Abstract
System of Systems case study: a warehouse in a logistics chain.
physical partitioning

functional model

quantification

#items/hour, order size, order variation, delivery time, storage capacity, etc.
Goods and Information Flow

**financial, administrative, and logistics control**

- planning
- purchase
- sales
- delivery

**order payment**

- invoice

**planning**

- planning
- purchase
- sales
- delivery

**outlets, e.g. retailers**

- trucks
- trains
- planes
- ships

- trucks
- trains
- vans

**factories**

- suppliers

**goods flow**
Functional Model Warehouse

- **loading** → **un-packing** → **routing** → **storing and fetching** → **routing** → **picking & packing** → **loading**
- **operators** → **forklifts** → **operators** → **robots** → **operators** → **robots** → **operators** → **forklifts**
Some Warehouse Jargon

- pallet
- case
- items
- tote
- pallet
Pick and Place workstation

Storage

Pick and Place workstation
Pick and Place Design Questions

One order at a time?

One item at a time?

Stock travels along many workstations?

What are the critical design choices?

What concepts are available?
From Human to Robot

- **Intelligent adaptive**
- **Many DOF**
- **Fine control**
- **Flexible**

**Human**
- **Brains**
- **Arms**
- **Hands**
- **Legs**

**General purpose**
- **Tactile nerves**
- **Flexible**

**Robot**
- **Camera**
- **Gripper**
- **Computer**
- **Software**
- **Arm design**

**Systems of Systems Case study**

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Robot Design Questions

What Gripper and Robot Concepts are appropriate?

What are the desired properties?

What kind of items must be handled, and how?

→ Use examples to explore
Example 1: Large Volume Drugstore

Large quantities
box-like packages

w, l, h: 0.1..0.5m
weight: 1..40 Kg

simple gripper
1 DOF

simple robot
"H" for X, Y, and Z movements
Example 2: High Dynamics

- supplier
- warehouse
- drug-store

Highly dynamic product mix and suppliers
Large quantities various packages
\[ w, l, h: 0.1 \text{..} 2.0 \text{m} \]
\[ \text{weight: 0.1 \text{..} 50 \text{Kg}} \]

Multiple grippers needed?

There is no time to teach (program) the robots how to handle package variety
And more variants...

supplier

warehouse

shop

small quantities
fragile packages
packaging constraints

production

critical delivery time
(e.g. fresh food)
delivery at shop
Recap: Levels and Partitioning

- Global goods distribution
- Warehouse
- Pick and place station
- Robot
- Vision
- Gripper
- Arm
- Sensor
- Recognizer
- Camera

- Super SoS
- SoS
- System
- Subsystem
- Component
Warehouse Control

this is a SoS in itself

planning
purchase
sales
delivery

warehouse scheduling

local control
local control
local control
local control
local control

Systems of Systems Case study
version: 0
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SOSCwarehouseControl
Typical Project Life Cycle

- tender
- design and engineering
- installation
- operation and maintenance
- disposal

customer interaction
visualizations
simulations

order

offer

acceptance
final payment

SoS Engineering
as pre-investment

in case of service business:
recurring revenues

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SOSCprojectLifeCycle