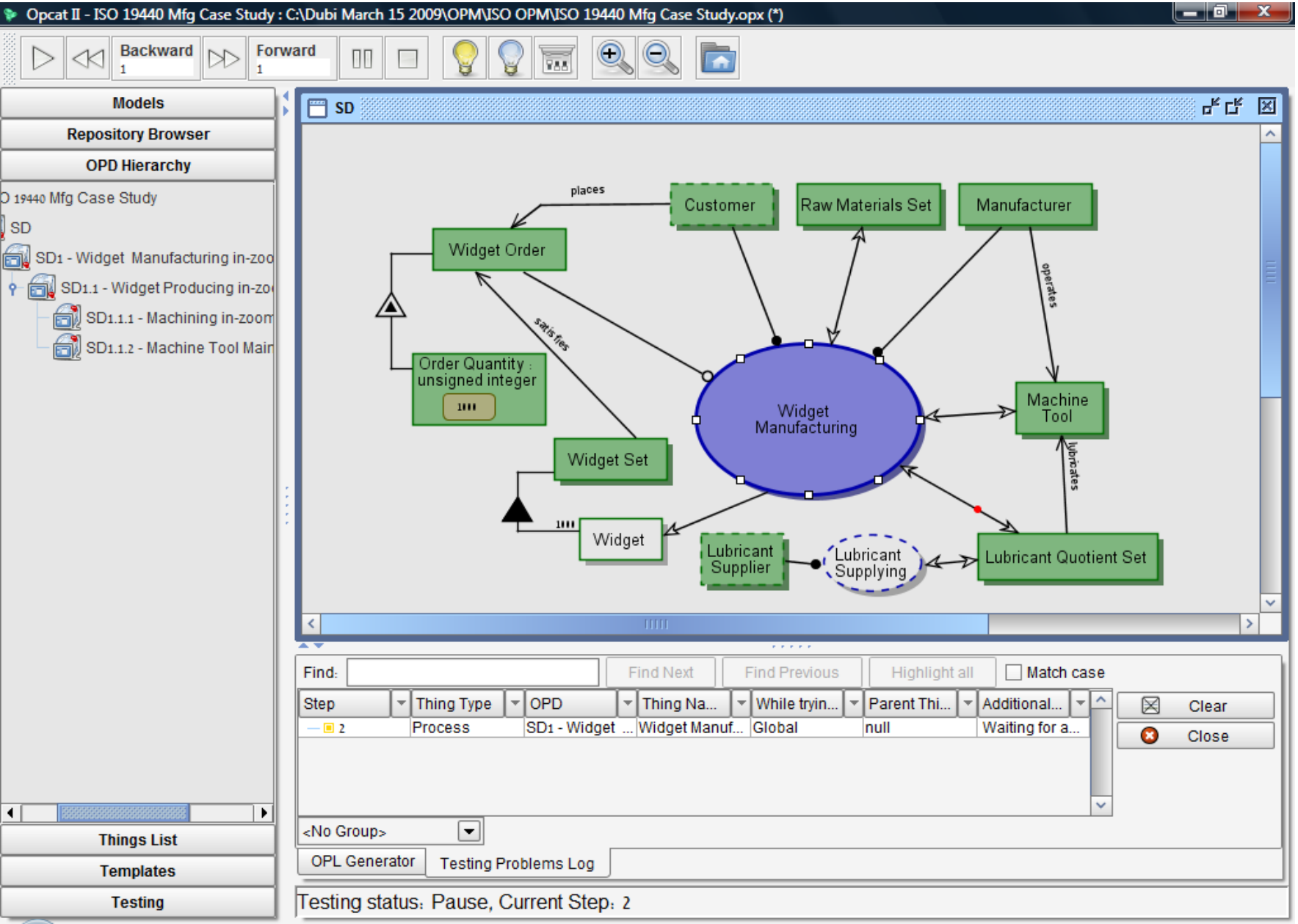
Animated simulation of the OPM model

Provides for:

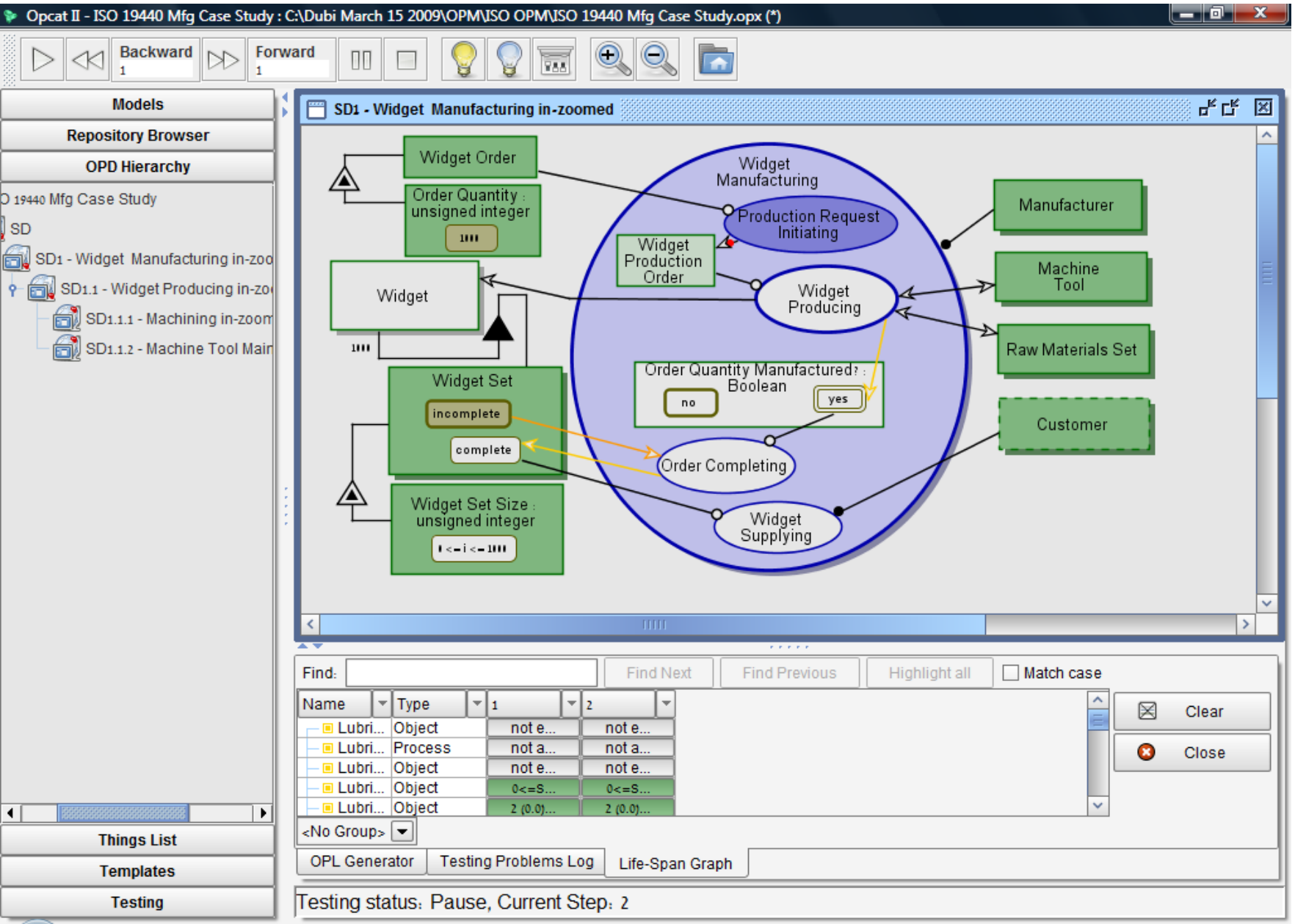
- Visualization
- Understanding
- Testing
- Conceptual "debugging"
- Communication
- Analysis via lifespan diagram:



Widget animated simulation step 2: SD



Widget animated simulation step 2: SD1



Widget animated simulation step 2: all OPDs