# *Product development and design methodology Research and application in industry*

*Professor em Jan-Gunnar Persson*

*Machine Design KTH*

***Design and Production Engineering***

***Berlin July 26 2016***

# Industrial revolutions

18th to 19th century: Steam Engines

19th to 20th century: Internal combustion engines, electric motors

Fossil fuel and nuclear based energy

→ Development & changes in many stages, long growth periods

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Today: chips, fiber optics, computer software, IT networks, ……

Transition to various forms of solar energy [ solar inflow 1 Bill TWh/y; global consumption 0.15 Mill TWh/y ]

→ Much faster development and changes

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## The fourth industrial revolution:

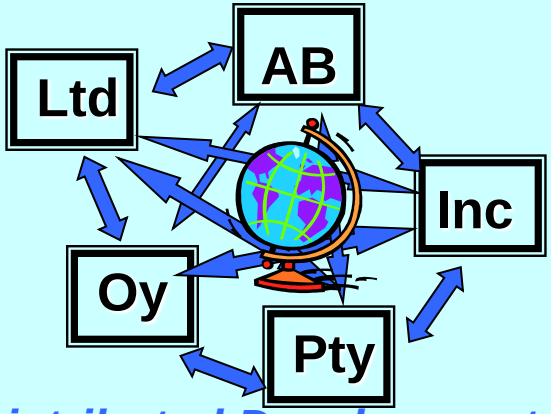
- Decentralized ”smart” factories
- Automation, robotization
- Knowledge based engineering
- Cloud based CAE, simulations
- Data exchange, cooperation and service monitoring in networks

Changes → { Opportunities / Risks }

# Current trends in Product Development



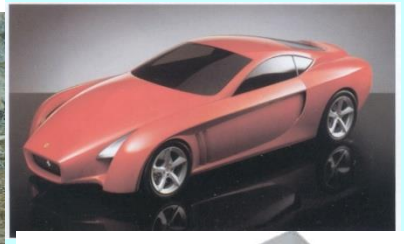

**Service systems**
**Function sales**
**producer ownership**




***Distributed Development***

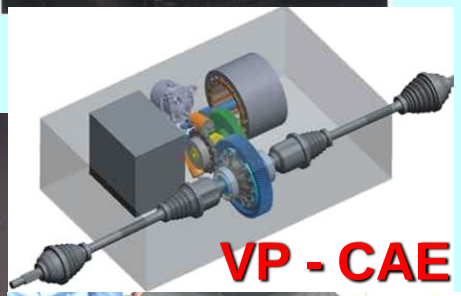
***Industrial Design Engineering***







***Modular Design***
***Product Platforms***

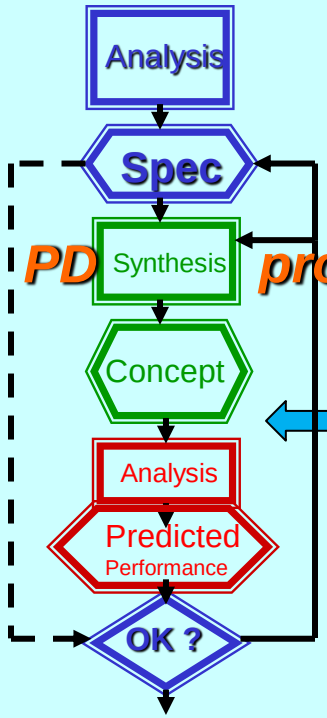


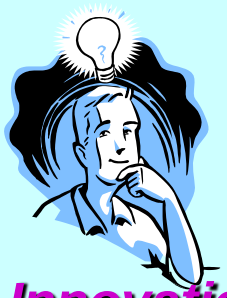
***VP - CAE***



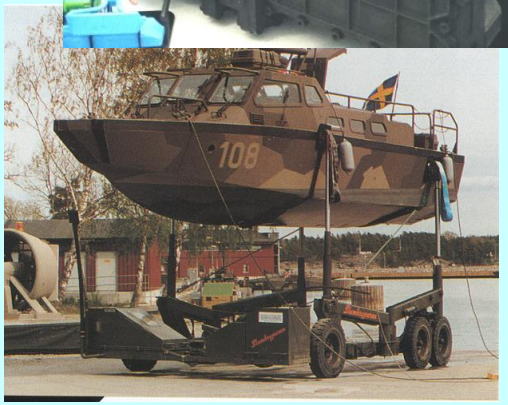


***Mechatronics & robotics***



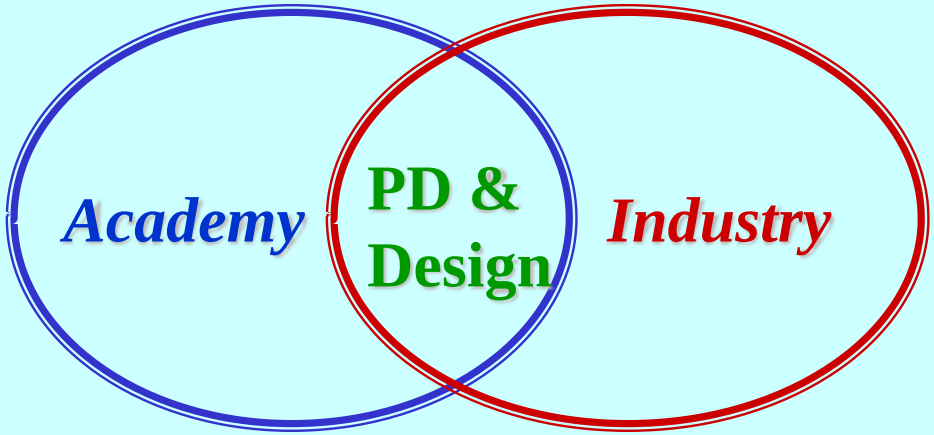
***Innovation***



***Mechanics - hydraulics***

# *Prodcuct Development & Design*

## *Characteristics:*




- ***A young research field***
- ***Holism***
- ***Synthesis***
- ***Sustainability***
- ***Integration - Innovation - Iteration***

# PD Driving forces

- **Technology** — laser, integrated circuits, cellular phones, GPS-navigation, fiber optics, ……
- **Market** — product modifications, ”annual face-lift”
- **Society** — environmental performance, sustainability, health & safety, life style

# *Product Design - current situation*

Complex Multi-Domain System Design

**Engineering Design**

**”Hard”** product properties = Nescessary Requirements

**Industrial Design**

**”Soft”** product properties = Basis for buing decision & competitiveness!

# *Product Development*

## *Improve Performance/Cost ratio!*

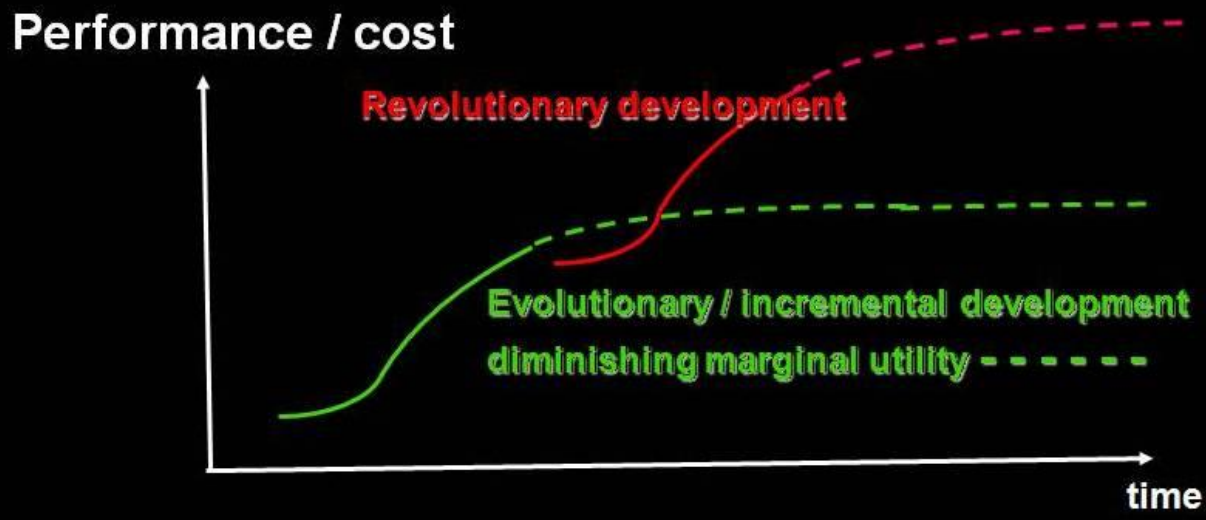
Hard & Soft Requirements

*"Performance"* = { *Technical performance, "**hard**" requirements*

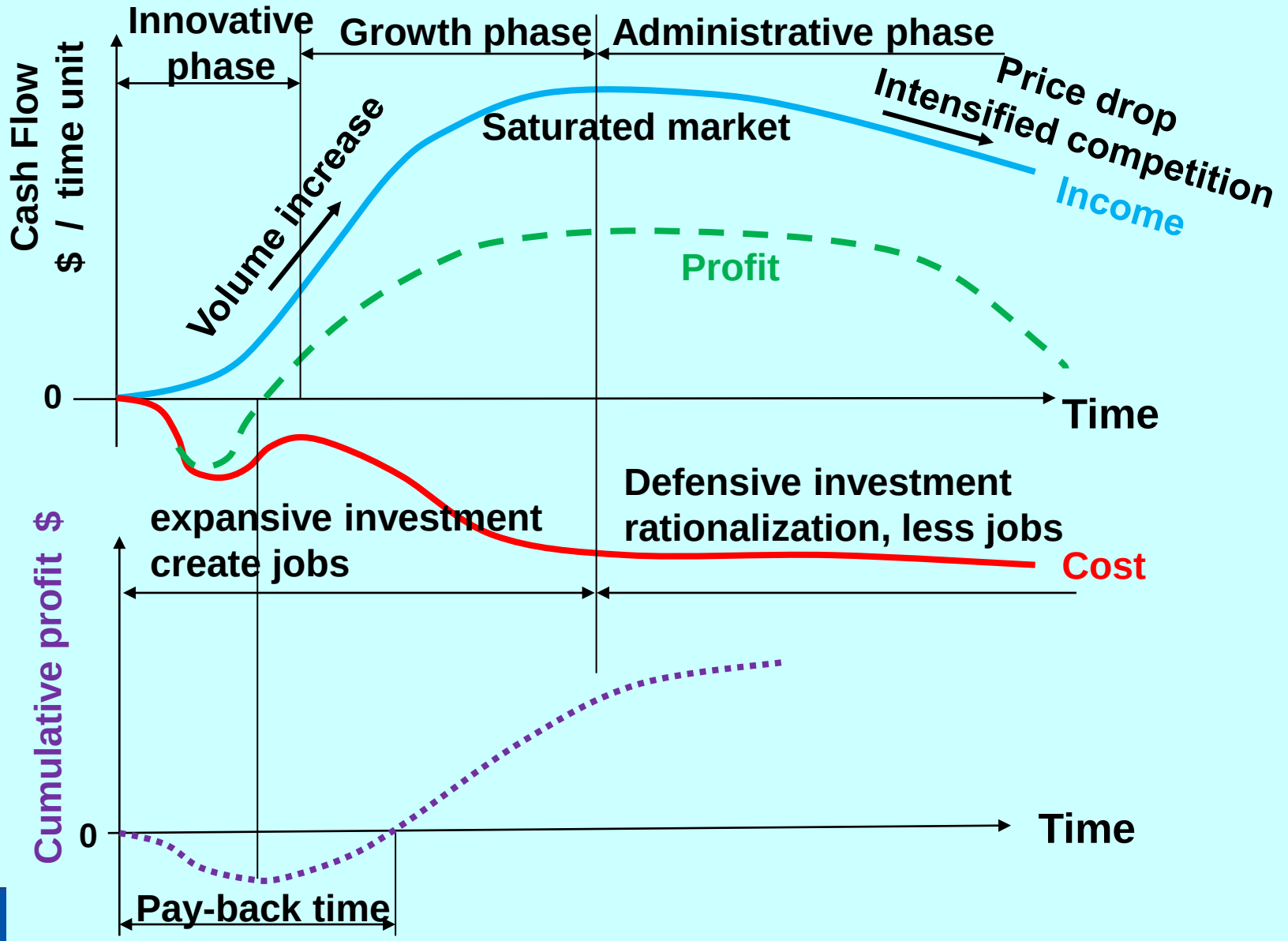
*Aestetics, ergonomics, user interface; "**soft**" req*

*"Cost"* = { *Economy for customer and manufacturer*

*Environmental impact over Product Life Cycle*

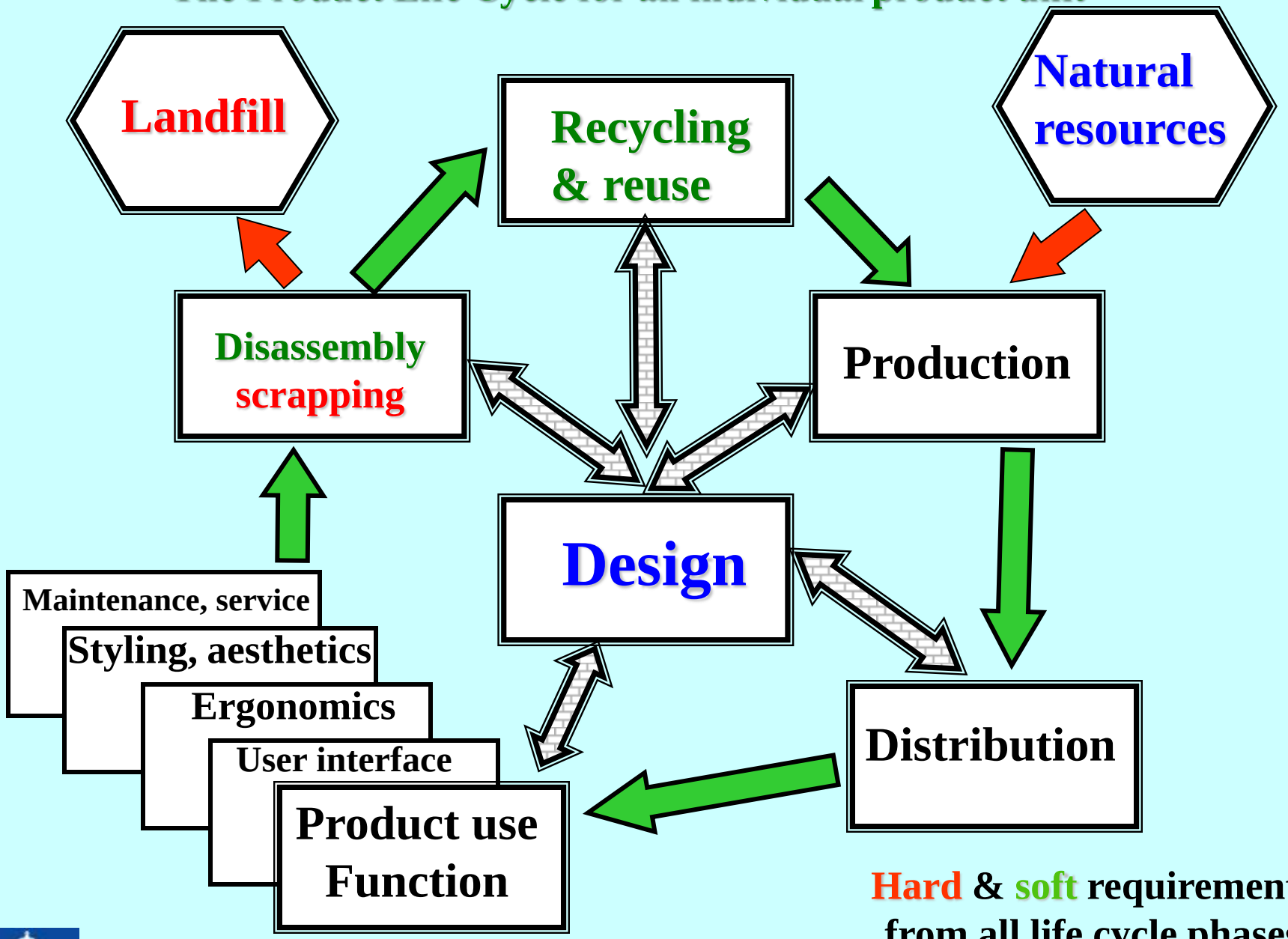


# A product generation´s life cycle on the market - ”S-curve”




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# The Product Life Cycle for an individual product unit




**Hard & soft requirements from all life cycle phases**

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# Products´ environmental load

**Active products**: **Energy consumption and emissions in user phase dominating**

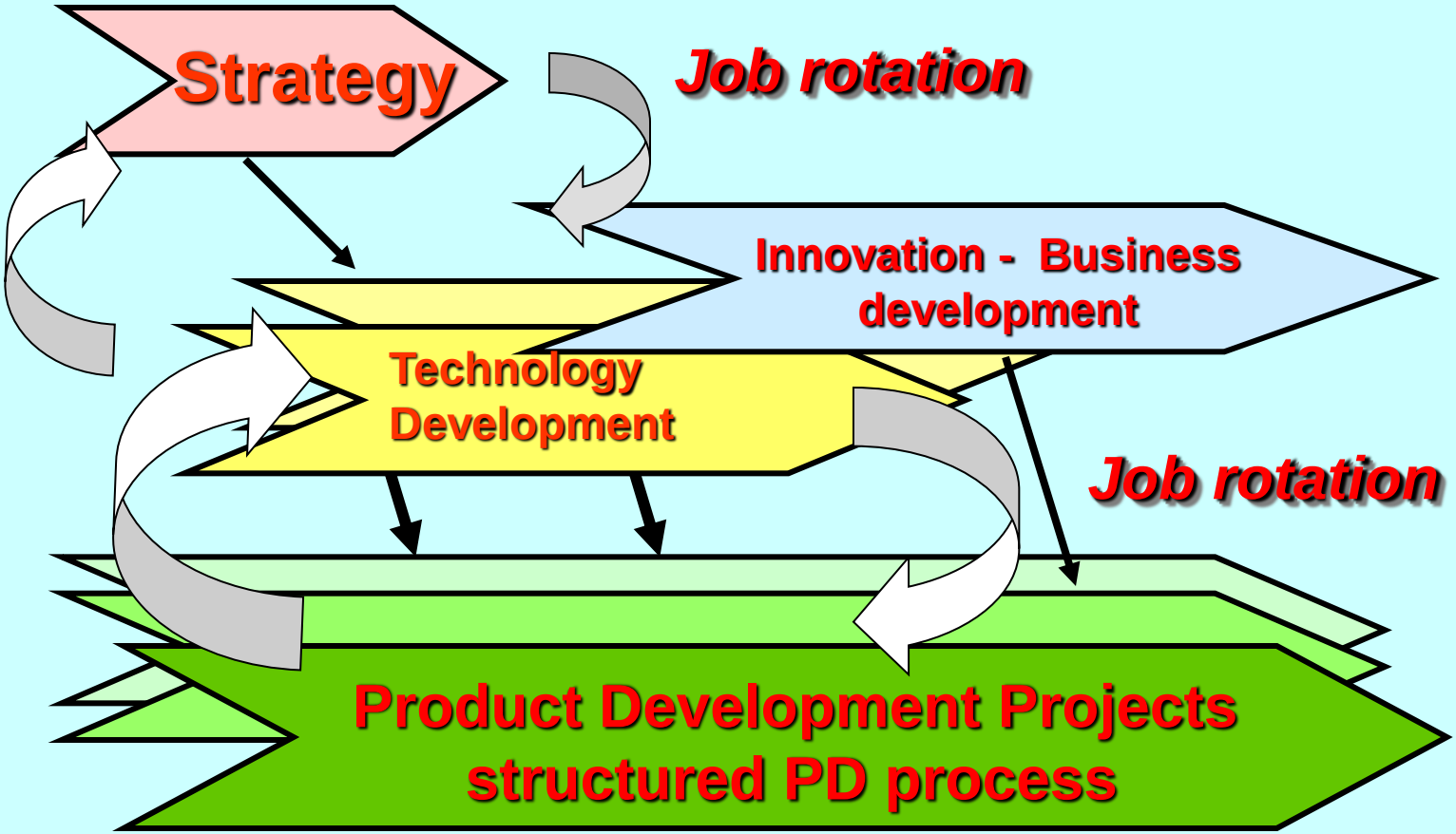
**E.g. vehicles, refrigerators, stoves,…..**

**Passive products**: **Virtually no energy consumption in user phase, energy & materials consumption in production and disposal phases dominating**

**E.g. Building structures, storage vessels, ……..**

# 3-stage Development Process

## Industry and academic research




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# Product Development (PD) Characteristics

**Iteration:** Speed up by simulation: CAE, Rapid Prototyping, VR-Virtual Reality

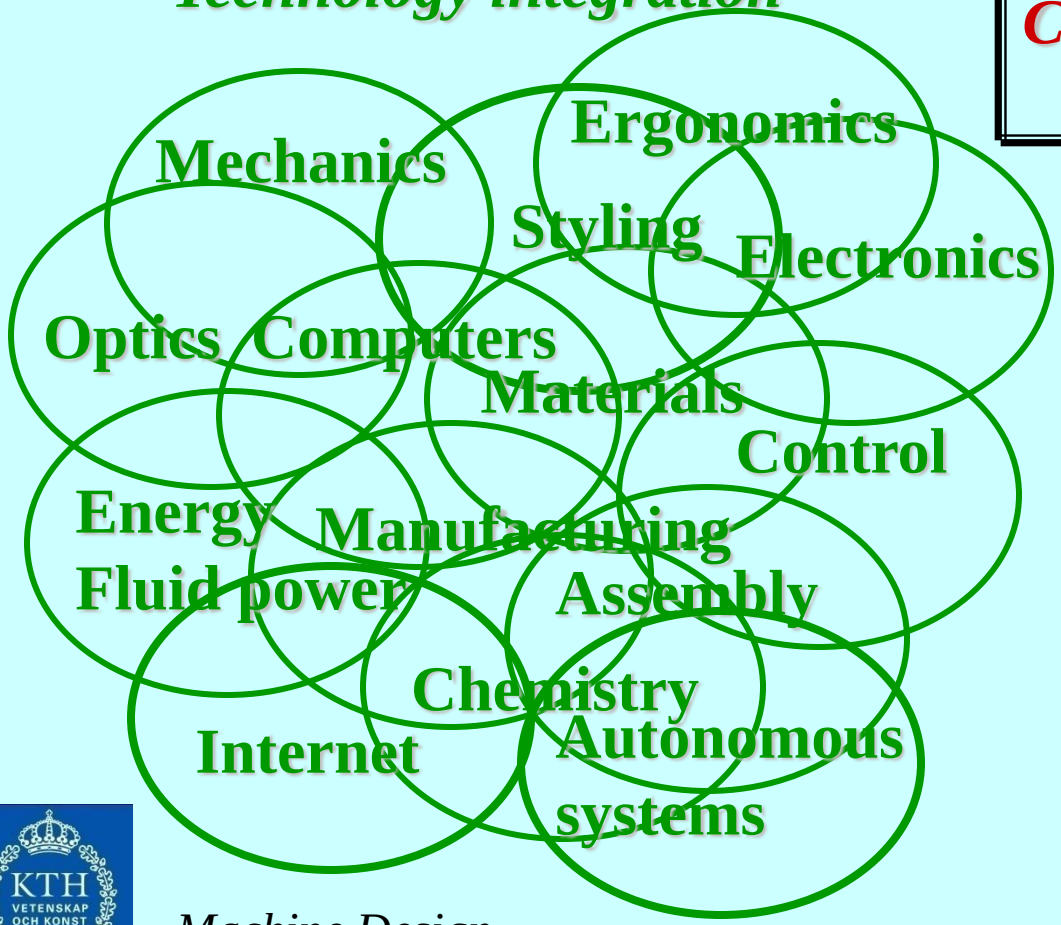
**Integration:**
- Engineering Design & Industrial Design
- Different technologies, multi-domain
- Organisational, Concurrent Engineering, IPD
- Distributed PD

**Innovation:** Free innovation vs´ controlled PD process

# Prodcuct Development

## Integration

*Technology integration*




*Organizational integration*
*Concurrent engineering*

- Marketing
- Engineering Design
- Industrial Design
- Production

# *Product Development – changing conditions*

**External pressures on companies**

- increased customer req., performance/price
- customer preferences, “soft” properties
- customized products
- increasing society demands
- tougher competition
- shorter product life cycles

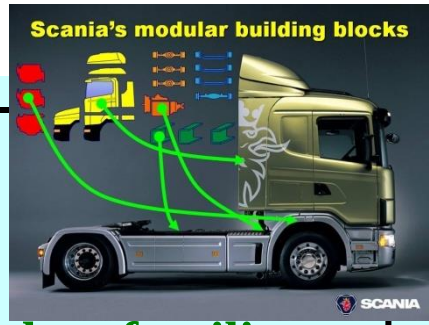
**Impact on companies**

- higher development cost
- many product variants
- project time (“time-to-market”) critical

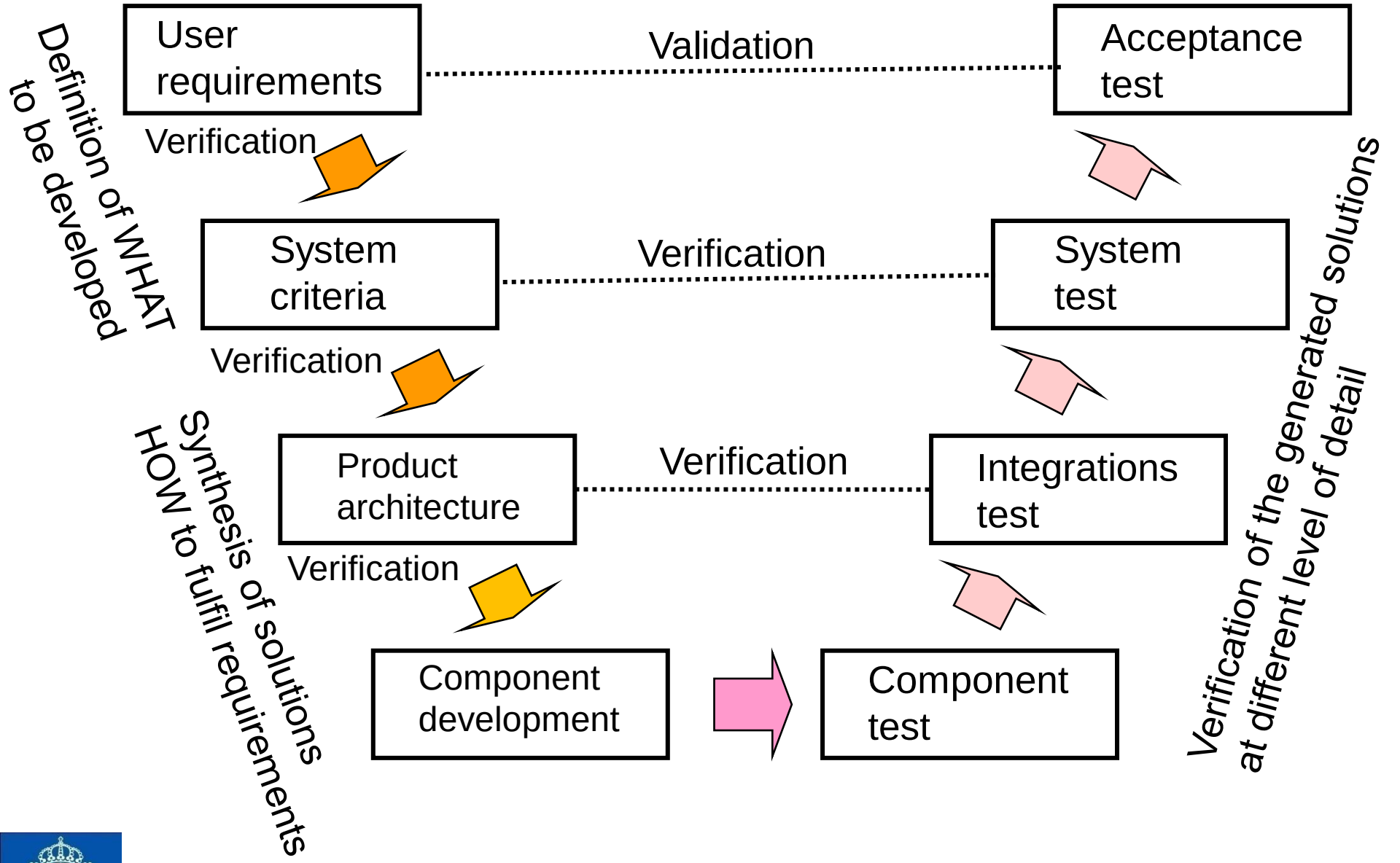
**Companies´ response**

- design systematics, PD-process
- integration
- standardizing ***and*** flexibility => modularized product families



# The well established ”V-model” for PD




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# Design support methods

## often used for support in design teams

QFD - Qality Function Deployment
Customer requirements → design solutions

FMEA - Failure Mode and Effect Analysis
bottom-up approach

FTA - Fault Tree Analysis
top-down approach

} Safety

DFA - Design for Assembly

DOE - Design of experiments

TIPS / TRIZ Theory of inventive problem solving – innovation support

LCC - Life Cycle Cost

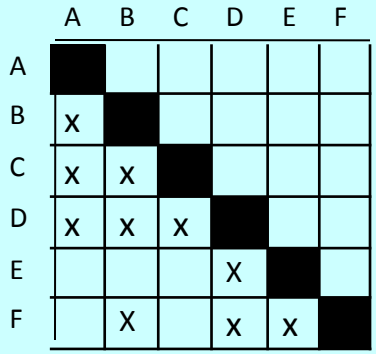
LCA - Life Cycle Assessment
Estimation of environmental load over all life phases
Complex method – for specialists

# Analysis of couplings and interdependencies

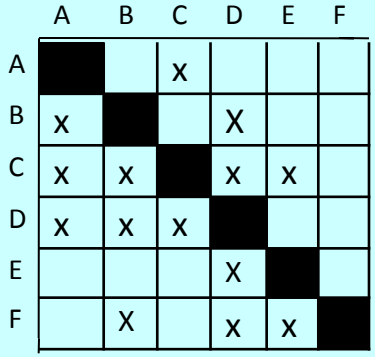
# Seek to minimize couplings!

## DSM – Design Structure Matrix:

**A, B, C,… can represent components, sub-systems, or project activities**




**Decoupling possible if sequential execution:**
**All activities (or subsystems) dependent on the previous activities**

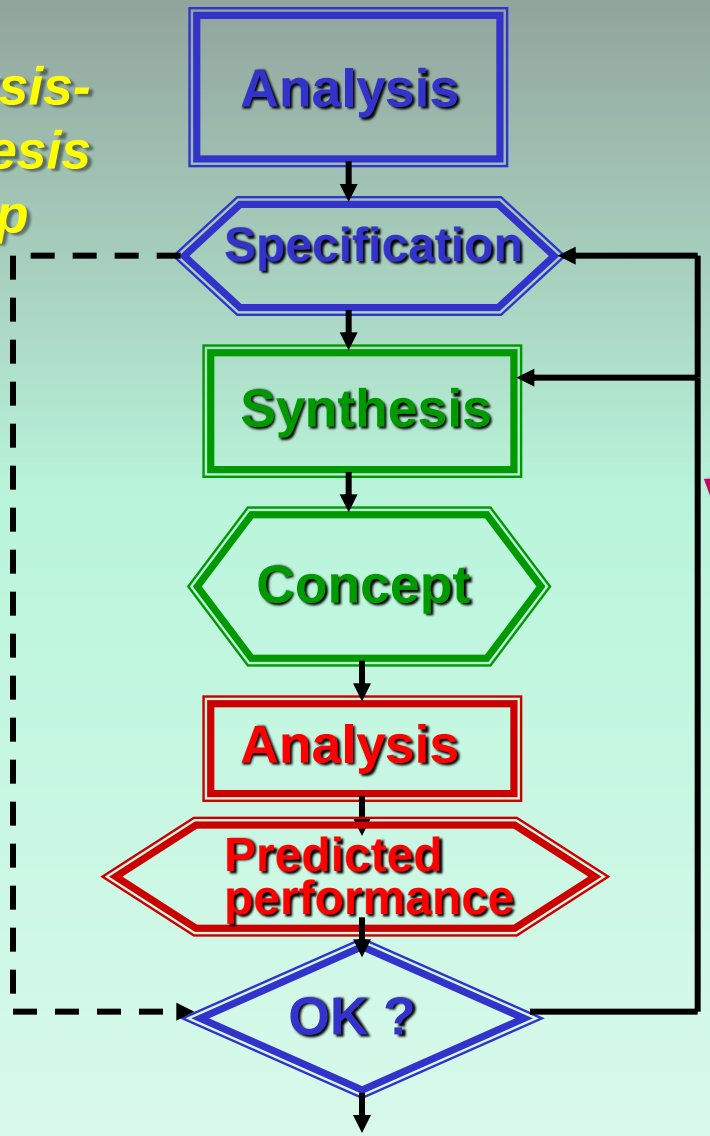



**Strongly coupled, decoupling not possible:**
**Activities (or subsystems) dependent on both previous and following activities**

**Axiomatic design: Similar approach – minimize couplings**

# Structured PD process
# Lean design

Analysis-Synthesis loop




VS´

## Free innovative Design



Visionary

Slack resources

”Skunk Works”


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# Innovation support – Industry sucess factors

- Investigate real needs – don´t ask customers!
- In-house R&D and development of key components
- Co-operate with major system integrators (globally)
- Visionary management persons, management support
- Freedom and responsibility
- Alternative solutions for critical subsystems

**Both needed!** { **structured PD process** **and** **free innovation**

# *Standards to be used in product development*

**ISO 9001 Quality management**

**ISO/TS 16949 (QS 9000) Automotive quality standard**
**AQAP 2110 NATO quality assurance**
**MIL-Q-9858A US military quality assurance**

**ISO 10303 STEP – Exchange of product model data**

**ISO 14001 Environmental management**

**ISO 50001 Energy management**

**ISO 27000 Information security**

**ISO 26000 Social responsibility (guidance)**

**……**




# Mechatronics Robotics

## Robot & human co-operation

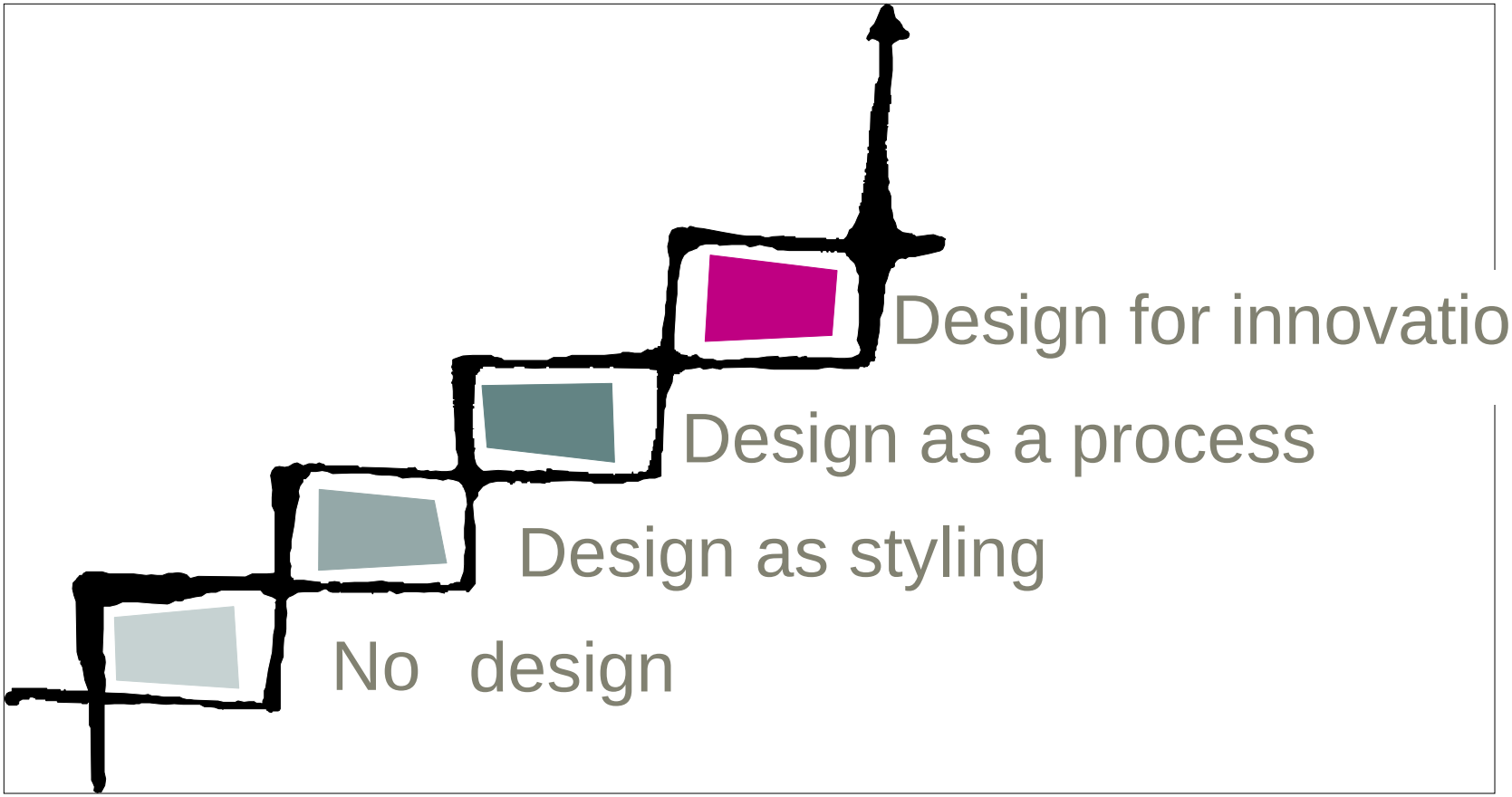
## Artificial senses robot haptics






# Industrial Design – more than just styling!

## The design ladder – the company's design maturity




(September 2003, Danish Design Centre, "The economic effects of Design" - the design ladder model)

# Current trends in Product Development

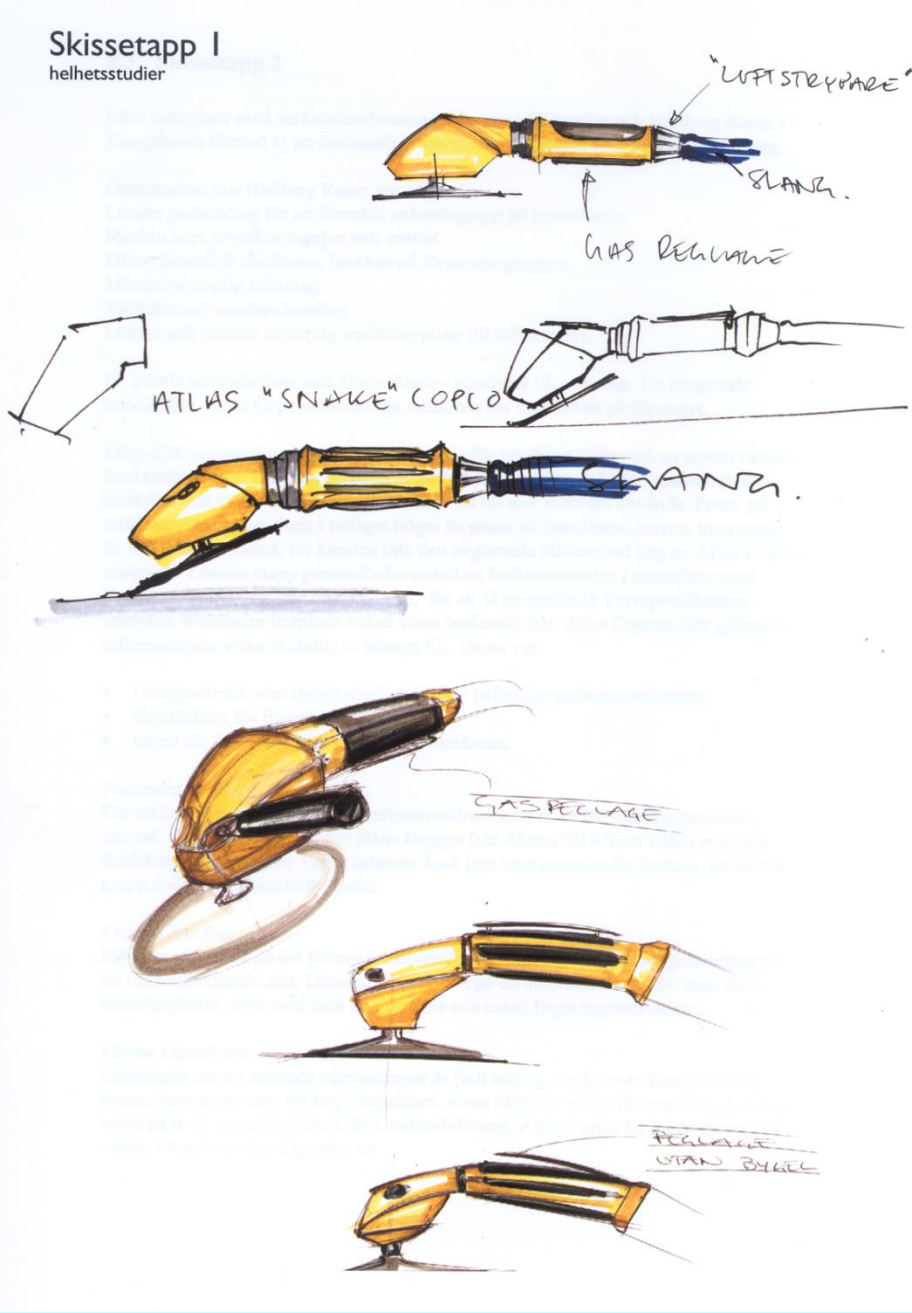
Industrial Design Engineering - synergy between Engineering and Industrial Design



- Ergonomics
- User friendliness
- Technology
- Performance
- Innovation

# ”Soft” Product properties:

- **Industrial Design**
  - Form
  - Colour
  - Surface structure (tactile, haptic perception)
  - Semiotics (product´s expression)
  - Sound, smell, …, all senses
- **Ergonomics**
  - Biomechanics (human force, power)
  - Anthropometrics (human geometry)
  - Perception (interpretation of signals)
- **Envirionmental Impact**



# Industrial Design of investment goods – B2B

## Atlas Copco




Mine Truck



Drill rig Control panel



Drill rig Operators cabin

# Volvo Construction Equipment




## Industrial Design of investment goods – B2B



**SSRS**

The Swedish Sea Rescue Society
Rescuerunner

# Industrial Design

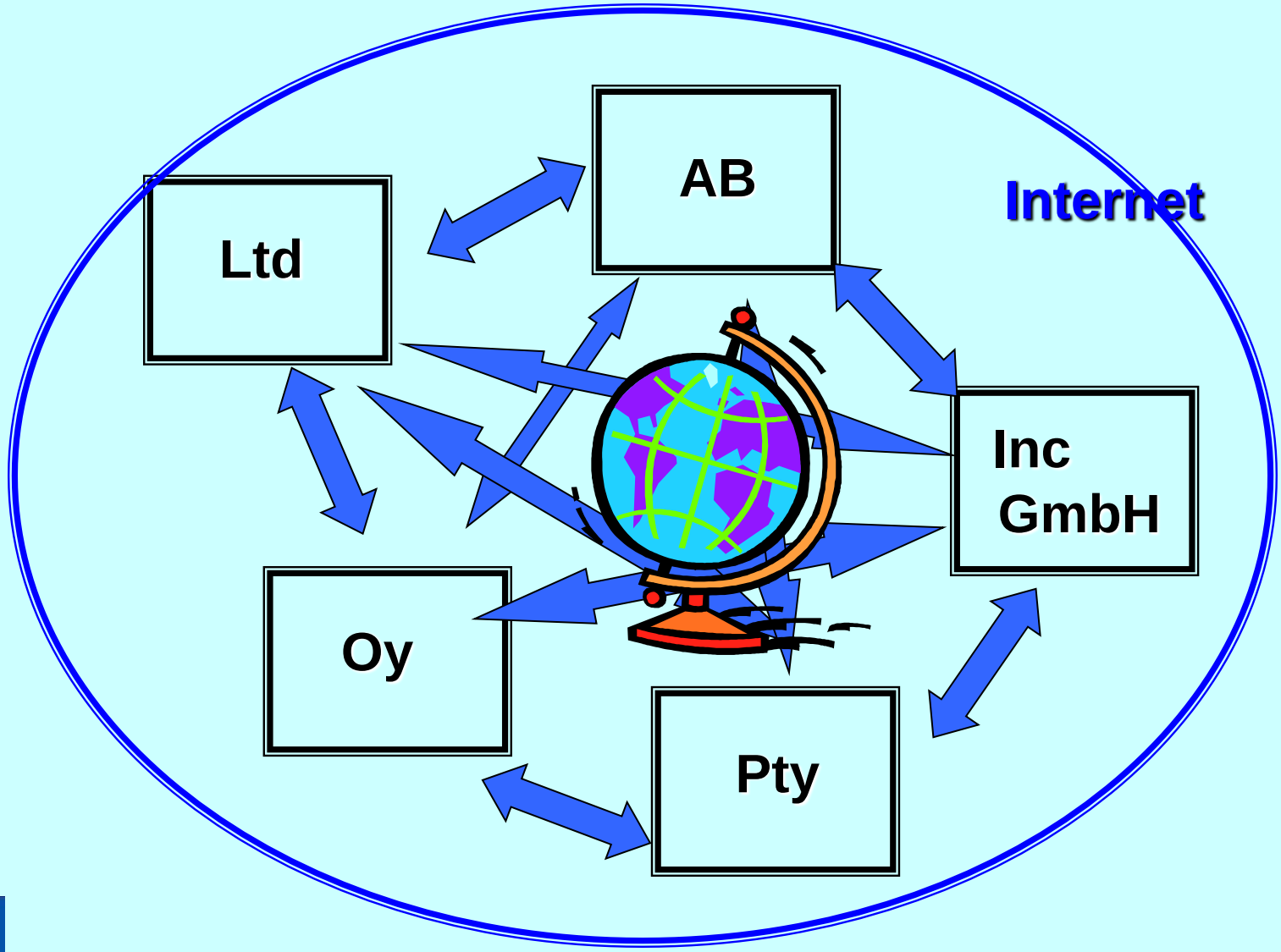







# Current trends in Product Development

## Distributed Development



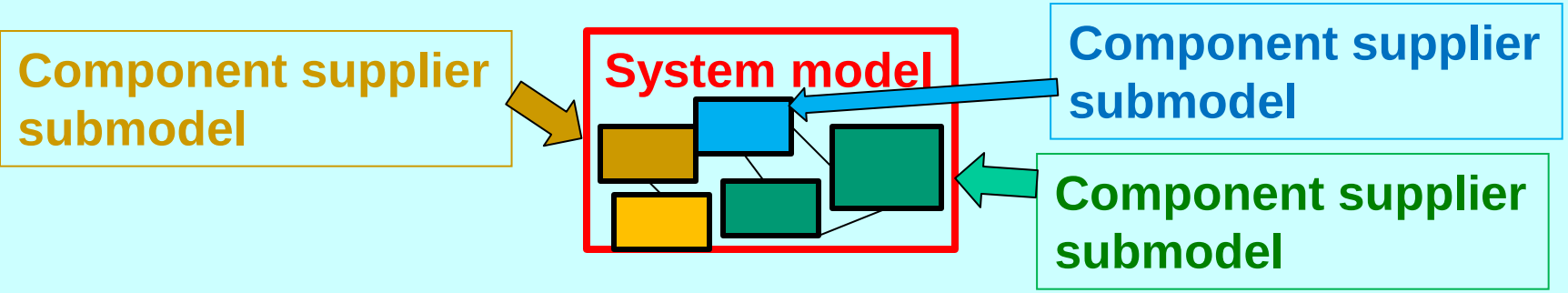
# Distributed Product Development

## Some examples:

### EC 5th FP project: NFCCPP

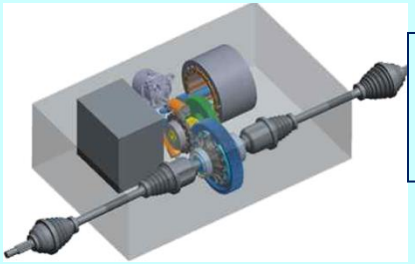
### – Numerical Fuel Cell Component Performance Prediction

### Fuel Cell modular system simulation




### EC 7th FP project: ODIN

### – Optimized electric Drivtrain by Integration



Power electronics

Gearbox

Cooling & lubrication Fluid

High speed electric motor

# PD - VP Model based development

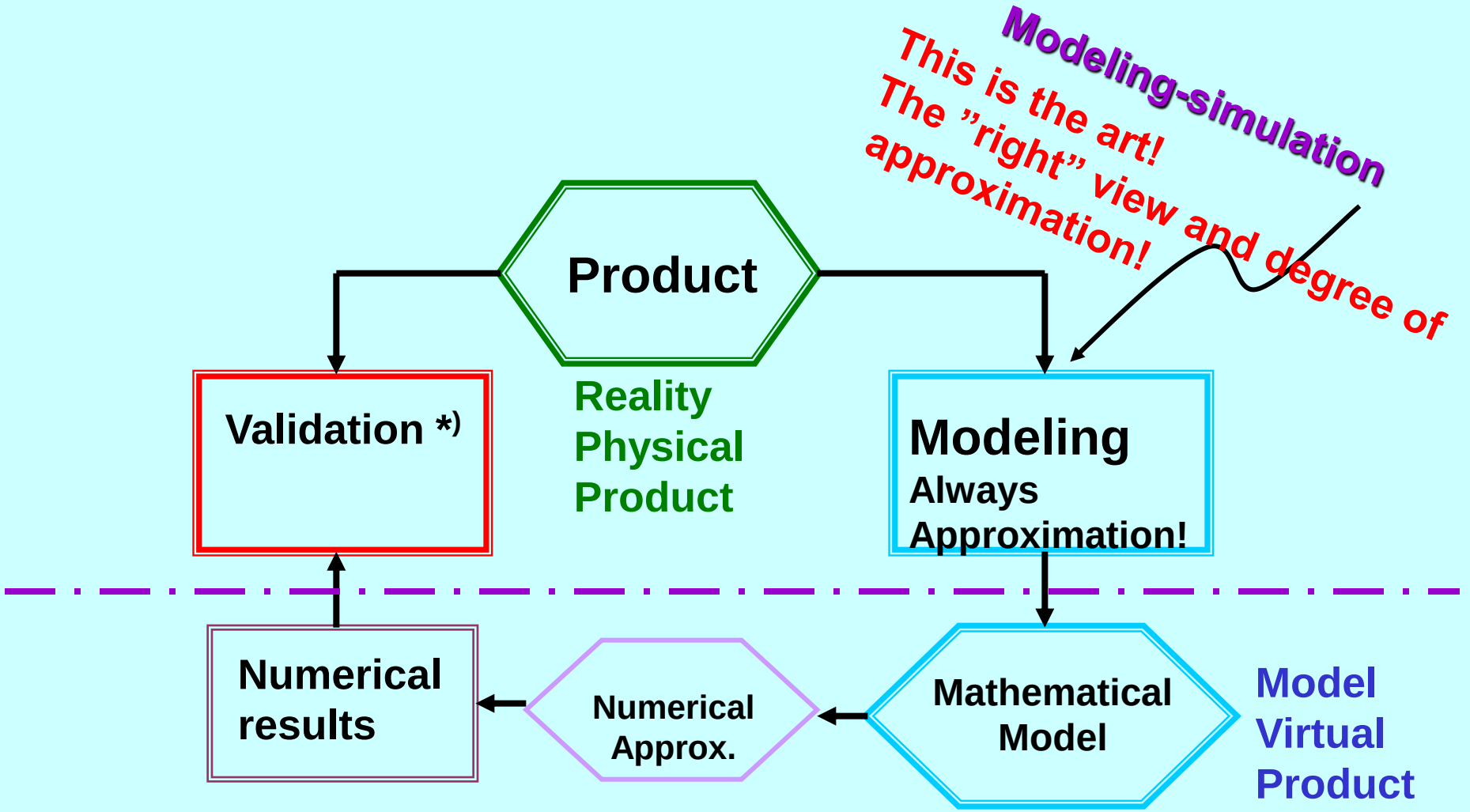
## Virtual prototyping – VP

- Extensive use of CAE (simulation, optimization) to minimize physical testing
- Simulation means much faster iterations, many more parameter sets evaluated
- Simulation results to define most relevant test cases



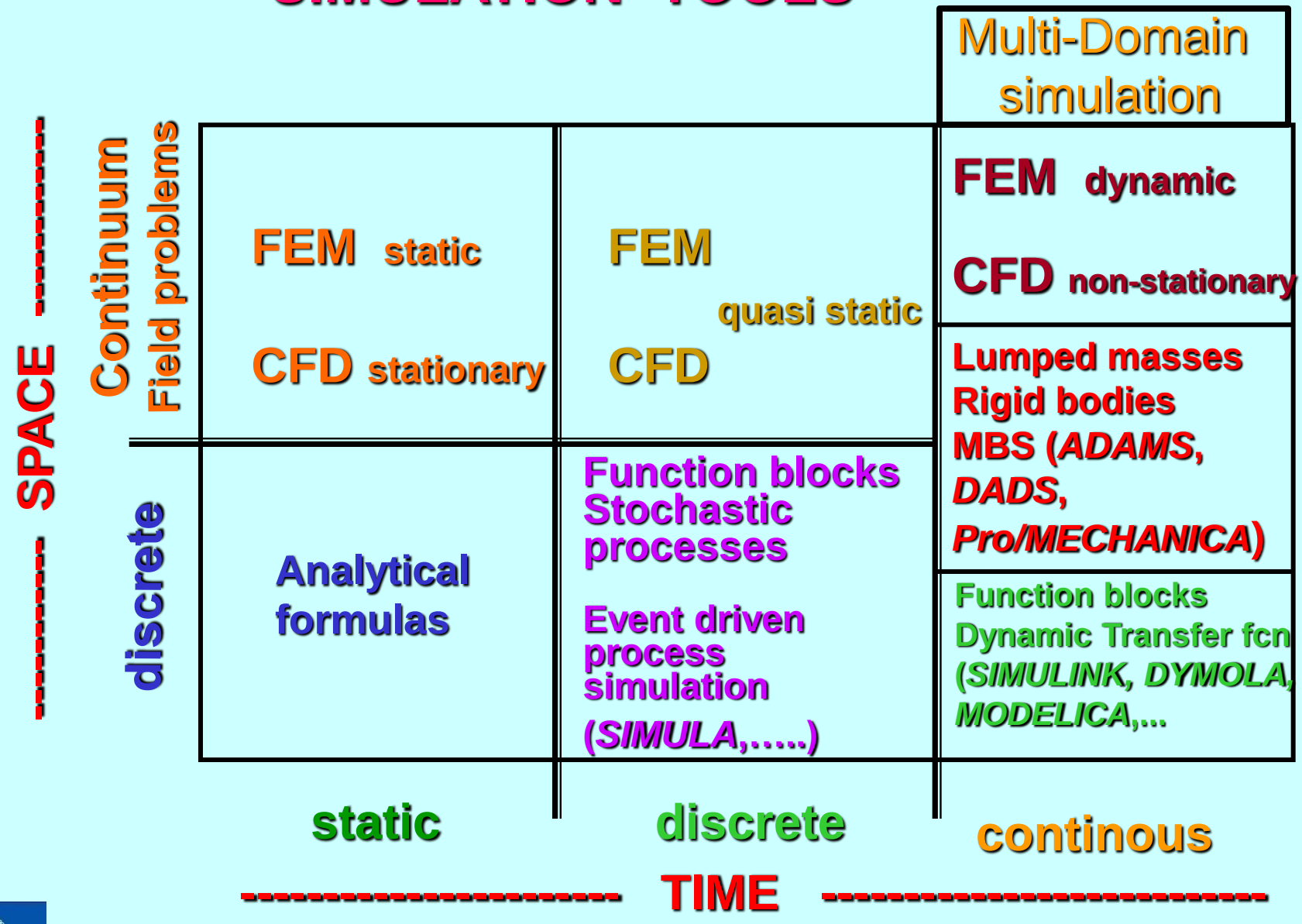
Interaction simulation – physical testing

- Test results to improve simulation models
  - anticipate the unexpected
- Integration of engineering analysis and design, replacing specialized analyst groups
- Modular model architecture




*) **Validation – verification & check for model relevance,**
**e.g. vs´ measured data from real prototype tests**
**The validity cannot be strictly proven!**

# SIMULATION TOOLS

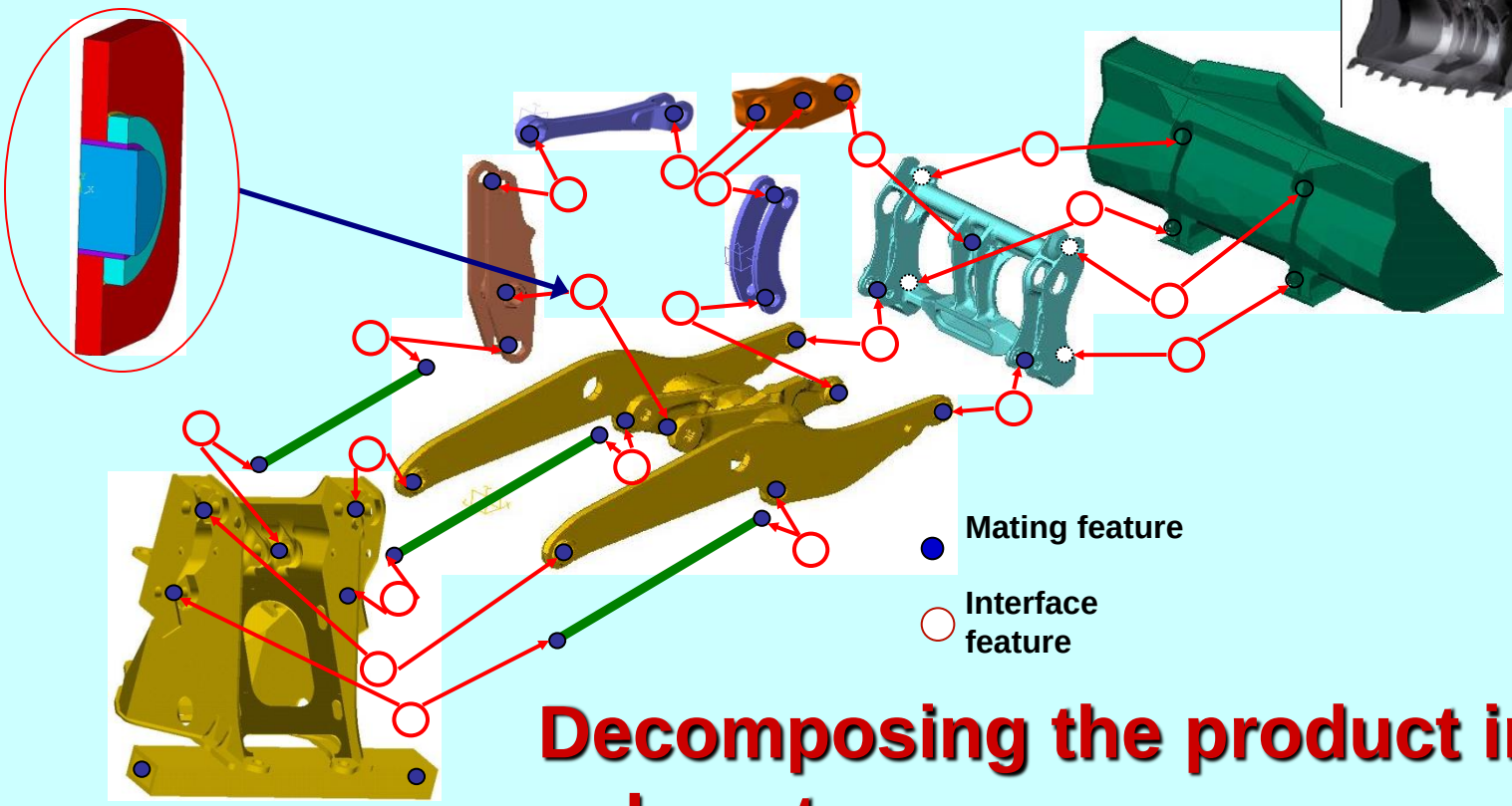


# Modular model architecture

## case Volvo VCE wheel loader







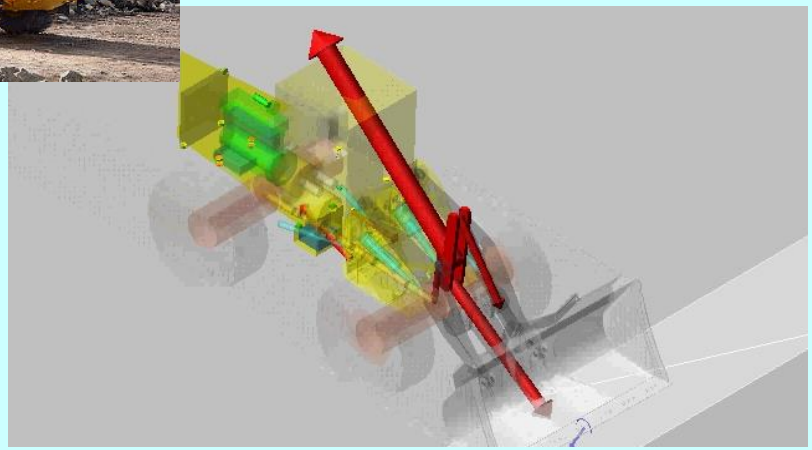

**Decomposing the product into subsystems**

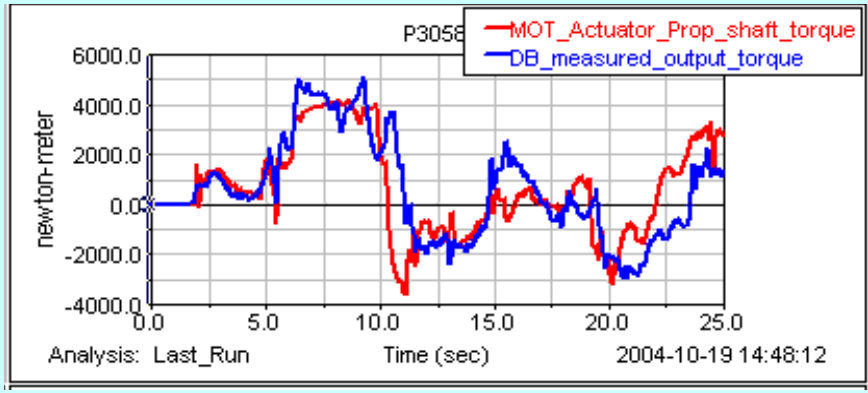
**MBS – rigid body software for analysis of motion and forces**

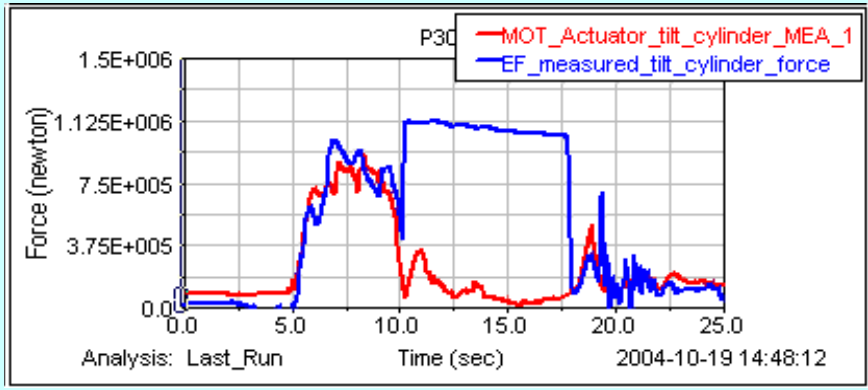
# Wheel loader example

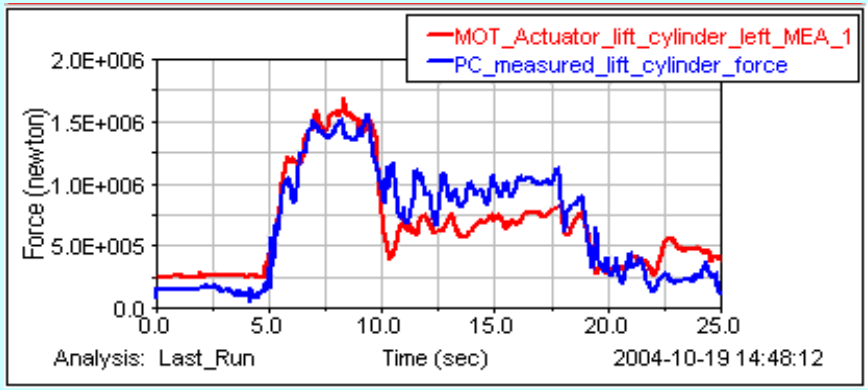
## Bearing loads, bucket frame





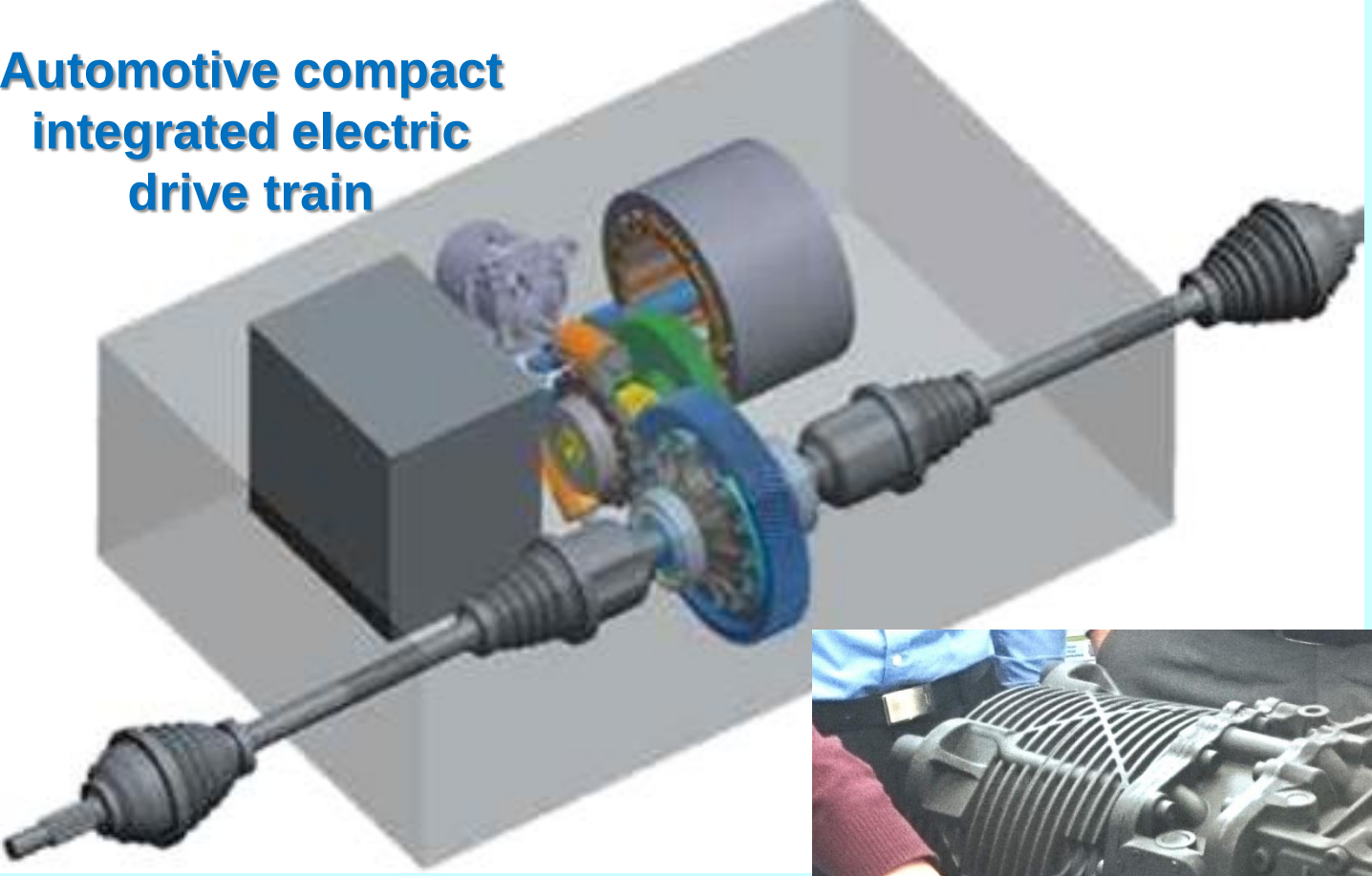


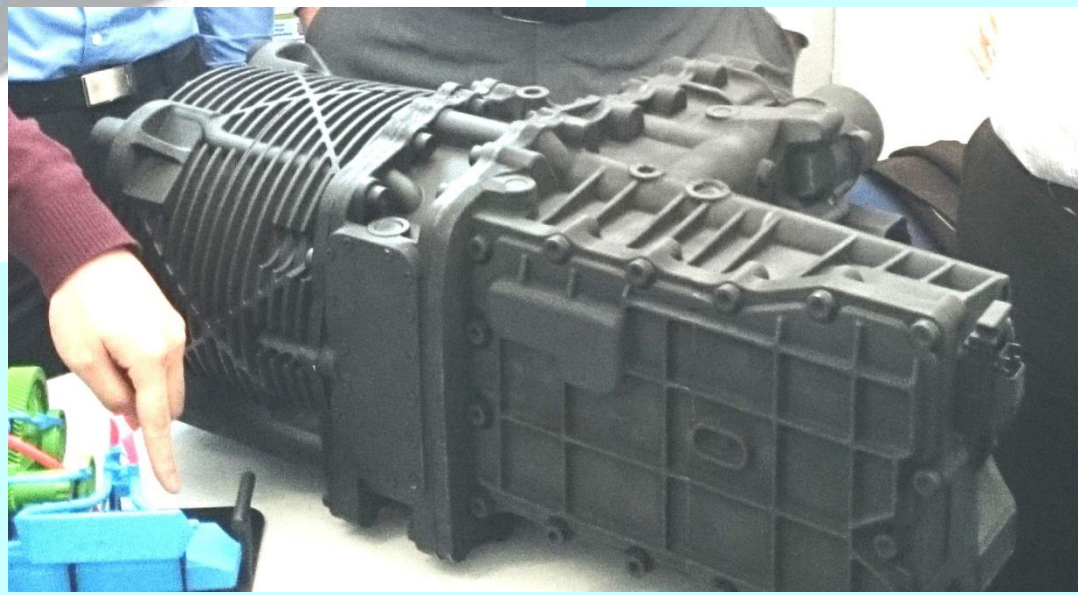

- **Comparing measured and simulated values**
- **Good correspondance except for the tilt cylinder (as hydraulics not modelled)**

**Automotive compact integrated electric drive train**



# Model based design

## VP - CAE



**Rapid prototyping electric drive train mock-up**

# S T E P  Express

## S T E P = Standard for the Exchange of Product Model Data
## ISO 10303

**Effective information exchange between different IT systems**

**Neutral file data storage and communication between CAD, CAM, CAE, PDM, PLM**
**E.g. geometry, dimensions, tolerances, manufacturing data, maintenance data,…..**
**Data for all life pháses of a product**

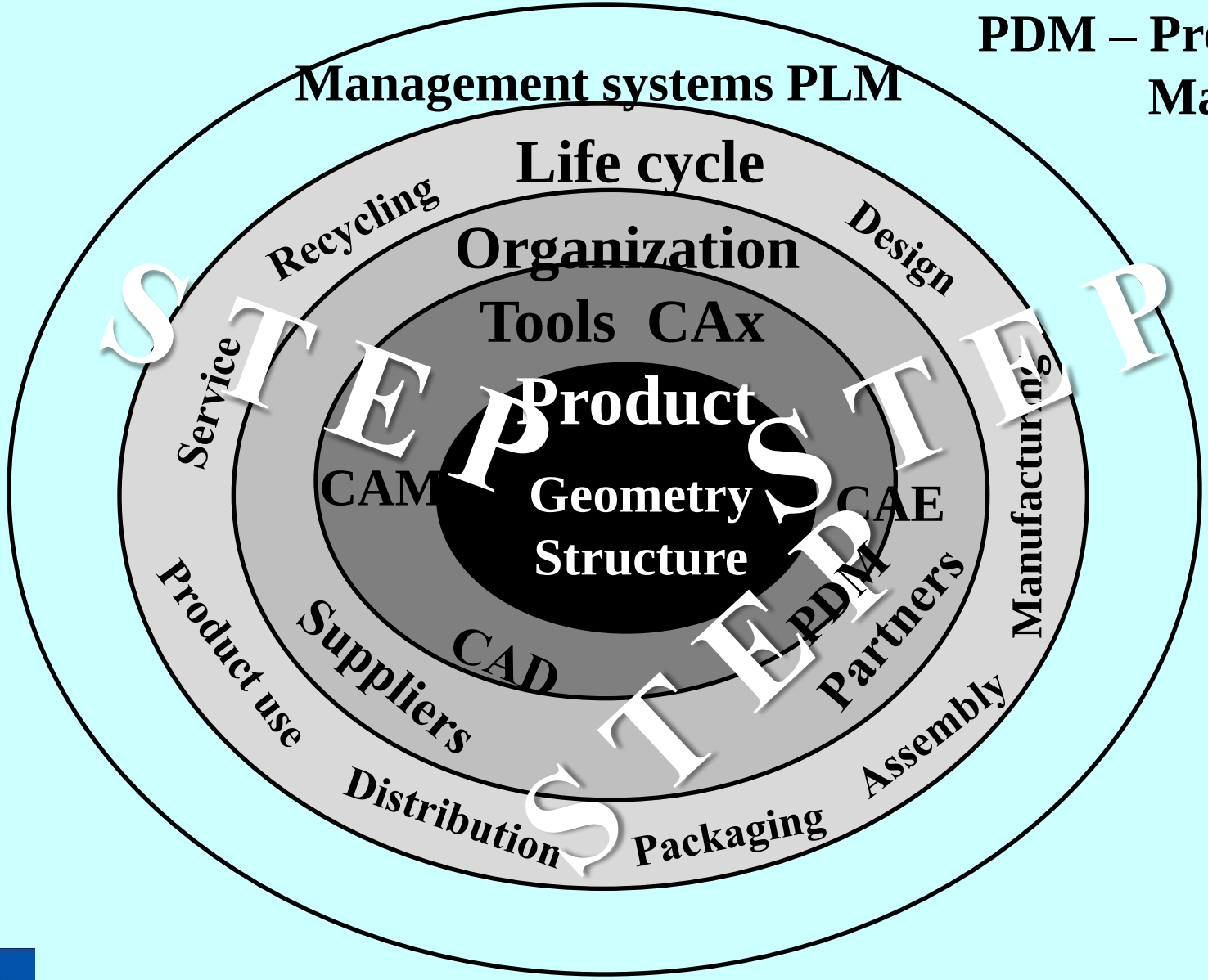
**STEP comprises several industry specific areas of application AP = *Application Protocol***
**E.g. AP 214 *for automotive mechanical design***

**Express = information modelling language**
**to unambiguously define concepts and logical relations**

**AP 203** ***Configuration controlled 3D designs of mechanical parts and assemblies***

# PLM – Product Life Management

**PDM – Product Data Management**



# Reverse Enginering - RE

## Physical product ⟶ CAD Model
## for spare parts, redesign, copying, …

”2D” designs: Measurement of critical dimensions

Complex curved ”3D” designs:

- 3D scanning by:
  - coordinate measuring machine
  - optical methods (e.g. laser scanning)
  - X-ray – computed tomography
- Data reduction of measured ”point cloud”
- CAD modeling from reduced point cloud

***Info on tolerances, material properties etc not directly obtained***

# Market analysis

## Products used in industrial processes

**Potential max utilization of the product, total ”fleet” of products**
**Global volume expressed e.g. in value, capacity, power**

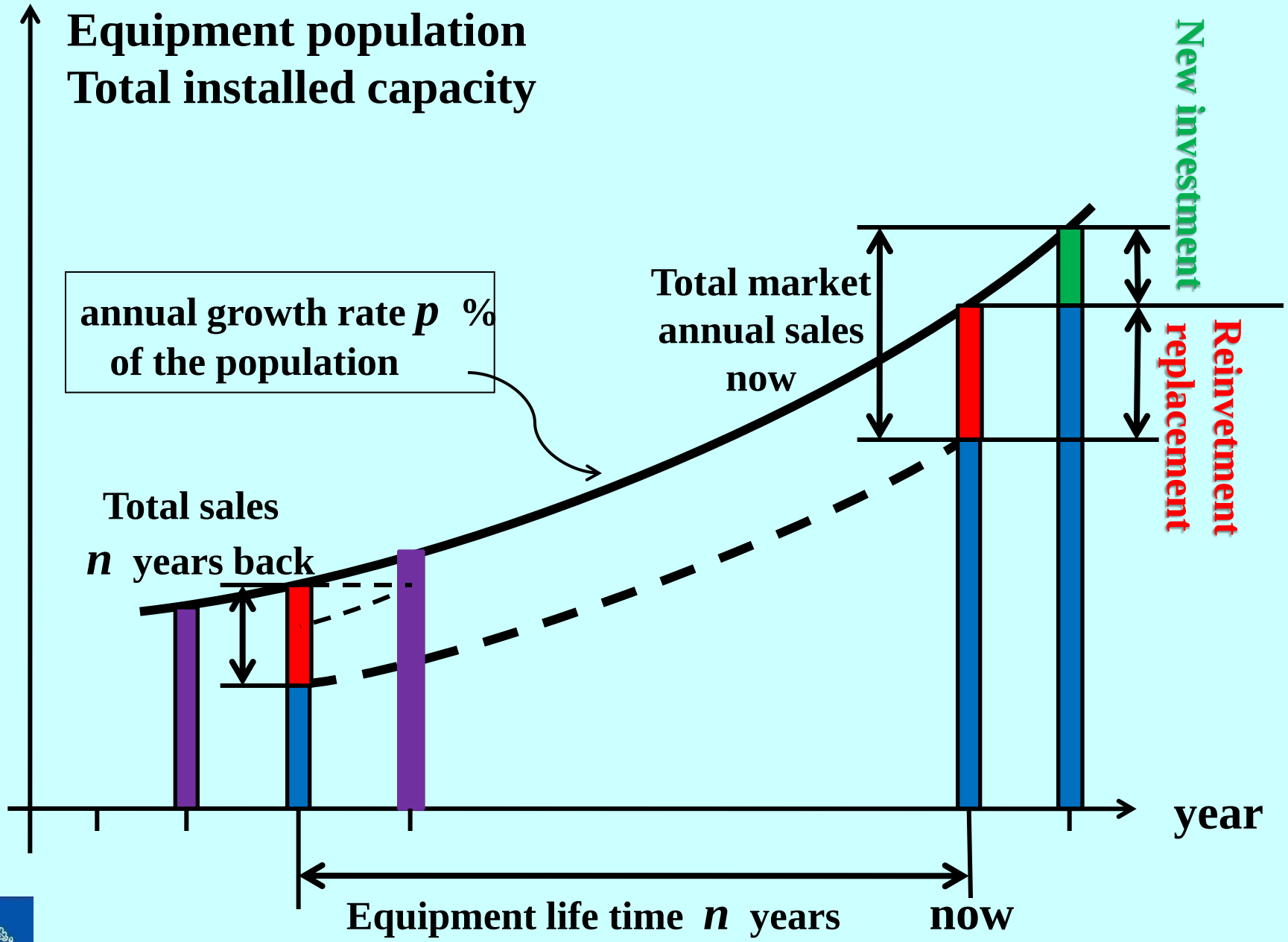
**Based on:**

- **business statistics, extent of the relevant industry processes**
- **the products´ share of the relevant industry processes**
- **process technology changes affecting the products´ use**

**Potential annual market $\chi$ for the product , in % of total ”fleet”**
**Based on:**

- **growth rate $p$ % for the relevant industry processes**
- **life time $n$ [years] for the equipment**

**Annual market $\chi$ % of total fleet:** $$\chi = \frac{p}{1-(1+p/100)^{-n}}$$


Equipment population
Total installed capacity
New investment
Reinvetment
replacement
annual growth rate p %
of the population
Total market
annual sales
now
Total sales
n years back
year
Equipment life time n years
now

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# Annual market $\chi$ in percent of the total population of products

**Business growth rate *p* % per year**
**Equipment life time *n* years**

$$\chi = \frac{p}{1-(1+p/100)^{-n}}$$

| Growth rate *p* % | 0 | 2 | 5 | 10 |
|---|---|---|---|---|
| $\chi$ for life time *n* = 3 years | 33 | 35 | 37 | 40 |
| $\chi$ for life time *n* = 10 years | 10 | 11 | 13 | 16 |
| $\chi$ for life time *n* = 20 years | 5 | 6 | 8 | 12 |

# Environmentally driven design

## Eco-efficiency

product improvements to reduce products´ environmental impact

- materials selection and design (e.g. weight reduction)
- energy efficiency
- disassemblability
- ……

## Eco-effectiveness

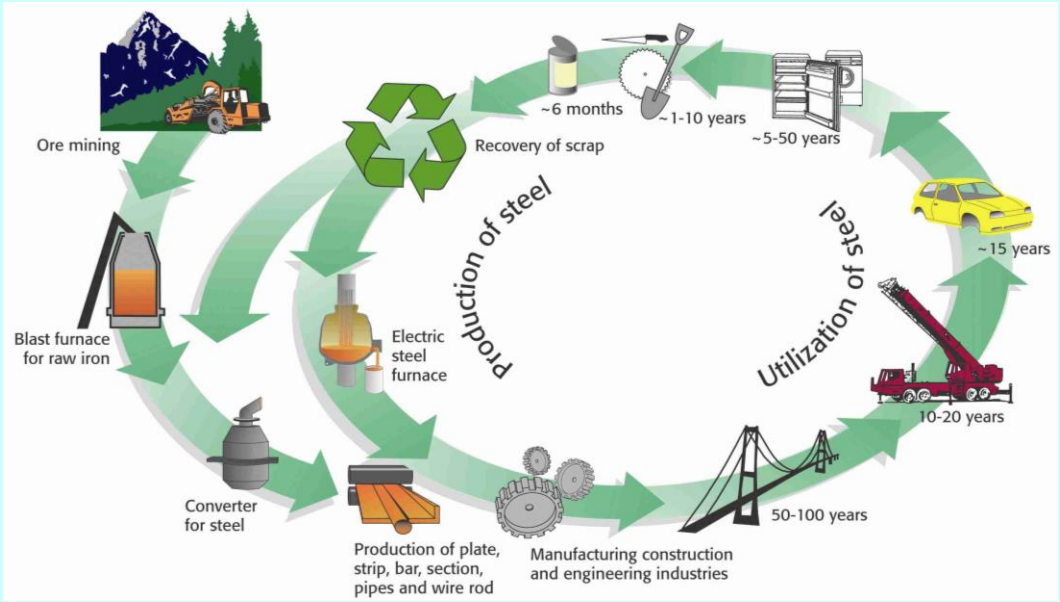
Alternative technical solutions to

- meet society´s functional requirements
- significantly reduce system environmental impact over life time

E.g. Various forms of solar energy, replacing fossil and nuclear

- Zero energy buildings
- New transport technology
- ……

# EcoDesign – example: Swedish Research program the Steel Eco Cycle




## The Steel Eco Cycle

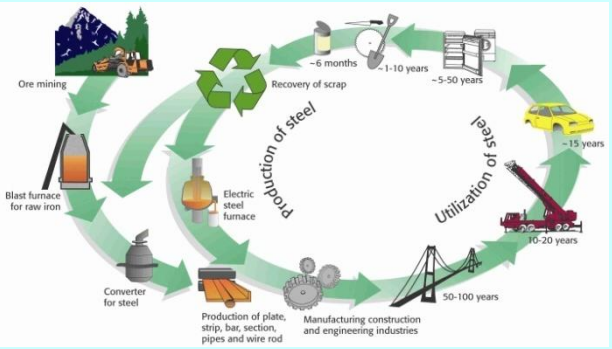
***Eco Effective Design***
***of steel products***

- ***Weight optimisation - reduction of all resurces used in production upstream***

- ***Weight optimisation of ”active” products reduction of energy consumption during use phase direct***

- ***Material hygiene – cleaner fractions in disassembly for improved quality in recycling downstream & upstream***

# EcoDesign – example: Swedish Research program the Steel Eco Cycle




***Eco Effective Design of steel products for***

- ***reduced amount of material***
- ***improved disassembly and cleaner recycling***

**State-of-the-art**

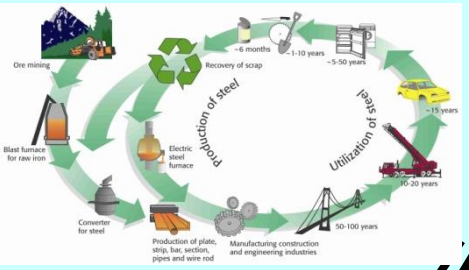
***Existing theory base: solid mechanics, physical metallurgy, welding, optimisation…, disassembly, scrapping & separation processes***

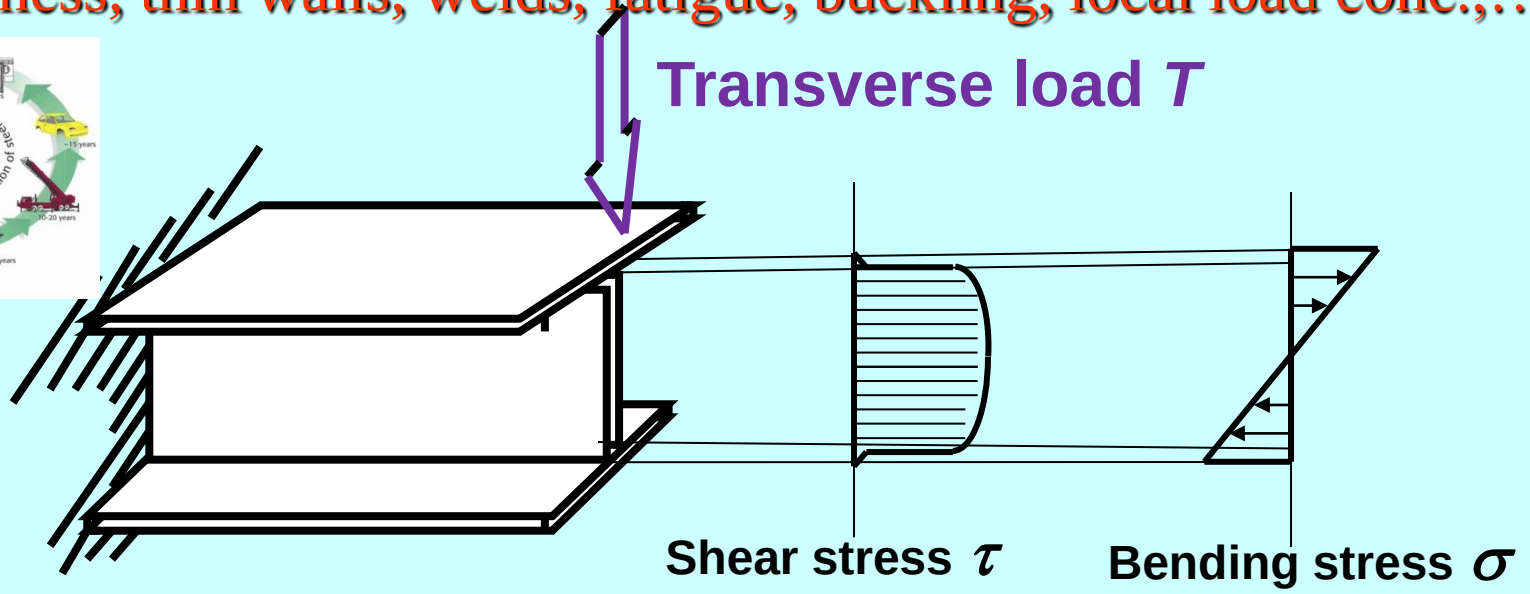
***Existing detailed design rules***

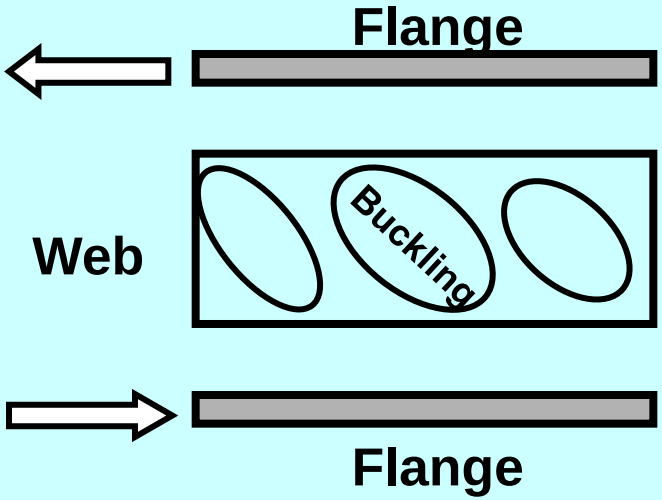
***but lacking overview – risk of sub-optimisation***

# How to utilise high strength steel properties?

## Strength-stiffness, thin walls, welds, fatigue, buckling, local load conc.,…

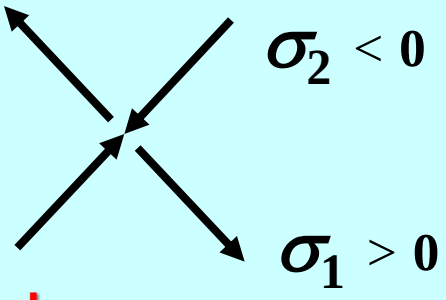



$\tau$

**Principal stresses for pure shear loading (in web)**




**Modulus of elasticity E same for all steel grades**

**=> use stiffernes to prevent buckling of thin walled structures**

# Some Design & Assembly rules to support disassembly, reuse and recycling

- Product structure adapted for easy disassembly
- No toxic or scarce materials
- Upgradable design ➡ longer product life
- Fasternes eliminated by geometrical locking
- Easy access to fasternes
- Standardized fasterners and screws just one tool needed
- No embedded metal parts in plastics moulds
- Design for ease of cleaning, avoid dirt traps
- Glue bonding: OK for metal, avoid for plastics
- Surface coating: OK for metal, avoid for plastics
- Disassembly info: manuals, integrated ”smart labels”
- ”Resting loadcases” – parts designed for prepared rupture
- ……..

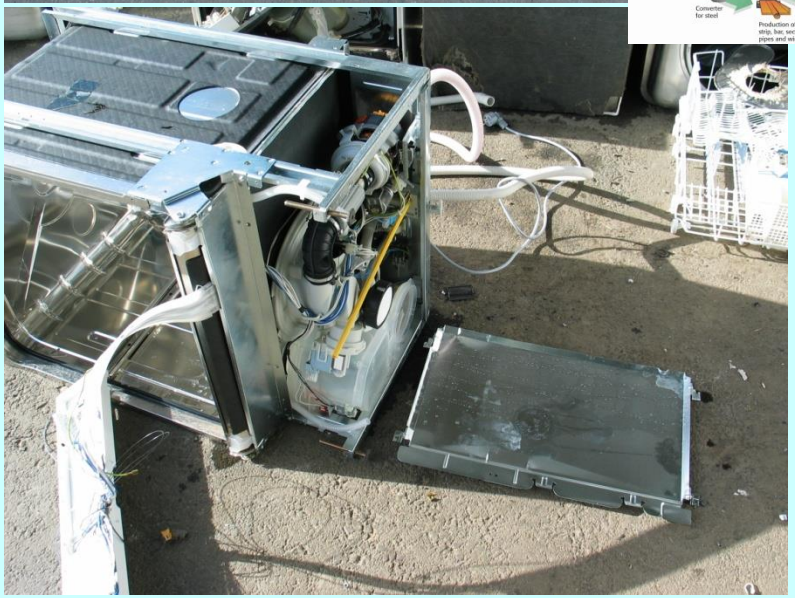
# The Steel Eco Cycle

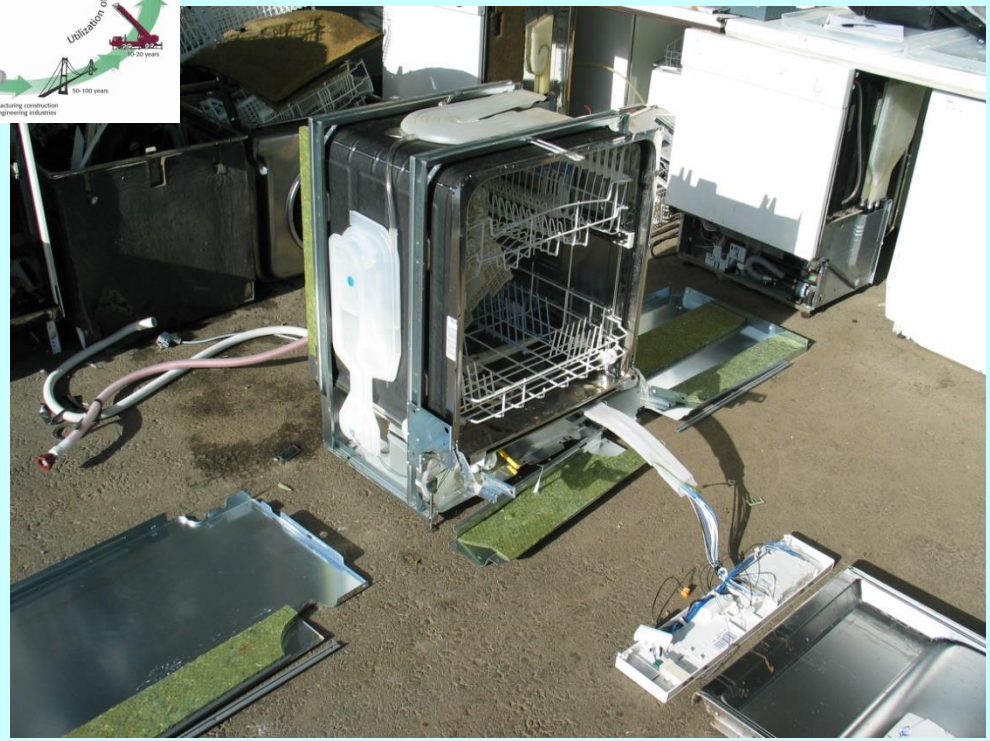
## *Eco Effective Design*
### *of steel products*

## *Disassembly tests – Dishwashers*
### *Product structure*



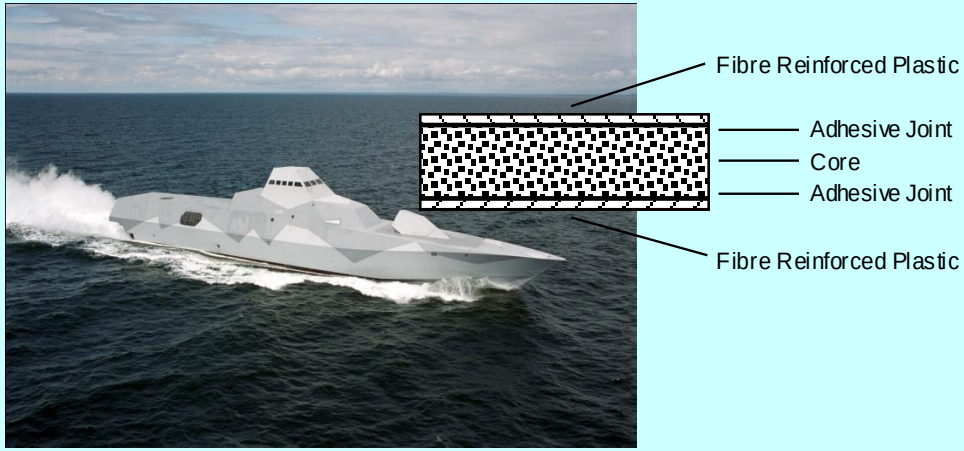


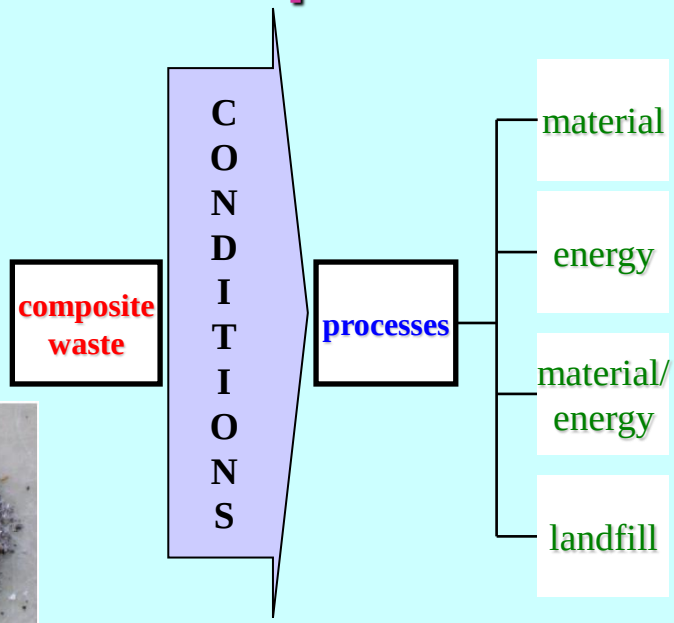


# Recycling and recovery of polymer composite materials

## Corvette HMS Visby



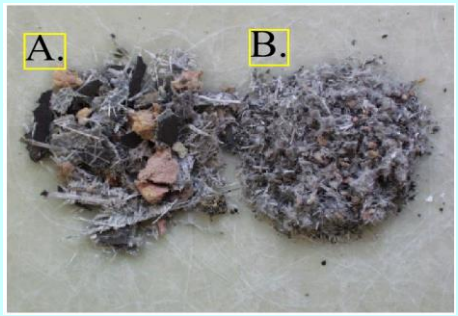

## Model for assessment of disposal



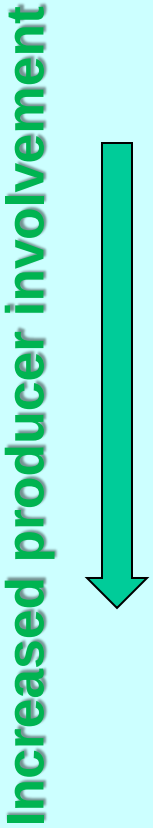

## Dismantling



## Grinding



# Service systems – function sales




- *Scheduled preventive maintenance*
- *Extended producer responsibility*
- *Producer ownership*
- *New business concepts*
- *Integrated product-service - life cycle optimized*



- **Increased/efficient utilization of resources**
- **Reduced environmental load**

# Current trends in Product Development

- **Integration**
  - * Complex Multi Technology Systems
  - * Industrial Design Engineering - ”Hard” & ”Soft”
  - * IPD – organisation, process
  - * Distributed PD over networks
- **Innovation**
- **Iteration - VP, model driven PD**

## Future technology and PD challenges

- **Flexibility to meet changing conditions**
- **Sustainability** – { **environmental**, **economic**, **social** }
- **Service systems – function sales, producer ownership**
- **Long term development to meet major global needs**
  **Energy supply, sustainable transportation, production,…..**

# *CURRENT TRENDS IN INDUSTRY:*

- *Fewer and larger suppliers*
- *Complex organisations*
- *Outsourcing – insourcing*
- *Distributed development, networks*
- *Industrial Design Engineering*
- *Integration of engineering analysis – engineering design*
- *Modular product architecture, platforms*
- *Virtual prototyping*
- *Service systems – new business concepts*
- *Sustainable technology development*